

ISSN 2300-1496

Research paper

https://doi.org/10.15576/GLL/194033

Received: 2.08.2024 Accepted: 2.10.2024 Published: 31.12.2024

Spatial analysis of traffic accidents using geographic information systems: case study of the wilaya of Sétif (Algeria)

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Summary

The road network of the wilaya of Sétif is facing problems with congestion and intense traffic, which calls for special attention to traffic detection. The aim of this study is to highlight the capabilities of GIS to identify areas where road accidents are frequent, to analyze their causes, and to guide the efforts of the authorities of the wilaya of Sétif to resolve this situation. Thus, we propose solutions and measures to improve road planning and effective traffic management. The spatial analysis of the phenomenon, which is based on a quantitative and descriptive analysis method using GIS, reveals that the national roads are the most exposed to road accidents, with an incidence of 56.69%, or 257 injuries and 35 total deaths for the year of 2022. This type of road network is heavily utilized, and the current statistical analysis of 515 accidents, compared to the years 2021 and 2020, shows an improving trend, which is worrying. The results highlight the urgent need for targeted interventions and strategic planning to improve road safety in the region. By using GIS technology, authorities can not only identify high-risk areas, but also develop data-driven policies that focus on infrastructure improvements and effective traffic management strategies to reduce the increase in accidents.

Keywords

analysis • accident • traffic • GIS • Sétif • Algeria



1. Introduction

Traffic accidents are a major economic, social and public health problem for all countries according to the World Health Organization [WHO 2020]. This phenomenon is a social epidemic that requires the mobilization of public authorities to reduce its severity [The World Bank 2014]. Unsafe road conditions can lead to an increase in the number of accidents and victims [Madani et al. 2019]. This high cost in human lives creates a public health problem at the national, regional and local levels [WHO 2020]. A study commissioned by the Ministry of Transport to assess this phenomenon concluded that the economic cost of road accidents is 1.4% of the country's GNP (Gross National Product) [Peden 2004]. However, public road safety policies differ from state to state and their application affects the current level of safety [Carnis 2014]. Traffic accidents are considered perhaps one of the most significant contemporary issues that impede social development due to the human and economic losses [Ben Cherif 2015]. Traffic accidents are also considered one of the leading causes of death in the world, and in Algeria in particular [Ouramdane et al. 2023]. Algeria is one of the countries with a particularly high rate of road accidents, resulting in a large number of deaths and injuries each year [Madani et al. 2015]. Each year, more than 25,000 road accidents are recorded Algeria, causing nearly 4,000 deaths, more than 35,000 injuries, as well as 3,000 to 4,000 new cases of disability [Hidra et al. 2022]. Many recent researches have addressed the phenomenon of road accidents in Algeria using geographic information systems in order to obtain satisfactory results for the treatment and reduction of this phenomenon. Among these studies, we rely on Derras [2023] with regard to road safety in road projects in Algeria, Boulkaibet et al. [2019] on the use of GIS in the study of the spatial coverage of public transport: the case of the city of Skikda, and Belloumi and Benadjemia [2015] on the implementation of a geographic information system for public transport management. As these studies, we recognize traffic accidents as a persistent and worrying problem in the wilaya of Sétif. On the one hand, the constant increase in the number of vehicles on the roads reflects a certain level of prosperity, as well as economic and social progress. However, this increasing motorization is also accompanied by particularly serious and worrying issues with road safety [Sidi Saïdy et al. 2017]. The wilaya's road network is subject to intense traffic throughout the year, involving various types of transport, whether private, public or commercial. This dense and constant traffic frequently leads to serious, often fatal, accidents. Given the recurrence of these accidents across the entire region's road network, it is crucial to analyze the root causes of this phenomenon. The central question of this study is therefore: how can we diagnose this situation using tools such as geographic information systems (GIS), and what strategies can be implemented to reduce the frequency and severity of traffic accidents? It is essential to provide precise answers and develop concrete solutions to improve road safety in the wilaya of Sétif, while taking into account the local specificities of the network and driving behaviors. This study aims at the spatial analysis of traffic accidents in Sétif at the wilaya level using geographic information systems. It is based on the representation of different accident points on three types of roads (highways, national roads and wilaya roads) for the year 2022.

2. Materials and methods

2.1. Presentation of the study area

The wilaya of Sétif is located in the eastern Algerian highlands. It lies between the parallels 35°36'58" and 36°35'45" north and the meridians 4°43'52" and 6°1'37" east. With an area of 6666, 14 km², it includes 60 municipalities grouped around 20 daïras [Benkhelfi and Bouchachoua 2021].



Fig. 1. Location of the study area

The wilaya of Sétif is bordered to the north by the wilaya of Bejaia and Jijel, to the east by the wilaya of Mila, to the south by the Wilayas of Batna and M'sila and to the west by the wilaya of Bordj Bou Arreridj (Fig. 1) [Ounas et al. 2021]. Demographically, the wilaya of Sétif is classified as the second largest after Algiers, with a population of 2,076,859 inhabitants in 2020, representing almost 5% of the Algerian population, and with an average density of 317 inhabitants/km² [National Statistics Office 2021]. The topography of the Sétif wilaya plays an important role in determining the routes of road networks and its significant impact on transport of all kinds [Zoghbi 2021]. It is characterized by a significant altitudinal variation ranging from 297 m to 2004 m (Jebel Babor). The climate of the study area is Mediterranean, with a cold, rainy winter and

a dry, hot summer. The average annual rainfall ranges from 399 to 453 mm [RainSphere 2023]. The average temperature is 18°C, the average minimum temperature is 1°C in February, while the average maximum is 38.81°C in July. Land use is mainly natural vegetation in the form of forests and scrubland, rangelands, agricultural land, bare and urban soil. Economically, the wilaya has a very important role in practically all sectors, which has contributed to the diversification and development of various commercial activities. The study area has an essential road network, consisting mainly of three types of roads: highways, national roads and Chemin de Wilaya [Sahari 2020].

2.2. Methodological approach

Each study adopts a specific methodology aimed at gathering and analyzing data pertinent to the phenomenon under investigation, ultimately leading to informed results, conclusions, and proposals. In this research, a mixed-method approach was adopted, combining both descriptive and quantitative analytical techniques to provide a comprehensive understanding of the traffic situation and accident patterns in the wilaya of Sétif. First, was employed the descriptive approach to capture an accurate picture of the current state of the road network. This approach was crucial in mapping out the various characteristics of traffic flow, road conditions, and infrastructure. By relying on observational data and existing records, this method helped illustrate the volume, density, and distribution of traffic across key routes in Sétif. The aim was to reflect the situation in a clear and accessible way, allowing for a detailed examination of the existing road conditions and usage patterns. Secondly, the quantitative analytical approach was applied to analyze traffic accidents systematically. This methodology was rooted in statistical tools and techniques, which enabled the research team to monitor, track, and evaluate accident data over a given period. By quantifying the accident rates, locations, and contributing factors, this approach provided insights into the frequency and severity of traffic incidents. Furthermore, statistical analyses, such as trend analysis, regression models, and correlation tests, were used to identify potential risk factors, and assess the relationship between traffic conditions and accident occurrences. By combining these two methods, the study not only described the current road and traffic situation in Sétif, but also provided an evidence-based analysis of accident patterns. This dual approach provides both a qualitative understanding of the network structure and a rigorous quantitative evaluation of accident data, allowing targeted improvements and safety measures to be proposed for the wilaya of Sétif.

2.3. Analysis tool

However, it is necessary, when studying such case as that of the Sétif wilaya, to be able to examine the phenomenon of transport accidents and their spatialization in order to identify problem points, using geographic information systems. In order to support such analysis, the Arc GIS 10.6 and Google Earth software was used.

2.4. Data collection

The collection of information on road accidents is entrusted to the police forces that intervene at the scene of the accident (the gendarmerie in rural areas and the police in urban areas), by filling in, first, a report for judicial use, and then a statistical sheet allowing the creation of the national file [Ben Cherif 2015]. Other sources of data come from the civil protection department, hospitals and insurance companies covering personal accidents. In our case, the basic data for this study, collected from various public administrations, cover the entire territory of the wilaya for the year 2022. These data essentially represent the road network, which has been digitized and displayed directly on the screen using the Google Earth tool, as well as the points of accidents that occurred during the above-mentioned date on the entire road network, which covers the entire territory of the wilaya. The data (accident points) obtained in paper format contain only the following information: geographical coordinates (X, Y) of the accident, the number of dead and injured. It is necessary to highlight the difficulties and obstacles encountered in collecting this data. In particular, there was a lack of data gathered on the type of vehicle, the age group, and the type of sex of drivers (male or female). According to the administrative services concerned, these data are not available at the level of their services or they are private, and therefore they cannot be obtained. So, these difficulties are not only due to the lack of data, but also to the lack of studies and research on this phenomenon at the level of this wilaya. As these data are not sufficient, we have resorted to intervening with the competent authorities in order to obtain additional information that would allow us to analyze this phenomenon later. All the data collected from different sources (administration, documentation, field survey) were integrated into a Geographic Information System to constitute a database for later use in the analysis and spatial distribution of this phenomenon at the scale of the study area.

3. Results

Transportation has been necessary for mankind since the beginning of history, and it coincided with the emergence and development of the road. Land transport still predominates over other modes of transport due to its ease of implementation and its direct relationship with the life of human groups [Ait Bara et al. 2022].

3.1. Type of the road network in the wilaya of Sétif

The road network of the wilaya of Sétif is estimated at a total length of 1449 km. This includes a highway with a length of 73 km, which divides the wilaya into two parts, and national roads, of which there are 13, with a length of 714 km, and several wilaya roads, of which there are 24,662 km long (Fig. 2).

As to type classification, this road network consists of highways, national roads and wilaya roads that link either the capital of the wilaya or the neighboring municipalities.



Fig. 2. Road network wilaya of Sétif

3.1.1. Highway

Highways are designed to high capacity and efficiency specifications, as they connect to national roads and those wilaya roads that connect major cities. These roads consist of two lanes in opposite directions, each lane containing three traffic lanes and each lane being 6 m wide, with a reinforced concrete median strip separating the traffic directions (Fig. 3).



Source: Authors' own study

Fig. 3. East-West Highway (2023)

3.1.2. National Road

It is one of the most important roads designed according to high-efficiency measures, as it connects the centers of the wilayas or major cities with each other. It is usually two-lane or single-lane with a width of up to 8 m. This type of road is made because of the importance of traffic between regions (Fig. 4).



Source: Authors' own study

Fig. 4. National road (2023)

3.1.3. Wilaya Road

These are the roads inside the wilayas, connecting the municipalities and neighboring villages. These wilaya roads generally have a single lane with a width of 8 m (Fig. 5).



Source: Authors' own study

Fig. 5. Wilaya road (2023)

3.2. The density of road network

Figure 6, which represents the density of the road network in the wilaya of Sétif, shows three different concentration zones which are: very high density areas represented by classes (39–55, 28–39), medium density areas represented by classes (20–28, 12–20), low density areas represented by the class of 0–12.



Fig. 6. Density of the road network wilaya of Sétif

The highest density was observed in the center and around the town of Sétif, and to the east in the municipality of Eulma and to the south is the municipality of Ain Ouelmen. This level of density is explained by the intensity of the activity and the great dynamism in this area towards the seat of the wilaya. The medium-density zones represent all the municipalities located in the first municipal service zone, offering fairly average services compared to the first quality service zone. The low-density areas located to the north and south of the wilaya generally represent mountainous areas and isolated places.

3.3. Causes of traffic accidents in the wilaya of Sétif

Traffic accidents are caused by specific factors, including the interaction between driver, road, vehicle, weather conditions Any failure of any part of this system can lead to traffic accidents. In this sense, vehicles import planning should only proceed if accompanied by regulations and controls to ensure their safe circulation. Accidents in the study area are caused by bends and narrow roads, thus driving vehicles that exceed the design capacity of the road contributes to these road incidents. Addressing this issue requires regular maintenance, road extensions, and installation of traffic signs and lighting to reduce the occurrence of this phenomenon.

3.4. Spatial analysis of accident points in 2022 in the wilaya of Sétif

Traffic accidents occurring in 2022 across the wilayas entire road network reached 293 accidents with 515 injured and dead. The spatial distribution of accident points in Figure 7 for the year 2022 shows that all these accidents are mainly concentrated in the north and the south on all types of roads (highways, national roads and wilaya road).



Fig. 7. Accident points for the year 2022 in the wilaya of Sétif

3.4.1. The distribution of accident points for the year 2022 by type of road

The number of traffic accidents differs between the road types, and the difference depends on the efficiency, length and width of the road.

For the highway category, 31 accident points were recorded for the year 2022 over a length of 73 km. The national roads type, which are 714 km long, recorded 167 traffic accidents during the same year. Wilaya roads are 662 km long and cover most of the territory of the wilaya, with the number of accidents estimated at 95 accidents (Fig. 8).



Fig. 8. Accident points by road type for the year 2022 in the wilaya of Sétif

3.4.2. The distribution of accident points according to the number of injured and dead

The number of traffic accident victims varies between road types, depending on the location of the road, the number of inhabitants in the area, and the number of passengers in different means of transport. On the highway, the human losses amount to 43 injured and 15 dead in 2022, while on the national roads this number reaches 257 injured and 35 dead , and on the wilaya roads the number of injured decreased to 135, with deaths per 30 people.

Table 1 shows that the average distance estimated by the type of road, i.e. km per accident, per number of deaths and injuries, varies from one road to another depending on the length of each type of road and the number of accidents recorded during 12 months of the year 2022. The lowest figures were recorded on the highways, with 31 accidents, i.e. 2.35 km per accident, 1.69 km per injured and 4.86 km per death. These figures increase significantly on national roads with 257 accidents, the average distance between one accident and another is estimated at 4.27 km per accident with 2.77 km per injured and 20.4 km per death.

The wilaya roads are generally the most frequented, because this type of road are joined to the national roads and highways, which connect all the municipalities and villages of the wilaya of Sétif. However, the number of accidents recorded on this type of road reached 95, which equals 6.96 km per accident, 4.9 km per injury and 22.06 km per fatality. The total number of accidents on the entire road network of Sétif, which is 1449 km long, wilaya was 293, with 435 injuries and 80 deaths. This gives 13.58 km

per accident, 9.36 km per injured and 47.32 km per death. These figures show a strong direct correlation between the length of each type of road, the number of accidents and the number of injuries and deaths, indicating that an increase in population leads to an increase in the number of vehicles, and the number of vehicles on the road leads to an increase in accidents (Fig. 9). These accidents are also increasing on the national road network, particularly at entrances close to the city center, where all services and infrastructure are concentrated, and as the pressure grows, this area is becoming a major accident area.

Road type	Year 2022						
	Length [km]	Number of accidents	Number of injuries	Number deaths	Distance km/accident	Distance km/injured	Distance km/death
Highways	73	31	43	15	2.35	1.69	4.86
National roads	714	167	257	35	4.27	2.77	20.4
Wilaya roads	662	95	135	30	6.96	4.9	22.06
Total	1449	293	435	80	13.58	9.36	47.32

 Table 1. Traffic accident statistics for the year 2022



Source: Authors' own study

3.4.3. The spatial distribution of accidents in 2022

In the wilaya of Sétif, despite the efforts, the problem with traffic accidents is still serious, displaying growing intensity and volume. Statistics show that this situation never improves. This is why we focused in this study on a precise image of the phenomenon of traffic accidents during the year 2022.

Fig. 9. Accident on the east-west highway in 2022 in the wilaya of Sétif

3.4.3.1. The geographical center of the phenomenon

The geographic center of the phenomenon is the main criterion that we adopt to precisely determine the focus of the phenomenon. It is adjacent to the center of the phenomenon this indicates that the closer the geographical center is to the center of the phenomenon, the greater the precision of the center, and vice versa (Fig. 10).

3.4.3.2. The center of the phenomenon

The center of the phenomenon is located on the highway near the main entrance to the urban center, which is a meeting point for all flows that connect the road network with the center of the wilaya. This area has great economic and tourist importance, having for example the commercial center in the town of El Eulma. All this has made Sétif a tourist destination because of its natural and recreational assets (Fig. 10).

3.4.3.3. The distribution of the direction of the phenomenon

The direction of the phenomenon from the south-east to the north-west is explained by the importance of the geographical location of the wilaya which is considered the gateway to the wilayas of Jijel and Bejaia. The coastal towns of Jijel and Bejaia are the most attractive tourist destinations in the country, especially in the summer season, but this fact causes traffic jams due to the increased number of cars (Fig. 10).



Fig. 10. Spatial distributions of accident points in 2022 in the wilaya of Sétif

3.4.3.4. The standard distance

The standard distance is a measure of the compactness of a spatial distribution of features around its mean center. It is generally represented by a circle or a radius of a circle. Figure 10 shows the standard distance calculated from the spatial distribution of accident points in 2022 in a circular form, i.e. 360°. This standard distance includes the black points for traffic accidents in 2022.

3.5. The spatial distribution of the number of injured and dead in 2022 in the wilaya de Sétif

The figures in the Figure 11 demonstrate the following: the spatial distribution of the number of injured and dead can be divided into five classes. Classes 0–1 and 1–2 mean a small number of victims, almost non-existent, especially in the southern regions because they are low in population density. Class 2–3 is predominant in the northern part in the region. Classes 3–4 and 4–7 indicate the largest number of injuries and deaths, due to the geographical location of the study area – the northern regions are mountainous with difficult roads and many bends.

In addition, natural factors, in particular frequent snowfall and ice, especially in the winter, as well as fog affecting the vision of drivers, lead to frequent traffic accidents.



Fig. 11. Numbers of injured and dead in 2022 in the wilaya of Sétif

3.6. The model of the spatial distribution of accident points

The data illustrated in the following graphic curve presents the model of the spatial distribution of accident points in 2022. The nearest neighbor analysis method, which depends on knowledge of the type of accident center, revealed that the model of the distribution of the phenomenon in 2022 is clustered. Given the score of -18.4467214186, there is less than 1% probability that this clustered pattern will be the result of random chance (Fig. 12).



Average Nearest Neighbor Summary

2022				
Observed mean distance:	1640.4438			
Expected mean distance:	3748.3887			
Nearest neighbor ratio:	0.43764			
Score-z	-18,446721			
p-value:	0.000000001			

Dataset information					
2022					
Input feature class:	Accident points				
Distance method:	Euclidean				
Study area:	6666146994.101360				
Selection set:	False				

Source: Authors' own study

Fig. 12. Nearest neighbor report of accident points in 2022 in the wilaya of Sétif

4. Discussion

The results of the study indicate that the wilaya of Sétif experiences a high incidence of traffic accidents, highlighting a serious issue with road safety. This situation suggests a lack of responsibility on the part of road users, but also the involvement of several entities that need to be more proactive in addressing this problem. The findings underline the need to bring together legislative, executive, technical, educational, and awareness-raising efforts to effectively tackle the issue, and reduce the number of accidents across the region.

4.1. Multi-sector efforts needed

Given the complex nature of the problem, it is critical that multiple sectors are involved in a coordinated manner:

Legislative efforts: There is a need for stricter traffic laws and policies that are rigorously enforced. New regulations should focus on reducing speeding, improving road safety, and ensuring that drivers are held accountable for offences.

Executive initiatives: Local government authorities must implement these laws effectively by improving road safety measures, ensuring better surveillance of accident-prone roads, and managing traffic more efficiently.

Technical improvements: Investment in the road infrastructure of the wilaya is essential, particularly in high-risk areas. Building safer roads, adding traffic lights, improving road signs, and ensuring better maintenance of existing roads should be a priority.

Educational programs: Driver education campaigns should focus on promoting responsible driving behavior, with particular emphasis on the dangers of speeding, the importance of respecting pedestrian rights, and the need to drive carefully on poorly lit roads.

Awareness campaigns: A broad public awareness campaign is necessary to inform both drivers and pedestrians about road safety measures. This can be accomplished through the use of media, schools, and local community organizations.

4.2. Novelty of the study

This research represents a new area of investigation at the local level. Prior to this study, there had been no formal research on traffic accidents in the wilaya of Sétif, making it difficult to compare the findings with existing national studies. The lack of previous data points to the novelty and importance of this research, as it lays the groundwork for future studies on the subject, and provides a starting point for addressing the specific challenges faced by the region.

4.3. Role of technology in road safety

One of the key highlights of the study is the effectiveness of technological tools in analyzing and addressing road safety issues. In particular, Geographic Information

Systems (GIS) have played an important role in conducting the spatial analysis of traffic accidents, allowing for the quick identification of accident black spots areas on the road network where accidents are more likely to occur. This modern technology provides significant advantages:

Time savings: GIS tools offer a faster method of identifying high-risk areas compared to traditional data collection and analysis techniques.

Precision: GIS allows authorities to create accurate maps that pinpoint exactly where accidents are most likely to occur, enabling targeted intervention.

Improved planning: With GIS data, local authorities can design better traffic management plans and prioritize infrastructure improvements in the areas where they are most needed.

4.4. Road network and accident distribution

The study provided an in-depth analysis of the road network in the wilaya of Sétif, which consists of: 72 km of highways, 714 km of national roads and 662 km of wilaya roads. The results showed that the highest number of accidents occurred on national roads. These roads, due to their interconnection and their design as single-lane roads, present a higher risk of accidents, especially in cases of reckless overtaking. The single-lane structure makes it easier for vehicles to collide head-on when drivers attempt dangerous passing maneuvers, contributing significantly to the overall accident rate. Additionally, the study found a direct relationship between economic activity and traffic volume on these roads. Areas that are hubs for industrial and tourism activities tend to experience heavier traffic, which increases the risk of accidents. As these roads become congested, especially during peak hours, the likelihood of collisions rises.

4.5. Spatial and technical distribution of accidents

The spatial analysis revealed not only where accidents occurred but also their directions and centers. This precise mapping allowed for a better understanding of the geographical distribution of traffic accidents across the wilaya. The data showed that certain axes of the road network were more accident-prone than others, enabling a targeted approach in addressing these high-risk areas.

4.6. Role of topography in accident rates

In addition to economic and traffic factors, the study also highlighted the role of topographical factors in influencing road safety:

Altitude: Roads situated at higher altitudes may present challenges such as poor visibility, harsh weather conditions, or difficulty in controlling vehicles on inclines.

Slopes: Steep slopes can increase the risk of vehicles losing control, especially when drivers fail to adjust their speed appropriately.

Soil type: The nature of the soil supporting the road network can affect the road's stability, particularly in areas where heavy rainfall or soil erosion is common.

These factors, in combination with the road infrastructure and driver behavior, contribute to the high accident rate in the region.

4.7. Economic, industrial, and tourism impact

The study emphasized that the wilaya of Sétif is a key center for tourism, industry, and commerce, with a high population density. The concentration of different economic activities cause traffic congestion, particularly in urban areas such as the city of Sétif. Traffic jams are more frequent during rush hours, which exacerbate the risk of accidents. The study noted a gradual increase in the number of traffic accidents over the study period, with a notable 57.45% rise in 2022. This surge reflects the growing pressure on the road network as economic activity expands and traffic volumes increase.

4.8. Causes of traffic accidents

Several key causes of traffic accidents were identified, including:

Excessive speed: This was found to be one of the primary causes of accidents, as drivers often exceed the speed limits, particularly on long stretches of national roads.

Failure to respect pedestrians: Many drivers fail to give way to pedestrians, increasing the risk of accidents in urban and residential areas.

Lack of lighting: Poor lighting on many roads, especially in rural areas, contributes to accidents, particularly at night.

Dangerous overtaking: Reckless overtaking, especially on single-lane roads, is a significant contributor to head-on collisions and severe accidents.

5. Conclusion

The study on the spatial analysis of traffic accidents has made us aware of the danger to which we are exposed to daily in our lives. This study is essentially based on the spatial analysis of traffic accidents produced in 2022 using the Geographic Information System. This technique made it possible to obtain the spatial distribution of traffic accident points at the level of the highway, national roads and wilaya roads. This spatialization also made it possible to calculate the center of the phenomenon and the geographical center, as well as the direction, the standard distance, and the model of the spatial distribution of this phenomenon. The spatial analysis shows that national roads are the most exposed to traffic accidents with a rate of 56.69%, or 257 injuries and 35 deaths, of the total accidents in 2022. This result is translated by high usage of this type of road network, and the current statistical analysis shows 515 accidents more than in years 2021 and 2020, which is alarming. Finally, in order to counteract this upward trend, the study put forward several practical recommendations aimed at improving road safety and reducing the number of traffic accidents

and their consequences. These proposals focus on both infrastructure improvements and behavioral changes:

Enhanced road markings: Clear and visible road markings are essential for guiding drivers and ensuring that they observe the traffic regulations. Better visibility of lane divisions, pedestrian crossings, and speed limits can help prevent accidents, especially on national roads and in low-light conditions.

Increased awareness campaigns: Public awareness campaigns are necessary to educate drivers about the risks of speeding, reckless overtaking, and disregarding pedestrians. These campaigns should also focus on the importance of following traffic rules and the dangers of distracted driving.

Establishment of adequate speed limits: Implementing and strictly enforcing appropriate speed limits on dangerous sections of the road network is crucial. Speed limit signs should be placed strategically, particularly in accident-prone areas, and should be enforced through regular monitoring by law enforcement.

Installation of surveillance cameras: The deployment of surveillance cameras along major roads, especially national roads, can act as a deterrent against reckless driving behaviors. These cameras should be installed in high-risk zones to monitor speed, dangerous overtaking, and traffic offences in real-time.

Distance sensors and monitoring devices: Advanced distance sensors and other monitoring technologies should be implemented to help drivers maintain safe distances between vehicles, reducing the risk of collisions. These sensors can be especially useful on highways and long-distance roads where high speeds are common.

Improvement of lighting and road conditions: Improving road lighting in poorly lit areas is essential, particularly on rural stretches of national and wilaya roads. Better road maintenance is also needed to fix potholes, damaged signs, and deteriorating road surfaces, all of which contribute to traffic accidents.

Roadside assistance and emergency response: Establishing a more efficient emergency response system along accident-prone routes can reduce the fatalities associated with traffic accidents. Rapid response teams equipped to handle road emergencies would be able to provide immediate medical attention and assistance in high-risk areas.

Acknowledgments

The authors would like to thank the members of the management of the national gendarmerie of the wilaya of Sétif for their help in collecting data. The authors would also like to thank the editors and reviewers for proofreading and evaluating this paper.

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