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Research paper

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Road safety challenges in mountainous regions: A case study of the Aures Mountains, Algeria

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Summary

This research analyzes traffic accidents in the mountainous area of the Aurès range from 2017 to 2022, focusing on their spatial and temporal distribution and main causes using geographic information systems and exploratory factor analysis, given their significant social and economic impacts.

Initially, we conducted a quantitative analysis of traffic accidents recorded by the relevant authorities, examining their distribution and their relationship with the ongoing dynamics of the national, provincial, and municipal road networks. In addition to that, we addressed the causes of traffic accidents through exploratory factor analysis of accidents in the area.

The study's results showed that the road network in the Aurès region witnessed a total of 930 traffic accidents between 2017 and 2022, which is an average of 1 accident every two days, or 6 accidents per 1,000 people. There is a direct relationship between traffic density and the rank and importance of the road, as national roads accounted for 58.27% of all accidents, provincial roads for 30.53%, and municipal roads for 11.18%. The study also confirmed that the main factors causing traffic accidents are primarily the driver, contributing 24.85% of the variance, followed by weather conditions at 18.64%, the road itself at 12.02%, and vehicle defects at 9.01%.

These results confirmed the seriousness of this phenomenon and its negative social and economic impacts, which led us to present a set of suggestions to mitigate it.

Keywords

traffic accidents • road safety • GIS • factor analysis • Aures mountains • Algeria

1. Introduction

In the present time, the world is facing a number of challenges regarding public safety, sustainable development, and economic growth, with one of the most significant being traffic accidents, which are viewed as a negative indicator of socio-economic development [Sheikh Shahriar 2020]. Approximately 1.3 million deaths are recorded annually, along with nearly 50 million people suffering various levels of injury [WHO 2022]. The estimated global annual cost is around 1.8 trillion US dollars, factoring in healthcare costs and material losses [World Bank 2022], in addition to productivity lost and psychological impacts.

Like many other countries, Algeria has not been spared from this phenomenon, which occurs continuously [Ouramdane et al. 2023]. In 2022, 17,186 accidents were recorded, resulting in 700 deaths and 20,575 injuries of varying severity [Algerian Press Service 2023], averaging about 47 accidents per day and an alarming severity rate of around 1.28%, significantly higher than the global average of 0.63% [WHO 2022].

Many recent studies have addressed the issue of traffic accidents using various modern research techniques and methods to obtain practical results to mitigate this phenomenon. Among these studies is Chen's [Chen 2019], which examined the impact of mountainous terrain on accident rates and found that slopes exceeding 6% increase the risk of accidents by 45%. It emphasized that sharp turns account for 30% of the causes of accidents in mountainous areas. Li's study [Li 2018] evaluated the effectiveness of safety barriers at turns and proved that improving lighting reduces accidents by 35%, while providing suggestions for infrastructure development. In contrast, a study conducted by Al-Harthi et al. [2020] asserted that climatic conditions such as fog and ice directly affect road safety.

In Algeria, a study was conducted by Saad al-Din Boutobal [2012] that focused on driver characteristics and their effect on traffic violations. Additionally, Sidi Saïdy et al. [2017] found that traffic accidents are an ongoing phenomenon facing the state of Sétif, confirming a direct relationship with the continuous increase in the number of vehicles. Furthermore, human factors, particularly driver behavior, play a key role in accident occurrences according to Ababneh et al. [2021].

The Aurès region in the province of Batna is notable for being a mountainous area with diverse geographical and environmental features, which is always bustling, making it an important model for study. It records high numbers of traffic accidents; from 2017 to 2022, there were around 930 accidents, averaging about 1 every two days, with a severity rate of about 1.5, which is higher than the national average [Algerian Press Service 2023]. This phenomenon has impacted the local population with an average of 6 accidents per 1,000 residents. The central question of this study is therefore: how to analyze the spatial and temporal distribution of traffic accidents on mountainous roads using tools such as geographic information systems (GIS) and what the contributing factors in the Aurès region are?

2. Materials and methods

2.1. Presentation of the study area

The Aurès region is located in the eastern part of the Saharan Atlas Mountain range and is bordered to the north by the Upper Constantinian Highlands and to the south by the Ziban area. Geographically, it lies between the latitudes 35°9'37" and 35°29'38" North, and the longitudes 5°50'0" and 6°38'42" East (Fig. 1).

Source: Authors' own study

Fig. 1. Location of study area

Administratively, it belongs to the province of Batna and includes six administrative districts: Arris, T'kout, Ichemoul, Théniat El Abed, Bouzina, and Menâa, along with seven municipalities: Oued Taga, Inoughissen, Foum Toub, Ghessira, Tighanimine, Tigharghar, and Chir. The area covers about 2051.51 km², bordered to the north by Tazoult and Timgad (both municipalities of Batna), to the east by the borders of province of Khenchela, and to the west and south by the borders of province of Biskra. As of around 2020, the total population of the region was approximately 172,165 according to the 2020 Batna Monograph, with a population density of about 83 people per square kilometer. A notable feature of the study area is its rural character, with 56.23% of the population residing in rural areas. Geographically, the area can be divided into several topographic units, primarily featuring the mountains that extend in all directions, the most notable being Mount Echemoul at 2100 meters and Mount Al-Mahmal at 2321 meters. These mountains appear almost parallel, creating slopes and foothills that serve as a base for some urban centers and form natural barriers between them. The second unit consists of basins, ranging in height from 1100 meters to 1300 meters, oriented from northeast to southwest. This includes the Oued Labiod Basin, which serves as the axis of the Aurès massif, with an estimated area of about 1292 km², and the Oued Abdi basin, which covers around 832 km² and narrows as we follow the course of the valley. The third unit represents the plains, which are extensive floodplains in the northern region that shrink southwards, with the most important ones being Bouzina, Oued Taga, and Foum Toub. Given their central location amid the mountain masses, these plains have considerable elevations reaching up to 1100 meters. Thus, we can say there is a variation in the topographic units within the study area, dominated by a mountainous character, making it a highly rugged region [Zeraib et al. 2018].

The region is characterized by a semi-arid climate with wet and cold winters, hot and dry summers, and significant irregularity and variability in precipitation due to the terrain, which sometimes acts as a barrier to rain and sometimes the opposite. Most of the rainfall occurs in two seasons: the first from March to April, and the second from September to December. December is the month with the highest rainfall, while July sees the least. The region receives between 153 mm and 417 mm of rain annually, with precipitation decreasing southwards. Snowfall is limited to the winter and spring season, occasionally extending to the end of fall and can last continuously for 15 days, according to [RainSphere 2023]. Meanwhile, the monthly average temperatures gradually increase starting in January, where the lowest temperature in December at −3°C at the Foum Toub and Ichmoul stations was recorded. The highest temperature was recorded in July at 40°C at the Ghessira station, while temperatures in the other months range from 2°C to 39°C.

The total length of the road network in the study area is 461.97 km, comprising 167 km of national roads, which cover 36.14% of the total length of the network. There are also 131.9 km of provincial roads, accounting for 28.55% of the total length, and 190.2 km classified as municipal roads, representing 41.17% of the overall length of the network. These roads experience constant traffic, with National Route 31 recording an annual daily traffic of about 14,103 vehicles per day, while National Road number 27 sees 9,278 vehicles per day, making them the main traffic arteries in the area. As for provincial roads, traffic density ranges from 615 to 2,423 vehicles per day. Meanwhile, the traffic density on municipal roads does not exceed 350 vehicles per day, according to statistics from the Public Works Directorate of the province of Batna in 2022.

2.2. Methodological approach and analysis tool

To address the research issue, we relied on the descriptive analytical method to understand the phenomenon of traffic accidents in mountainous areas and analyze their spatial distribution on the road network, as well as their temporal distribution over the period from 2017 to 2022. We aimed to highlight the variations in annual figures by months and by hours of the day, in addition to identifying the main factors and causes of these incidents. For this, we conducted an in-depth field study, starting with gathering information from various relevant authorities, including the Civil Protection Directorate and its various units within the study area, along with the National Gendarmerie teams and Health Services represented by hospitals and multi-service clinics in the region. We collected annual statistics on traffic accidents and their locations, as well as data on the causes of these accidents. To analyze this phenomenon, we used Arc GIS 10.8 software to examine the spatial distribution of the phenomenon, understand the trends of its spread, and identify black spots using Spatial Pattern Analysis:

- plotting the Mean Center to identify the average point of accident concentration,
- plotting the Directional Distribution to determine the spread direction of accidents,
- analyzing the distances between accidents using the line Distance tool to study the relationship with infrastructure or critical points,
- conducting Hot Spot Analysis using the density line tool to identify the most frequently occurring areas.

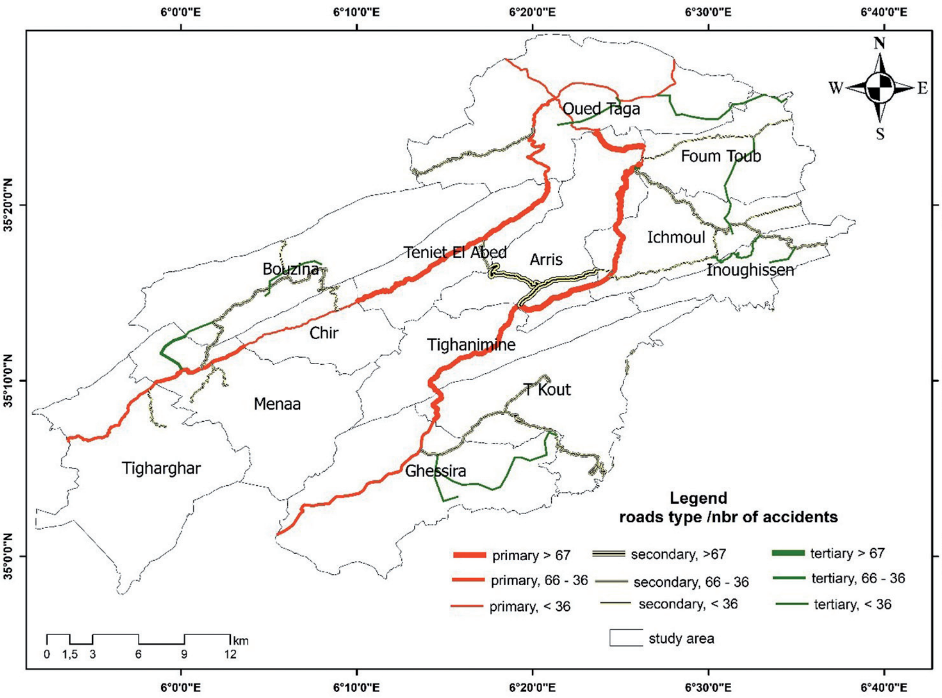
We also used the SPSS 2020 software to apply Exploratory Factor Analysis which is one of the most important statistical methods for reducing the number of variables and clarifying the relationships and correlations between them. To carry it out using SPSS, we followed the steps below:

- **Data preparation:** Here, we presented the variables in columns, while the rows represent the incident data
- **Testing the suitability of data for factor analysis:** To check the suitability of the data, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity were used.
- **Determining the extraction method:** The factor extraction method was determined, and we chose Principal Component Analysis (PCA).
- **Determining the rotation method:** To clarify the interpretations, we rotated the factors using the Varimax method to visualize the factor weights.
- **Naming and interpreting the factors:** After performing the analysis, we obtained results that included the KMO and Bartlett tests, and the rotated component matrix, while the factor weights in the rotated matrix are used to determine the variables associated with each factor. We classified the variables associated with each factor based on the factor weights in the Rotated Component Matrix, and then we named each factor to reflect the nature of the variables related to it, contributing to the formulation of the theoretical interpretations related to the analysis results.
- **Inserting and analyzing the results:** We inserted the final results in form of a table containing the number of extracted factors, the names of the factors, and the proportions of each variable.

3. Results and discussions

3.1. The geographical distribution of traffic accidents on the road network of the study area

The Aurès road network recorded 930 traffic accidents between 2017 and 2022, averaging 1 accident every two days and 6 accidents for every 1,000 residents. The national roads accounted for about 542 accidents, making up 58.27% of the total, while 284 accidents occurred on provincial roads, representing 30.53% of the total accidents. Additionally, municipal roads recorded around 104 accidents, or 11.18% of the total. This is mainly due to the proportional relationship between traffic density and traffic accidents over the years of study, as well as the region's challenging topography, which features rough roads and dangerous curves. The maximum speed limit doesn't exceed 80 km/h on national roads and 60 km/h on provincial roads in the best conditions regarding road conditions and weather.



Source: Authors' own study

Fig. 2. Traffic accidents on the road network of the study area

We recorded 383 accidents, accounting for 41.18% of the total, on the main traffic axis represented by National Route 31, which cuts across the area from north to south, linking the town of Arris, the first city in the region, with Batna to the north and Biskra to the south. It also serves Tighanimine, T'kout, and Ghessira, and has the highest annual daily traffic in the region, estimated at 14,103 vehicles per day per year. In second place is National Route 87, which experienced significant accidents totaling 152 and constituting 16.34%. This is due to the importance of the road, which is the second main artery, linking the municipality of Ouad El-Tarif, the second largest city in terms of population, towards the city of Biskra to the south, passing through Théniat El Abed, Menâa, and Tigharghar. This road also sees a large annual daily traffic volume in the region, estimated at 9,278 vehicles per day per year.

As for the provincial roads, the highest numbers were recorded on provincial roads number 45 and 05, with 83 and 79 accidents respectively, which corresponds to 8.9% and 8.49% during the same period. This is an average figure compared to previous years, given the daily annual traffic volume, which reached 3,579 and 2,423 vehicles per day per year, respectively.

Meanwhile, other provincial roads had similar figures ranging between 22 and 35 accidents during the same period. Provincial road number 54 recorded the lowest number of accidents in the area with 12 accidents, accounting for 1.29% of the total number of accidents, which is attributed to the road recently reopening after being abandoned due to security conditions.

In total, municipal roads recorded 104 accidents, which is due to the low daily traffic volume that does not exceed 350 vehicles per day per year (Fig. 2).

3.2. Spatial analysis of traffic accidents in the study area

3.2.1. The geographical center

The geographical study of traffic accidents focuses on analyzing spatial distribution metrics. We applied the ideal central point or central phenomenon and spatial average [Ben Chenna Abdel Ali 2019], as shown in (Fig. 3). The geographic center is located near the city of Arris, due to it being the first city in the area that features all the essential urban facilities and services, making it a significant attraction for residents of neighboring municipalities. Additionally, it is served by National Route 31, which is the main traffic route in the area, thus this city recorded the highest figures over the years of study.

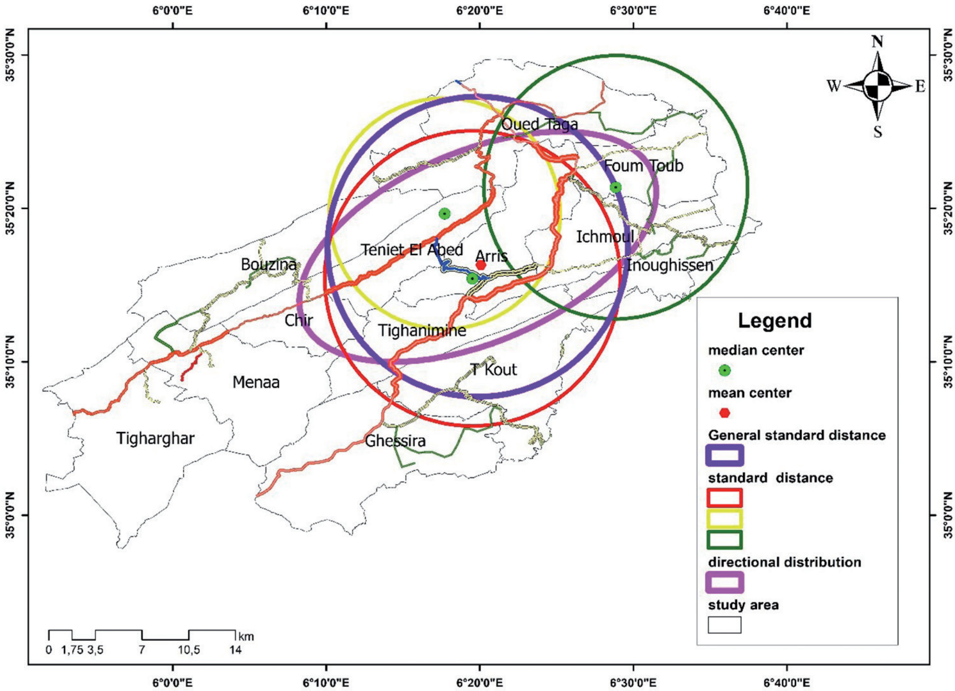
3.2.2. The Central Phenomenon and standard distance

We can see from (Fig. 3) that the standard distance shows the concentration of the phenomenon along the national roads in the largest area marked in red, which includes National Routes 31 and 87, covering a larger area that includes the city of Arris. This is due to the same reason mentioned earlier.

As for the standard distance indicating the spread of the phenomenon along the municipal roads marked in green, it ranks second in terms of distance as it includes Inoughissen, Ichmoul, and Foum Toub, which are municipalities with a rural character where municipal roads make up a large proportion of their total road network. Coming in third place, marked in yellow, the spread of the phenomenon along the provincial roads includes Arris, Bouzina, and Théniat El Abed, which is attributed to the dynamics seen in the provincial roads in these municipalities.

3.2.3. The distribution trend of the phenomenon

The oval shape on (Fig. 3) indicates that the distribution of traffic accidents in the study area extends from the northeast towards the southwest, aligning with the main traffic roads of National Routes 31 and 87. This trend can be explained by the presence of the city of Batna to the north and the city of Biskra to the south, which serve as constant magnets for the residents of the study area due to the services and job opportunities they offer, leading to daily commutes to these cities (Fig. 3).

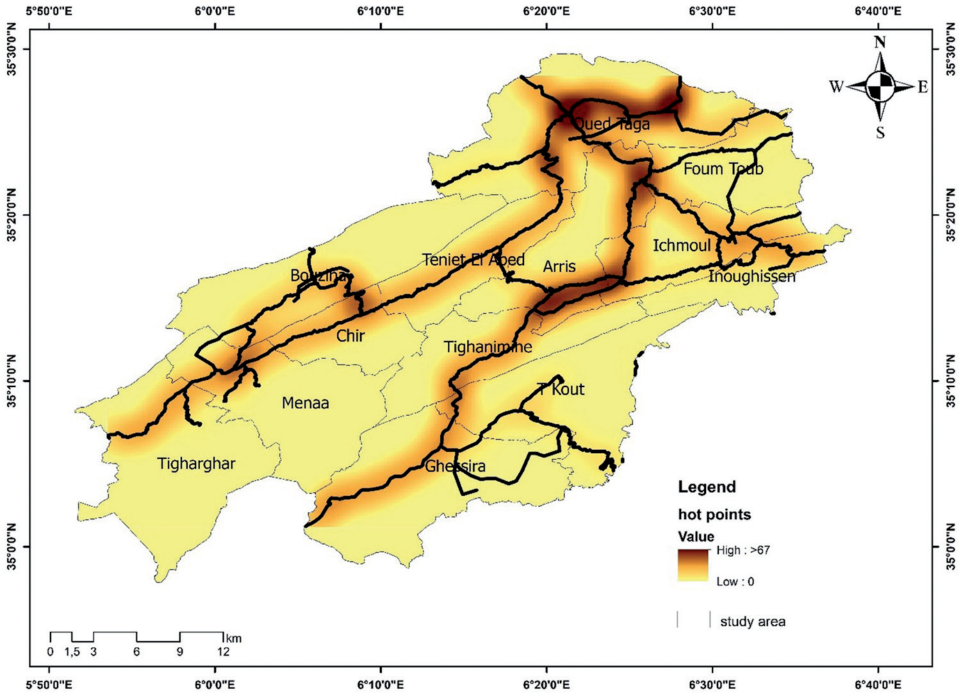


Source: Authors' own study

Fig. 3. Spatial analysis of traffic accidents in the study area

3.2.4. Identifying hotspots

We input the number of traffic accidents on each road and generated the map using Density line technology. We found that the hotspots are concentrated along the National roads, particularly in the Arris and Oued Taga municipalities, and the energy regions, which are characterized by high population density and constant movement. To a lesser degree, we observe hotspots at the intersection between the Foum Toub municipality and National Route 31, as well as others on National Route 87. This is attributed to the significant terrain variations in these areas, which feature dangerous curves, especially in winter when icy conditions and fog are more frequent (Fig. 4).



Source: Authors' own study

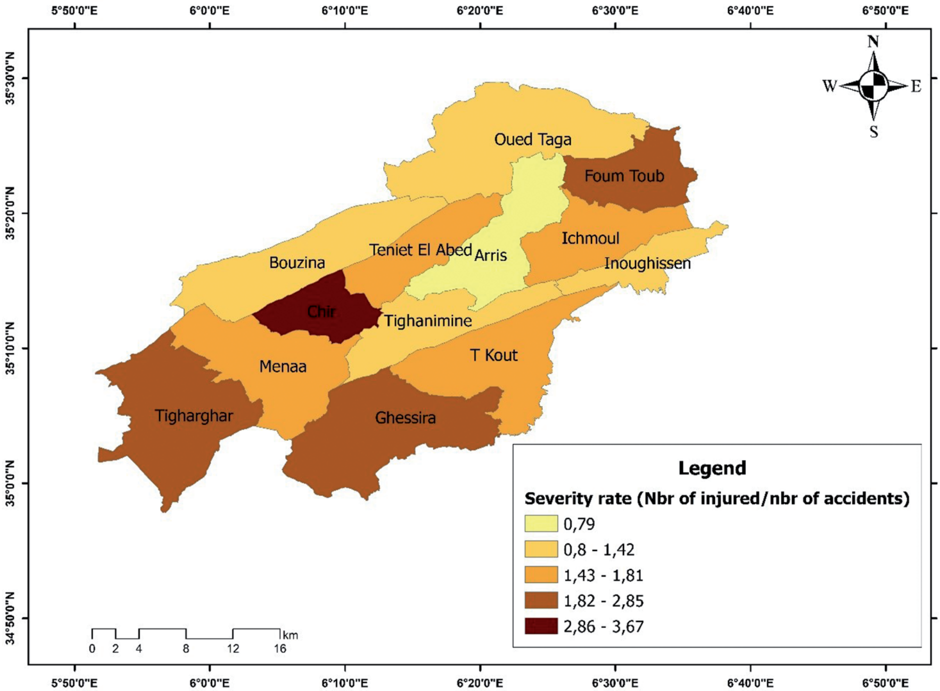
Fig. 4. Identifying hotspots of traffic accidents in the study area

3.2.5. The geographical distribution of the accident severity rate in the study area

Severity rate is a measure that indicates the severity of traffic accidents, expressed as a percentage representing the number of injuries per accident. Based on the statistics obtained from various health authorities, we found that the severity rate in the study area reached 1.87%, which is considered high compared to the national average of 1.28%.

The highest rate recorded was in the municipality of Chir, at 3.67%, followed by Tigherghar, Foum Toub, and Ghassira with rates of 2.85%, 2.56%, and 2.23% respectively. It's noticeable that these rates are inversely proportional to the number of traffic accidents, attributed to the topography of the mentioned municipalities that leads to fatal accidents. In contrast, the municipalities of T'kout, Menaa,Théniat El Abed, and Echmoul had Severity rate of 1.82%, 1.74%, 1.68%, and 1.67%, respectively, which are above average, primarily due to the nature of the incidents themselves, as most were accidents with material consequences.

As for Oued Taga, Bouzina, Tighanimin, and Inoughisen, they recorded risk rates around the overall average of the study, ranging from 0.8% to 1.42%. At the lower end of the severity rate, we found the municipality of Ariss with a rate of 0.79%, which is attributed to the nature of accidents primarily involving material damages, and secondly to the number of accidents occurring within the urban space (Fig. 5).



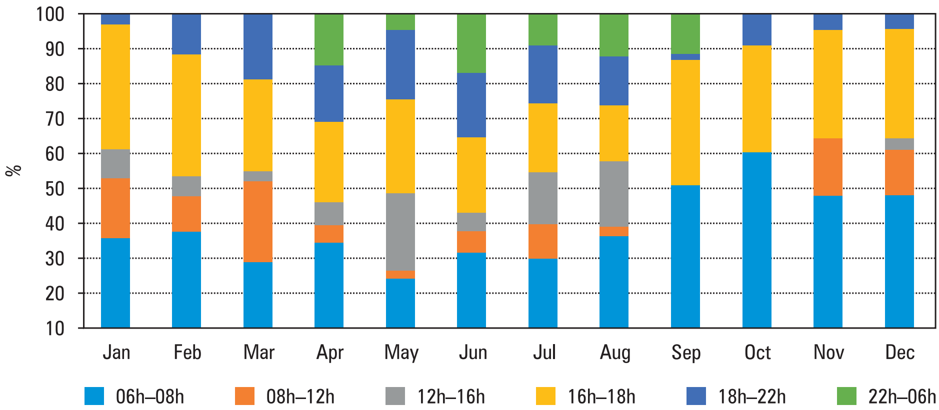
Source: Authors' own study

Fig. 5. The geographical distribution of the accident severity rate in the study area

3.3. The temporal distribution of traffic accidents in the study area

In Figure 6 we observe that traffic accidents from 2017 to 2022 showed a decrease from 2017 until 2021, where in 2017 there were about 201 accidents, accounting for 21.61% of the total accidents recorded in the city of Arris, which had the highest number with 62 accidents. This is due to the city's significance in the study area, as it is the primary city with a wide range of public services attracting people, served by National Route 31, which experiences significant traffic, as mentioned earlier. In contrast, we find Tigharghar, Chir, FumToub, and Inoughissen with 2, 2, 3, and 5 accidents respectively in the same year, attributed to the fact that these municipalities are marginal and are served by provincial and municipal roads that have minimal traffic and a small population compared to other municipalities. In 2018 and 2019, we saw a slight fluctuation in the annual accident numbers with 190 and 178 accidents respectively, maintaining the same distribution across various municipalities in the study area. The fluctuation continued in 2020 due to measures enforced by the state to combat the COVID-19 pandemic, which included imposing curfews that completely restricted vehicle movement, especially during nighttime from 6 PM to 6 AM. In 2022, the number of traffic accidents rose significantly, with 178 accidents after all precautionary measures related to the COVID-19 pandemic were lifted and traffic returned to normal. It should also be noted that the distribution of traffic accidents across the months was varied, with the largest number of accidents in the study period occurring in July with 119 accidents, followed by August with 109. In contrast, January, February, May, November, and December experienced accidents ranging between 62 and 88, close to the average. Meanwhile, for April, September, and November, the lowest figures recorded were 55, 55, and 56 accidents respectively, marking the smallest values. This varying distribution is attributed to continuous movement 24 hours a day in summer months (June, July, August), unlike winter months and, to a lesser extent, autumn, where movement tends to be almost nonexistent at night due to harsh weather conditions, including ice and fog.

As for the distribution of incidents throughout the day, we recorded 284 accidents from six to eight in the morning and 277 accidents from four to six in the evening, which are peak hours since they coincide with the typical time for people to start and end work. It's worth noting that locals frequently travel to the state capital (Batna) for their daily needs, alongside the hazards of ice and fog during the morning hours from six to eight. This also explains the occurrence of 124 accidents between six and ten in the evening, especially in the winter season, while there were about 85 accidents from noon to four in the afternoon due to reduced traffic. The nighttime period is related to the lowest numbers with 66 accidents, largely due to almost no traffic in several months of the year because of the tough weather conditions the area faces (Fig. 6).



Source: Authors' own study

Fig. 6. The temporal distribution of traffic accidents in the study area

3.4. Factor analysis of traffic accident causes in the study area

To use exploratory factor analysis, we collected data on 350 accidents in the study area during the period from 2017 to 2022 and divided it into parts. The first part relates to personal data consisting of 3 defining axes aimed at understanding the personal aspects of the vehicle driver, and the second part is about the causes of traffic accidents, consisting of 23 variables that were entered into the SPSS Statistics 20 software. After that, we followed the necessary steps as follows.

3.4.1. Examining the Suitability of the Correlation Matrix for Factor Analysis

We obtained a table showing the correlation matrix in the upper half and the statistical significance of the correlation coefficients in the lower half. Most of the correlation coefficients were statistically significant, with a large proportion of these correlations exceeding the level of 0.2 [Ben Zarqa 2022]. Additionally, the matrix had no correlation coefficients greater than 0.00001, indicating that there are no extremely high correlations. The determinant value was 1.190, which is higher than 0.00001. Therefore, the correlation matrix does not exhibit high correlations, nor are there linear relationships among the variables.

Regarding the Bartlett test, it is statistically significant, indicating that the correlation matrix is not an identity matrix devoid of relationships; it has at least the minimum required relationships. As for the KMO test, according to the Kaiser simulation, values ranging from 0.5 to 0.7 are acceptable, values from 0.7 to 0.8 are good, values from 0.8 to 0.9 are very good, and values exceeding 0.9 are excellent [Tighza 2012]. We find that the KMO value shown in Table 4 equals 0.645, which is an acceptable value. Thus, we can say that the sample size is sufficient for conducting factor analysis.

Moreover, the MSA measure for each variable is above 0.5, as indicated in the diagonal cells of the correlation coefficients in the lower rectangle of the correlation matrix (Table 1).

Table 1. KMO Indicator and Bertlett scale

Precision measurement of 'sampling of Kaiser-Meyer-Olkin'		0.645
Bartlett Sphericity Test	Chi-square approximation	0.460 949
	Ddl	190
	Significance of Bartlett	0.000

3.4.2. Extraction and naming of factors

Below is a table of loadings for the variables related to the causes of traffic accidents when using SPSS20 for exploratory factor analysis. After rotation using the Varimax method, we obtained all the high, medium, and low loadings, which were used to identify the four factors based on the common meaning among the variables loading onto each factor. The extracted Factors can be named as follows (Table 2).

Table 2. Extraction and naming of factors

No.	Branching elements	Factors names	Factors saturation percentage	Covariance ratio
01	Racing experience	The driver	63.6	24.85
	Driver's cultural level		59.5	
	Driver's gender		51.1	
	Not respecting the safety distance		38.4	
	Excessive speeding		34.8	
	Racing under the influence of a drug		33.4	
02	Time of accident	Weather conditions	65.5	18.62
	Accident due to ice		64.2	
	Accident due to fog		60.2	
	Month of accident		38.2	
	Accident due to snow		33.2	
	Accident location environment		30.6	
03	Accident due to dangerous curves	The road	55.5	12.02
	Potholes and bumps		51.0	
	Accident due to lack of traffic signs		48.3	
	Type of accident		41.8	
	Road type		30.2	
04	Accident due to brake failure	The vehicle	49.7	9.01
	Accident due to imbalance and instability		48.9	
	Accident due to mechanical failure		45.3	
	Accident due to worn tires		42.0	
	Vehicle type		37.2	

3.4.2.1. The first factor – the driver

Accounts for 24.85% of the common variance and has highlighted six factors that include the driving experience accounts for 63.6% of the factor, showing that drivers with less than two years of experience are more prone to accidents, followed by those with 2 to 5 years of experience. This highlights the dangers of driving in mountainous areas, which feature difficult roads and require significant focus, experience, and mental presence. The driver's cultural level has a saturation level of 59.5%, reflecting the awareness and sensitivity to the dangers resulting from traffic accidents and their various consequences that affect individuals and society. The gender of the driver also holds a saturation level of 59.5%, indicating a direct influence where men are more likely to have accidents than women, primarily due to a high number of males operating vehicles. An accident due to not respecting the safety distance set by traffic law has a saturation level of 38.4%, and an accident caused by speeding accounts for 34.8%, both indicating the driver's disregard for traffic laws. Lastly, an accident caused by driving under the influence, as mentioned earlier, requires significant focus and mental presence, has a saturation level of 33.4%.

3.4.2.2. The second factor – weather conditions

This factor contains six variables that explain 18.64% of the variance, including the timing of the incident with a factor loading of 65.5%, incidents caused by ice with a factor loading of 64.2%, the month of the incident with a factor loading of 60.2%, incidents caused by snow, and incidents caused by fog with factor loadings of 38.2% and 33.2% respectively. This is attributed to the poor weather conditions, especially in winter, due to the mountainous region's location and climate characteristics, which are prone to snowfall and hail leading to the formation of ice and fog, contributing to accidents, particularly in winter. Additionally, the variable related to the accident environment has a factor loading of 30.6%, which relates to the weather conditions factor. In our view, this is due to the connection between traffic accidents caused by bad weather, road conditions, and the level of road preparedness, in addition to the relationship between traffic density and the timing of the incident.

3.4.2.3. The third factor – the road

Includes 5 variables that explain 12.02% of the shared variance. They are accidents due to dangerous curves with a factor loading of 55.5%, accidents due to potholes and bumps with a factor loading of 51.0%, and accidents due to a lack of traffic signs with a factor loading of 48.3%. The type of accident is mainly attributed to the area's topography, characterized by roads with dangerous curves that don't meet global standards in terms of geometric design, in addition to the overall condition of the roads caused by water accumulation, rough surfaces, and the level of public facilities, with factor loadings of 41.8% and 30.2%, respectively.

3.4.2.4. The fourth factor – the vehicle

Attracted four factors explained 9.013% of the common variance, and they are as follows: accidents caused by brake failures accounted for 49.7% saturation on factor, accidents due to wheel alignment and balance issues had a saturation of 48.9% on factor, accidents caused by mechanical faults showed a saturation of 45.3% on factor, accidents due to tire wear had a saturation of 42.0% on factor, and the type of vehicle showed a saturation of 37.2% on factor. These are faults that affect the vehicle, related to the road or resulting from the owner's negligence.

4. Conclusion

Through our study, aimed at analyzing the issue of traffic accidents to understand the spatial and temporal distribution of the phenomenon and the main contributing factors, we found that the numbers recorded on national roads are the highest, with National Route 31 topping the list, followed by National Route 87, followed by provincial and then municipal roads. This distribution was found to correlate with traffic density and the significance of the cities served by these various roads. In terms of temporal distribution, we discovered that the phenomenon's occurrence is related to seasonal variations and peak hours of the day. We also found that traffic accidents are complex events involving interactions between many factors. Among these, driver-specific factors accounted for a common variance of 24.85%, making them the main contributor to accidents, in addition to environmental and weather-related factors at a common variance of 18.64%, as well as vehicle-specific factors and road defects at common variances of 12.02% and 9.01%, respectively.

In an attempt to alleviate the issue of traffic accidents, and based on our findings from the applied study, we propose the following solutions to all stakeholders in the field of traffic accidents: recognize the painful reality of the human and material losses that citizens bear, and implement practical solutions to reduce the frequency and consequences of these accidents.

There is a need to establish a scientific framework for handling the reality of traffic accidents through scientific analysis and the use of modern information systems for recording data and information related to this phenomenon. We should utilize the analysis of this information as a vital means for evaluation and study, determining the losses incurred from traffic accidents, and identifying ways to address the situation.

An effective mechanism for cooperation among various concerned bodies, including traffic departments, media, schools, municipalities, institutes, universities, and health organizations, as well as informal entities, should be established to help achieve the desired goal of ensuring traffic safety.

The role of security media must be activated to cultivate social responsibility among all individuals and institutions in the community, starting from mosques, families, schools, universities, and media outlets.

Strict rules and regulations should be instituted for issuing driver's licenses, which would require passing actual tests and mandating periodic medical examinations to assess individuals' sensory capabilities and their ability to drive safely.

We should strive for intensive monitoring of driver behavior and enforcement against violators of traffic regulations.

Media should provide informational programs and periodic updates on traffic awareness, broadcasting campaigns to reduce traffic accidents, serious injuries, fatalities, and the resultant loss of life, especially emphasizing the use of traffic safety measures and first aid principles.

Traffic safety concepts and principles should be included in the school and university curricula.

Increased attention should be given to medical care and its effective role, proposing the placement of ambulances and mobile hospitals on highways and vital routes. Having a well-organized medical service system can save many lives that are lost due to traffic accidents.

There is an urgent need to focus on research and scientific studies aimed at reducing traffic accidents, and the state should allocate a specific budget for studying these incidents and working on minimizing their occurrence and the resulting losses.

Warning and guiding signs should be placed at adequate distances.

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