Journal for Technology and Science
Homepage : https://journal.antispublisher.com/index.php/IPTEKS
Email : admin@antispublisher.com

e-ISSN : 3047-4337
JOTECH, Vol. 3, No. 4, October 2026
Page 72-86

Identifying Hazardous Traffic Crashes Area Utilizing the Application of GIS

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DOI : https://doi.org/10.61796/ipteks.v3i4.586

Sections Info

Article history:
Submitted: May 07, 2026
Final Revised: June 26, 2026
Accepted: July 18, 2026
Published: August 15, 2026

Keywords:
Geographic information system
Hot spot analysis
Traffic crash

ABSTRACT

Objective: *This study aims to explore the problems related to the current design of the city of Al-Diwaniyah-Iraq, address the problems it faces of road deficiencies and traffic crashes, and find alternative solutions to them.* ***Method:*** *The program (ArcMap 10.8.2 and ArcGIS pro-3.0.2) and aerial photos were used from the Al-Diwaniyah municipality Directorate and spatial analysis to carry out this study, and the data from the Al-Diwaniyah Teaching Hospital.* ***Results:*** *The number of crashes in the City of Al-Diwaniyah reached 14,243 from 2015 to 2023. According to the results, using hot spot analysis, the hottest area with the highest number of crashes is the Al-Jamieih district, which has a rate of 50.13 crashes per mile on paved roads only. The results showed that the hottest region was the Al-Jumhurii Al-Sharqii, with a rate of 9.5 crashes per mile. The road area is small, with 7.65 miles occupied by 654 crashes.* ***Novelty:*** *The crash rate was also estimated by roads in general (paved and unpaved).*

INTRODUCTION

Every year, almost millions of people lose their lives as a result of traffic crashes, and many of them suffer non-fatal injuries and become disabled as a result [1], [2]. In addition, these crashes cause great economic losses to individuals, their families, and the entire country [3], [4]. Many reasons affect the occurrence of traffic crashes and the severity of injury; among these factors are the high speed of road users, poor planning, failure to comply with traffic laws, sudden malfunction of the vehicle itself such as an explosion of tires, insufficient lighting, road defects, bumps and potholes scattered everywhere in addition to environmental factors, weather conditions, and dust storms that impede visibility, making driving unsafe [5], [6], [7], [8]. Spatial data and its analysis are one of the most important tools for traffic crash analysis. The location of the highest crash occurrence can be defined as a point or area where there is a particularly frequent recurrence of an event, and these locations are determined statistically. There have been various visual methods and reports about the use of the ArcGIS tool in crash analysis, which include intersection analysis, segment analysis, cluster analysis, density analysis, pattern analysis, and spatial crash analysis modeling techniques. Since the 1990s, ArcGIS has been used in the field of transportation [9], and it can organize the various types of data and maps that can be easily stored, shared, and manipulated [10]. Although the enhancing of traffic safety is the primary concern of highway agencies, traffic crashes have been increasing rapidly in recent decades; this is due to many factors, including a sharp increase in vehicles using road networks, driver behavior, road condition, weather, and many other external factors [11]. Iraq has recently

witnessed a sharp increase in cars, but it still needs to modernize its transportation infrastructure. This increase usually leads to a significant increase in traffic crashes, and as a result, society bears a heavy financial burden from traffic crashes [12]. Crashes on the road have an important impact not just on the economy but also on society. Several transportation organizations and police departments have used geographic information systems to analyze and manage data about urban traffic crashes (UTAs) and made decisions that tried to lower crashes and increase safety [13]. It has been assessed that the damages generated by these crashes amount to about 518 billion USD worldwide [14], [15], [16]. Traffic crashes significantly contribute to the death of many people and the loss of property, and they cause many psychological stresses for humans as road safety is an important aspect of transportation that aims to minimize crashes and injuries, and safety ensures that the trip is completed without any property damage [17]. Al-Diwaniyah Governorate in Iraq is exposed to a serious scarcity in both urban and residential areas, which leads to a noticeable increase in indiscriminate expansion and encroachments on neighboring lands [18]. Given how there is an increasing need for transport infrastructure at the same time, the quality of transport infrastructure service is not high, it is difficult to meet the needs of Social Development, and this leads to an increase in traffic momentum and crashes [19]. The current problem of traffic crashes in the City of Al-Diwaniyah is a complex and multifaceted challenge that requires comprehensive investigation and analysis. According to the statistics of the Al-Diwaniyah Governorate, there has been an increase in the number of traffic crashes from 2015 to 2023, where the total number of crashes reached 14,243. Crashes are the result of one or more variables, and among the factors that lead to such crashes are: Poor road conditions in Iraq, Violation of traffic laws: There are many violators of the laws, and some lack knowledge of traffic laws, Poor infrastructure that cannot withstand overpopulation, the increase in the number of vehicles is separate from development in the services sector of the transportation and communications network that keeps pace with this increase. Therefore, the number of crashes on transportation roads is increasing.

However, no study has yet to be conducted that considers the crash's spatial characteristics, and the city's hot spot needs to be clearly visible. This work will use ArcGIS software to investigate the existing data in an effort to close this gap in knowledge. This study aims to determine the geographic regions most impacted by crashes by analyzing incident-related geographic data using ArcGIS methodologies.

Traffic crashes are among the most important and complex contemporary humanitarian problems many societies suffer. Crashes involve a collision between two cars or a car colliding with any other obstacle, such as pedestrians or walls, resulting in death, injury, or property damage [20]. Depending on the type of crash, the severity of the injury varies and is usually measured with five injury levels known as the KABCO scale: (K) fatal, (a) incapacitating injury, (B) non-incapacitating injury, (C)potential injury, and (O) no injury [21].

Although the enhancing of traffic safety is the primary concern of highway agencies, traffic crashes have been increasing rapidly in recent decades; this is due to many factors, including a sharp increase in vehicles using road networks, driver behavior, road conditions, weather, Poor road design, fog and rain, and many other external factors [11]. The World Health Organization conducted a survey that included most of the world's countries, including Iraq. It indicated that there are approximately 1.3 million victims of road traffic crashes per year, equivalent to more than two deaths every minute [22].

In Iraq, some research has focused on traffic crashes. One was a study conducted by researcher Omar Jabbar in Baghdad Governorate, where crash data was collected for the city of Baghdad, amounting to 9727 recorded incidents from 2010 to 2016. The study focused on the factors contributing to the occurrence and severity of traffic crashes in the city of Baghdad. The researcher used the Direct analysis of the percent frequencies of crashes and the Logistic regression model to develop a prediction relationship between crash rate and motorization level. The results indicated that the main contributing factor is the driver, which accounted for more than 53% of the total crashes for the data collected [12]. The researcher Roaa Hamed studied the analysis of crashes from 2010 to 2020 for fifteen provinces in Iraq. Al-Diwaniyah Governorate holds the fifth position in the number of crashes, as shown in Figure 1.

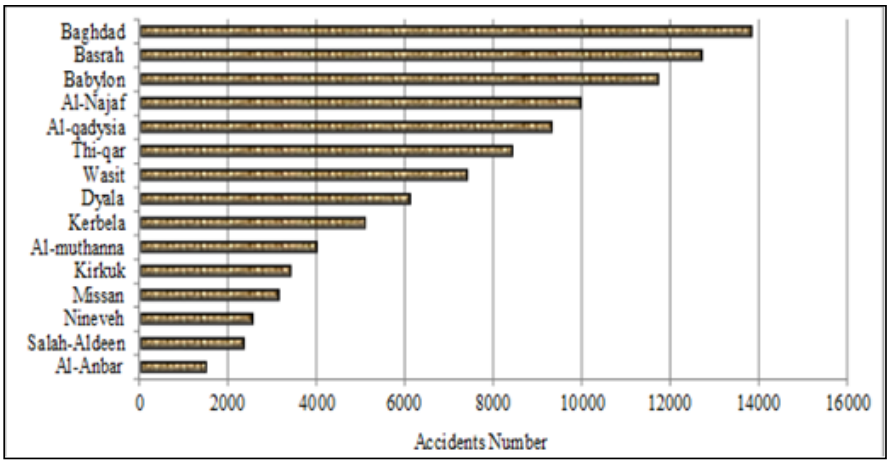


Figure 1. Crashes distribution [12].

The researcher concluded that there are about 25 crashes a day in Iraq, the average death toll of which is about seven people per day, so the researcher recommended that the key to development and saving people from the dangers of traffic crashes is to develop infrastructure, expand the road network and support the public transport system in the country [23]. Another study conducted by [24] studied traffic crashes in Iraq in 2018. The total number of 9852 incidents was studied, including 1712 crashes on highways, 5266 on main roads, 2234 on secondary roads, and 640 on rural roads. Geographically, using data from various sources, where crashes were obtained from the annual statistical reports of transportation agencies, population

estimates were also obtained, and using a geographic information systems program to study run-over crashes in Iraq, Basra Governorate had the highest percentage of run-over incidents, at a rate of 17%. The study recommended building bridges, expanding the streets, enforcing traffic laws, and reducing the excessive import of cars into Iraq.

These and other studies contribute to guiding national policies and programs to enhance road safety and reduce the occurrence of traffic crashes in Iraq. Still, the factors mentioned above should have taken into consideration the spatial analysis effect on crash distribution and clustered crash location.

This study will utilize methods and tools to analyze geographic data to determine the frequency of crashes and the regions most susceptible to them. These techniques will then be applied to a collection of real data. Stated differently, this effort aims to improve road and community safety by using ArcGIS technology to understand traffic crash trends better and pinpoint the areas most susceptible to these crashes. This will aid in the development of prevention and intervention methods. Identifying the areas most prone to crashes and determining their severity is vital to improving safety and emergency strategies [25].

RESEARCH METHOD

Figure 2 shows a flowchart of the research methodology. One of the approaches used in this study is the spatial analysis method, which aims to reveal the relationship between the variables related to the traffic system by conducting a spatial analysis of traffic crashes in Al-Diwaniyah City. The most appropriate tool that can be used to conduct this research is the use of Spatial Statistical Tools in the application of spatial dispersion and spread analyses by Geographic Information Systems (GIS) is a means based on its work on the use of the computer in collecting, processing, displaying and analyzing data associated with geographical locations to deduce information of great importance in making appropriate decisions. Perhaps traffic engineering is one of the first applications in the field of traffic that rushed to take advantage of this modern technology, as is the case with many other parties that strive to find radical solutions to many of the daily problems that plague the nation. Studies have indicated that there is an increase in the number of traffic crashes in the City of Al-Diwaniyah. Based on the data obtained from the Al-Diwaniyah General Educational Hospital, it was found that there were approximately 14,243 traffic crashes for the period from 2015 to 2023. As noted, several types of data analysis can be conducted to support roadway safety depending on the available crash, roadway, and exposure data they include [26]:

Trend analysis

a. Crash rates.
b. The direction of distribution of traffic crashes in the city.

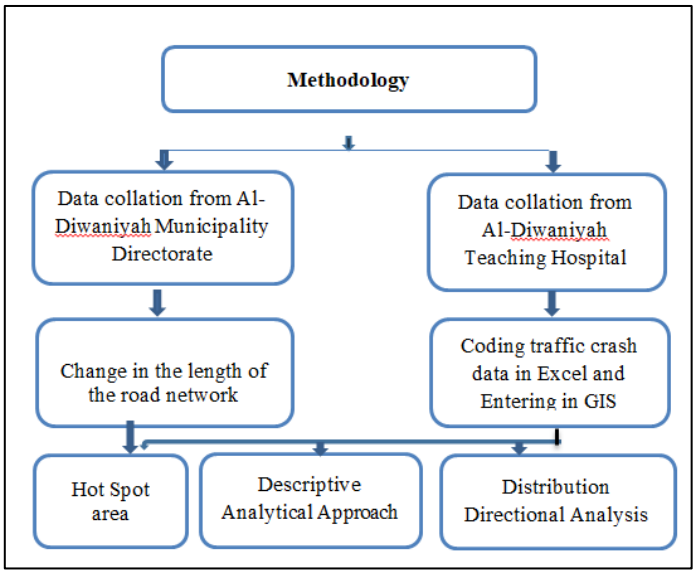


Figure 2. Flowchart of Research Methodology

Iraq is one of the Arab countries with a high number of population [27]. The study focused on the City of Al-Diwaniyah due to the need for more scientific research and studies on urban planning and traffic safety. There are many reasons to raise concerns regarding the current traffic situation in the city. It has been found that the causes of these crashes are due to many associations, including those caused by drivers or due to the quality of road infrastructure, the narrowness of the old streets in the city, and other factors. The City of Al-Diwaniyah is located between latitude -32.5° north and longitude -44.5° east [18]. Hence, it constitutes about 1.9% of the total area of the country. 8.1% of the total area of the governorates is located in the middle Euphrates region. Figure 3 shows the study area represented by the City of Al-Diwaniyah and the residential areas within the City.

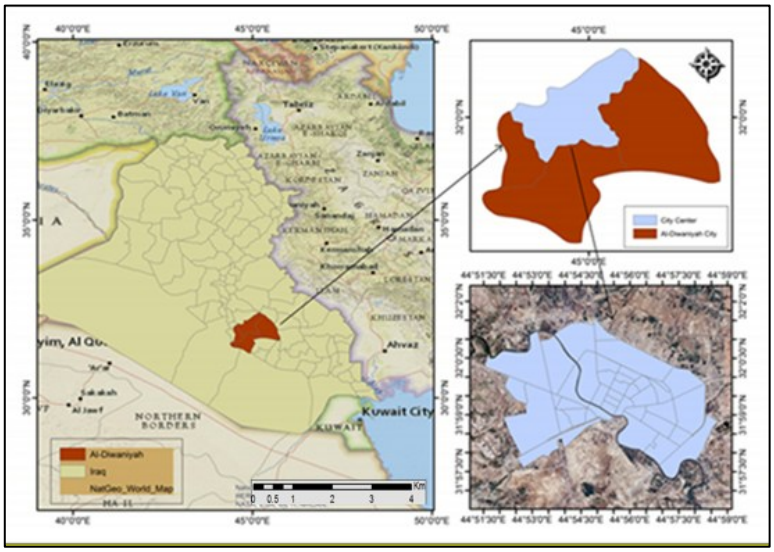


Figure 3. Extracting the location of the study area represented by the Center of Al-Diwaniyah Governorate (researcher preparation)

Trend analysis of crashes involves examining crash data over a period of time to identify patterns and trends. This analysis helps understand whether crashes are increasing, decreasing, or remaining stable. This analysis is crucial for developing effective safety measures and policies to reduce the number of crashes and improve road safety. From the traffic crash data, crashes were plotted, and a predictive analysis was performed using the Excel program for six sectors in Al-Diwaniyah City, represented in Figure 4. Figure 5 shows an increase in the number of crashes per sector from 2015 to 2023. In the first sector, the number of crashes in 2015 was 86, while in 2023, the number of crashes reached 827. In the second sector, the number of crashes in 2015 was 71, while in 2023, the number of crashes was 535, and in the third sector, the number of crashes in 2015 reached 85; in 2023, the number of crashes became 451, and the number of crashes for the fourth sector in 2015 was 50, while the number of crashes became 1154 in 2023, also note in The fifth sector had 30 crashes in 2015, while it became 370 crashes in 2023, in addition to the sixth sector had 54 in 2015, but it became 600 in 2023. Using the Excel program, it was predicted that the number of crashes would increase for all sectors in the coming years.

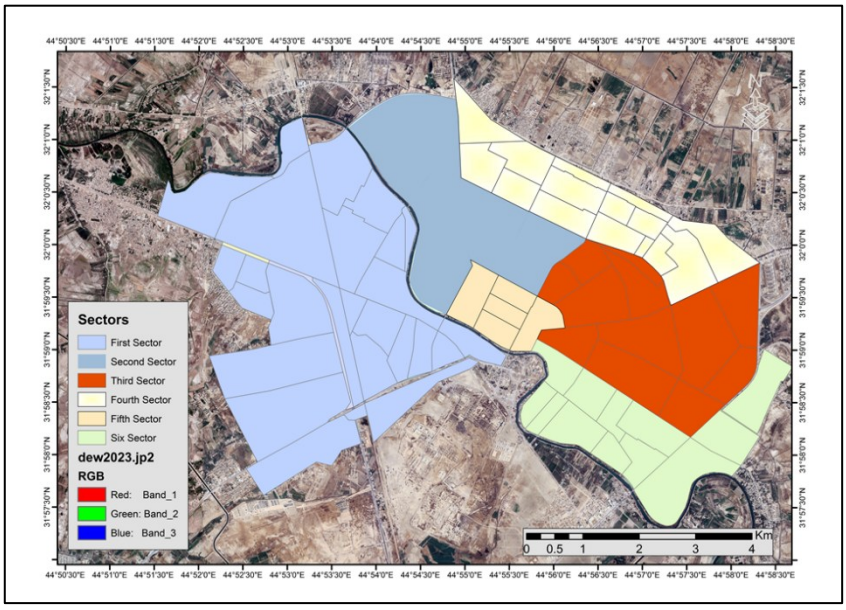
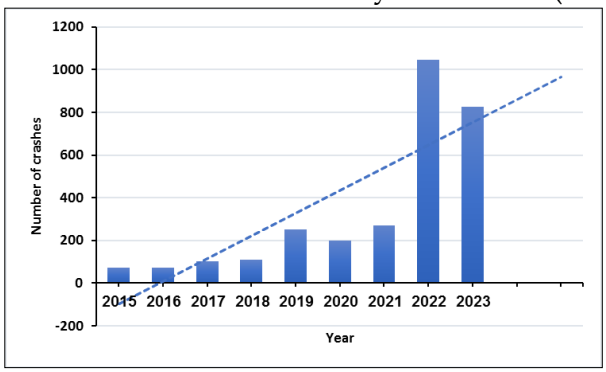
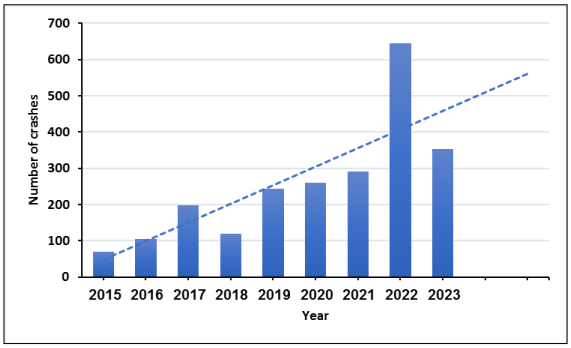


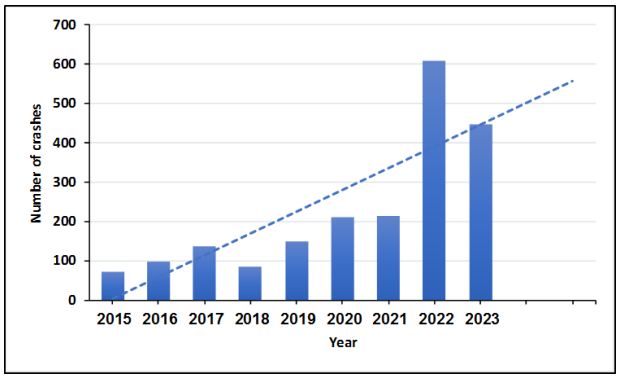
Figure 4. Sectoral distribution of the center of Al-Diwaniyah City, which is represented by six sectors (researcher preparation)



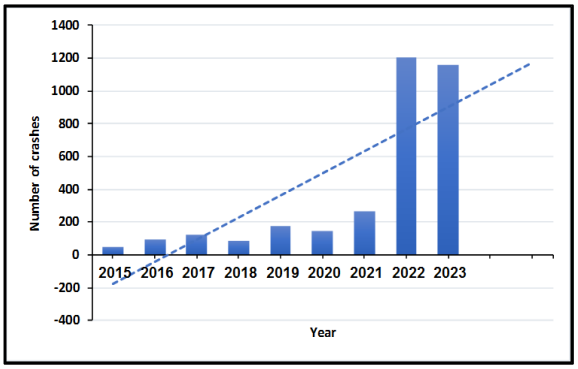
Crashes in Sector One



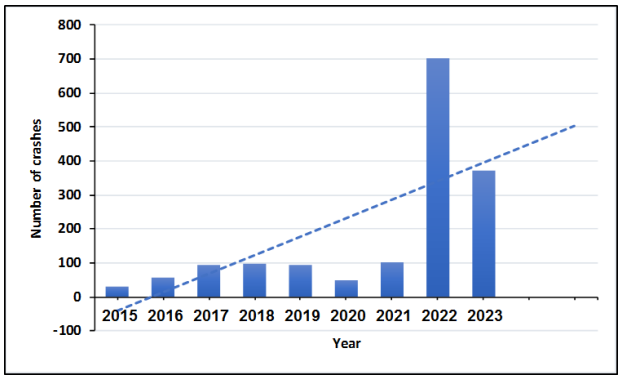
Crashes in Sector Two



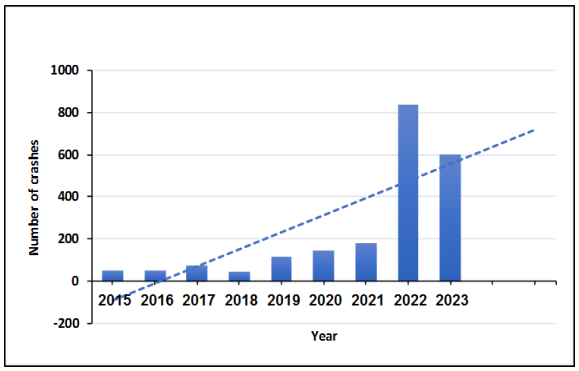
Crashes in Sector Three



Crashes in Sector Four



Crashes in Sector Five



Crashes in Sector Six

Figure 5. Trend Analysis of Crashes

Traffic crash hot spot analyses allow identification of roadway segments that may be of safety concern. This research indicates risk areas by hot spot analysis, allowing more informed decision-making regarding roadway safety. The purpose of studying the relative safety of a particular stretch or road intersection is done by conducting a traffic crash rate analysis, which usually uses crash data in the form of traffic volumes or the number of kilometers on the road. The benefit of studying the crash rate analysis is that it provides a more effective comparison of similar sites with safety problems and is also more accurate, as shown in Table (1), so estimating and comparing crashes on roads of different lengths by estimating the rate of traffic crashes per mile of the road, a "crashes per mile" rate for road segments is calculated as [26]:

$$R = \frac{C}{N \cdot L} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:

R: Crashes per mile of road per year

C: Total number of crashes for each zone in the study period

N: Number of years

L: Length of the road segment in miles

The procedure includes drawing and calculating the lengths of paved and unpaved roads for the year 2023 using the Geographic Information Systems program, as in Figure (6-7). Using these lengths per mile and the cumulative number of crashes for

nine years from 2015 to 2023, the severity of crashes is calculated for each neighborhood of Al-Diwaniyah City.

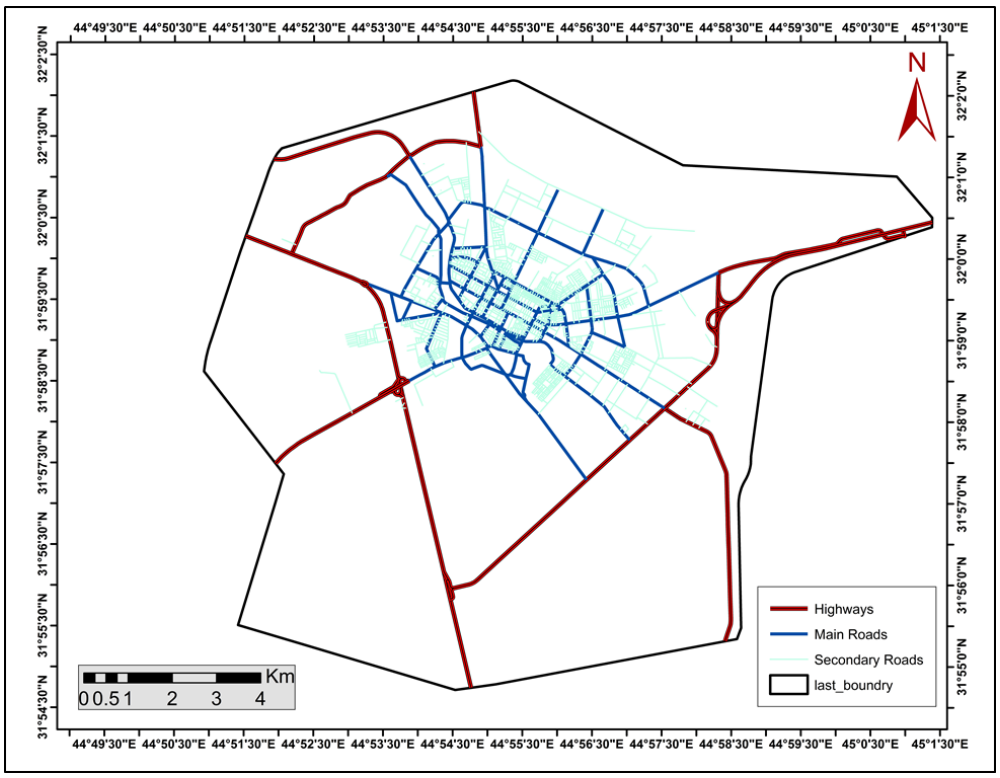


Figure 6. Al-Diwaniyah Spatial-Temporal Changes in Transport Infrastructure 2023 (Paved road)

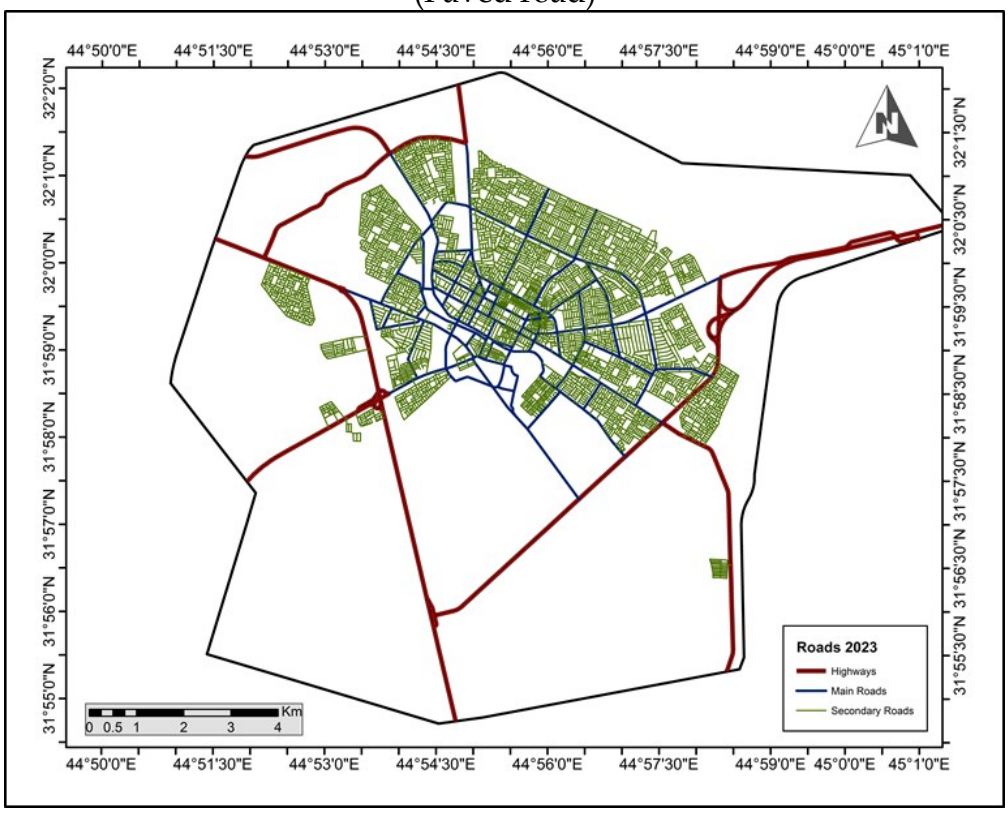


Figure 7. Al-Diwaniyah Spatial-Temporal Changes in Transport Infrastructure 2023 all roads (paved and unpaved road)

Distribution directional analysis involves examining the spatial characteristics of data, such as central tendency, dispersion, and directional trends. This type of analysis is often used in fields like geography, meteorology, and transportation to understand patterns and trends in data with a directional component, such as wind directions and traffic flow. The Directional Distribution aims to determine the direction or the distributive direction of the parameters of the phenomenon by drawing an ellipse or an ellipse that represents the direction of the geographical extension of the phenomenon on the surface of the study area [28]. This technique is used to determine the general trend of the spread of traffic crashes on the surface of Al-Diwaniyah City by calculating the variation on both the x and y axes separately, and the result is presented in the form of an ellipse showing the distribution curve as in Figure 8.

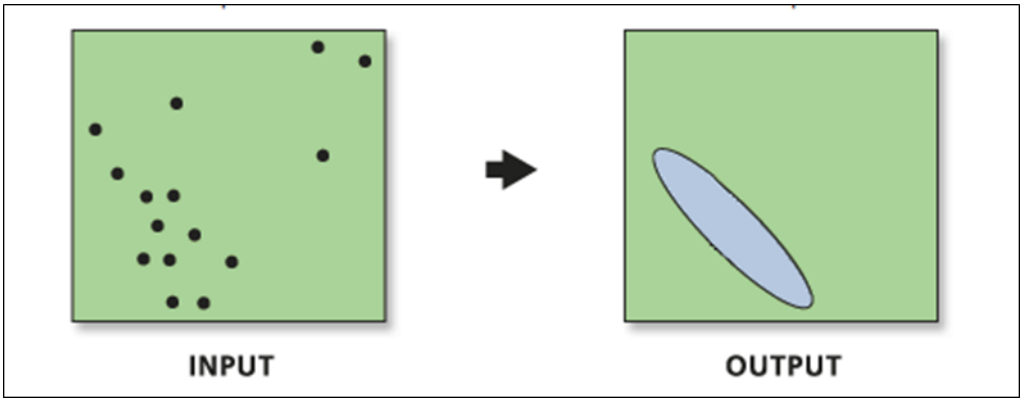


Figure 8. Inputs and outputs of the distribution Directional analysis [28]

RESULT AND DISCUSSION

Result

According to the data obtained from the General Hospital in Al-Diwaniyah, after sorting, typesetting, and analyzing these data, the rate of crashes was calculated for each of the six sectors in Al-Diwaniyah City, as shown in Table 1, where it was studied in two stages:

a. The crash rate was estimated based on paved roads only because most drivers prefer to walk on paved roads, so most crashes are on them. The results shown in Table 1 show that the hottest area with the highest number of crashes is the university district, which has a rate of 50.13 crashes per mile.
b. The crash rate was also estimated by roads in general (paved and unpaved) due to the possibility of a crash occurring on any part of the road, whether the road is paved or unpaved, as vehicles usually drive on alternative roads during traffic jams, especially at the start and end of the shift, or the roads may be ineligible or unpaved by themselves, but used by vehicles for necessity or for any reason, which leads to the possibility of a crash. The results showed that the hottest region was the Eastern Republic, with a rate of 9.5 crashes per mile. The road area is small, with 7.65 miles occupied by 654 crashes.

Table 1. Distribution of lengths and crash rates for each district per mile

Name	Crash (2015 - 2023)	All Road (mile)	No. of Years	Crash Rate	Paved Road (mi)	Crash Rate
Al-Urubah	890	28.72	9	3.44	24.14	4.10
Al-Saray	106	15.27	9	0.77	14.70	0.80
Al-Mutaqaeidin	122	14.41	9	0.94	10.68	1.27
Al-Furat	302	32.96	9	1.02	14.49	2.32
Al-Dubaat	229	14.16	9	1.80	9.33	2.73
Al-sadr	2508	67.41	9	4.13	15.91	17.51
Hadara	653	12.89	9	5.63	7.52	9.65
Al-Adhariya	22	4.14	9	0.59	3.97	0.62
Al-Jazayir	593	18.82	9	3.50	15.98	4.12
Al-Muealimin	27	4.13	9	0.73	2.97	1.01
Towards Al-Shamiya	122	8.93	9	1.52	9.13	1.48
Al-Turath	533	18.92	9	3.13	12.30	4.81
Ramadan	109	6.14	9	1.97	3.25	3.73
Al-Sinaeii	53	20.92	9	0.28	15.98	0.37
Al-Hakim	16	37.18	9	0.05	11.67	0.15
Al-Jamieih	794	17.02	9	5.18	1.76	50.13
Al-Thaqafii	0	5.24	9	0.00	5.45	0.00
Al-Jadida	691	11.39	9	6.74	10.99	6.99
Aleasri	240	16.74	9	1.59	16.30	1.64
Al-Fadilia	26	9.49	9	0.30	9.09	0.32
Al-Karama	0	10.10	9	0.00	8.95	0.00
Al-Jumhurii Al-Gharbii	529	11.91	9	4.93	11.74	5.01
Al-Istaqama	0	8.17	9	0.00	4.24	0.00
Al-Jumhurii Al-Sharqii	654	7.65	9	9.50	3.22	22.56
Al-Adala	726	16.48	9	4.89	12.81	6.30
Al-Jamiya	68	7.72	9	0.98	2.12	3.57
Al-Ansar	3	12.10	9	0.03	6.27	0.05
Al-Zaraeen	18	5.77	9	0.35	0.61	3.27
Zain Al-Abidin	0	7.85	9	0.00	4.44	0.00
Al-Shartih	128	24.91	9	0.57	6.69	2.13
Al-Taqiyya	681	24.70	9	3.06	13.94	5.43
Al-Nahda	921	14.84	9	6.90	10.94	9.36
Al-Sadiq Al-Awwal	807	27.93	9	3.21	19.57	4.58
Al-Wafa	324	21.18	9	1.70	13.21	2.73
Al-Tadamon	2	21.24	9	0.01	9.68	0.02
Al-Ghadeer	198	21.67	9	1.02	10.94	2.01
Al-Zahraa	48	13.12	9	0.41	8.36	0.64
Textile and	1099	27.55	9	4.43	11.34	10.77

Name	Crash (2015 - 2023)	All Road (mile)	No. of Years	Crash Rate	Paved Road (mi)	Crash Rate
Rubber Factory South	1	28.25	9	0.00	6.00	0.02

Figure 9 shows that the Ellipse shape included 28 sectors out of 39 sectors. These areas include 8000 traffic crashes out of 14,243 crashes, which indicates that the crashes were occurring in specific areas of the city, where these areas are characterized by high population density and traffic. The value of the angle or deviation of the distribution of these crashes is 111.604 degrees, which is approximately in the north-west direction.

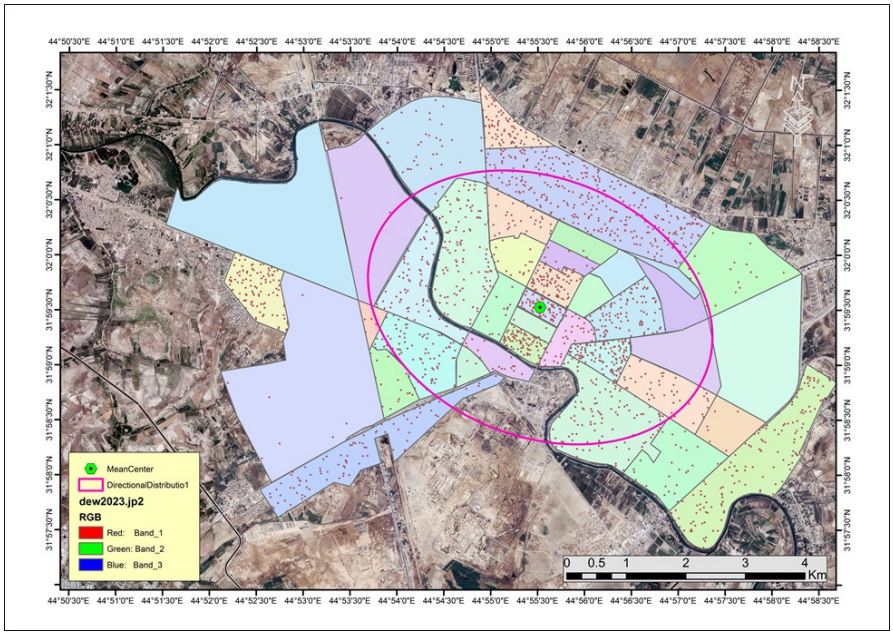


Figure 9. The distribution Directional of traffic crashes in the City of Al-Diwaniyah during the period from 2015 to 2023

Discussion

The findings demonstrate that traffic crashes in Al-Diwaniyah City are not randomly distributed but are concentrated in particular sectors and districts with different levels of road exposure. A total of 14,243 crashes were recorded during the 2015–2023 period, while the trend analysis indicates a substantial increase in crashes across all six sectors of the city. Particularly noticeable is the fourth sector, where the number of crashes increased from 50 in 2015 to 1,154 in 2023. Similar increases were observed in the other sectors, suggesting that traffic safety problems have intensified alongside the development of urban mobility. This finding is consistent with previous studies in Iraq indicating that increasing vehicle use, limitations in road infrastructure, driver behavior, and road conditions contribute substantially to traffic crashes [12], [23], [27]. Therefore, the observed increase should be considered not only as a transportation problem but also as an indication of the growing pressure placed on the existing urban road network.

The crash-rate analysis provides a more detailed understanding of the spatial variation in road safety because it considers the length of the road network rather than relying only on the absolute number of crashes. When paved roads were considered, Al-Jamieih had the highest crash rate, reaching 50.13 crashes per mile. Although 794 crashes were recorded in this district, the paved road network was only approximately 1.76 miles long. This combination of a relatively large number of crashes and a limited paved road length resulted in a considerably higher crash rate than in other districts. The finding demonstrates the importance of considering road exposure when determining hazardous locations because a district with fewer total crashes may still represent a more critical safety problem when crashes are concentrated along a short road network. This approach is consistent with GIS-based traffic safety studies that emphasize the usefulness of spatial analysis and crash-rate indicators for identifying locations requiring priority intervention [2], [9], [13], [25].

When both paved and unpaved roads were included, Al-Jumhurii Al-Sharqii emerged as the district with the highest crash rate, at 9.50 crashes per mile, with 654 crashes distributed over only 7.65 miles of roadway. Its crash rate on paved roads was also relatively high at 22.56 crashes per mile. These results indicate that road surface classification can substantially influence the identification and ranking of hazardous areas. Considering only paved roads may be appropriate because they carry a substantial proportion of urban traffic; however, including unpaved roads provides a broader representation of actual vehicle movement, particularly when alternative roads are used during congestion or when access through unpaved streets becomes necessary. Consequently, evaluating both categories of roads allows transportation planners to distinguish locations where crash risk is associated with highly concentrated traffic on paved routes from locations where risks extend throughout the wider road network.

The directional distribution analysis further confirms the existence of a spatial concentration of traffic crashes in Al-Diwaniyah. The standard deviational ellipse included 28 of the 39 sectors and approximately 8,000 of the 14,243 recorded crashes, representing more than half of all crashes documented during the study period. The orientation angle of 111.604 degrees indicates that the general distribution of crashes extends approximately toward the northwest. This spatial pattern supports the use of GIS as an effective instrument for identifying geographic concentrations that may not be evident from conventional tabular statistics alone. Previous studies have similarly demonstrated that GIS-based hot spot and spatial distribution analyses can reveal clusters of traffic crashes and assist transportation authorities in identifying priority locations for road-safety improvements [9], [10], [13], [25].

The concentration of crashes in particular districts also has practical implications for road-safety management in Al-Diwaniyah. Rather than applying safety measures uniformly throughout the city, interventions could be prioritized in locations characterized by high crash rates and strong spatial clustering, particularly Al-Jamieih and Al-Jumhurii Al-Sharqii. Measures related to road condition improvement, traffic

regulation, appropriate speed management, road signs, parking organization, and the provision of public transportation may be particularly important in these areas. This interpretation is in line with previous Iraqi studies recommending improvements in road infrastructure, expansion of transport networks, stronger enforcement of traffic regulations, and better transportation planning to reduce traffic crashes [23], [24]. The present findings extend these recommendations by providing spatial evidence that can be used to determine where such interventions should be prioritized.

Overall, the results demonstrate that integrating historical crash records with GIS-based crash-rate and directional distribution analyses provides a useful framework for understanding traffic safety problems in Al-Diwaniyah City. The analysis identifies not only districts with large numbers of crashes but also locations where crashes are disproportionately concentrated relative to road length. Nevertheless, the present assessment is primarily based on crash frequency, road length, and spatial distribution. Other variables identified in the manuscript, including traffic volume, driver behavior, vehicle characteristics, road geometry, pavement condition, environmental conditions, and crash severity, were not simultaneously incorporated into the spatial model. Future studies could integrate these variables with GIS-based analysis to provide a more comprehensive explanation of why crashes concentrate in particular locations and to support more targeted traffic-safety interventions.

CONCLUSION

Fundamental Finding: Traffic crashes in the city of Al-Diwaniyah for the years from 2015 to 2023 amounted to 14,243, and according to the results, the hottest area with the highest number of crashes is the Al-Jamieih district, which has a rate of 50.13 crashes per mile on paved roads only. The crash rate was also estimated by roads in general (paved and unpaved). The results showed that the hottest region was the Al-Jumhurii Al-Sharqii, with a rate of 9.5 crashes per mile. The road area is small, with 7.65 miles occupied by 654 crashes. **Implication:** Traffic crashes have become one of the most prominent problems that hinder the development of societies because of the human and economic losses they cause. The geographical contribution to the study of the social problems of traffic crashes is highlighted in an attempt to reduce the loss of lives and property and, therefore, achieve traffic safety for users of these roads in light of the increase in the number of traffic crashes, necessitates maintaining the safety of all users of these roads, as a vital requirement to face such problems. Through work on this study, some suggestions and recommendations were reached that can be followed to reduce crashes and their severity. Obliging state departments to provide parking spaces for vehicles or provide public transportation for employees. Determine the types of roads and appropriate speeds for each road and set directional and traffic signs. Traffic reveals the mutual relationships between the elements of the geographic system and provides the necessary solutions to help decision-makers make the right decisions in dealing with traffic crashes. **Limitation:** The study is limited to the spatial analysis of

traffic crashes and road characteristics in Al-Diwaniyah City from 2015 to 2023, without incorporating other potential contributing factors such as traffic volume, driver behavior, vehicle conditions, and environmental conditions. **Future Research:** Pay attention to traffic statistics and use programs based on geographic information systems. Taking advantage of the modern technologies provided by these programs to build a spatial database for traffic crashes is beneficial. This will build an important information reserve that helps in completing research and reports to study the causes of crashes.

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