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Identification of hotspot areas for traffic accidents and analyzing drivers' behaviors and road accidents

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ABSTRACT

Despite the significant efforts made by the government to reduce traffic accidents in the UAE, there is still a need to understand the root causes of these accidents. Therefore, this research paper investigates the various causes of road accidents in Abu Dhabi city, including circumstantial factors, demographic characteristics, traffic violations, accident faults, and driver behavior. The study employs a GIS statistical approach, namely spatial autocorrelation analysis, to identify the hotspots of traffic accidents in the city for the year 2014. Additionally, a questionnaire survey was conducted in 2017 among drivers involved in road accidents in Abu Dhabi City, which was divided into six major categories: accident-related, seatbelt-related, speed-related, policy-related, and general socio-related. The responses of 1,072 drivers were analyzed using logistical regression models, revealing careless driving as the primary reason for city road accidents. The study also found that age and driving experience had a significant impact on accident probability, indicating that middle-aged drivers were more likely to be involved in accidents and that the risk rate decreased as driving experience increased. The study concludes with suggestions for preventive measures to improve traffic safety in Abu Dhabi City. Finally, the study evaluated the hypothesis that most accidents occur near central business districts using 2014 crash data for Abu Dhabi city. The findings demonstrate the effectiveness of the Getis-Ord Gi* statistic method in pinpointing and ranking high-density vehicle crash areas near the central business district of Abu Dhabi urban settings.

Introduction

As per the factsheet of the World Health Organization (WHO), every year, more than 1.25 million people lose their lives as a result of a road traffic crash. Between 20 and 50 million more people suffer non-fatal injuries, with many incurring disabilities due to their injuries. Road traffic crashes cost most countries 3 % of their gross domestic product (World Health Organization, 2015). The number of road traffic accidents in Gulf Cooperation Council (GCC) countries is higher than in other countries with the same income level (Abbas et al., 2011). According to the Ministry of Interior, there were 381 traffic-related fatalities and 2,620 injuries in the United Arab Emirates (UAE) in 2021, compared to 256 fatalities and 2,437 injuries in 2020 within all seven emirates of the UAE (Al Amir, 2022). Consequently, traffic accidents are reported as one of the 10 major leading causes of death and will be the third leading cause of disability by 2020 (Peden et al., 2002). Studies show that the significant variables for traffic accidents are the economic, societal, and cultural parameters of the country or city (Le et al., 2021; Ryan et al., 1988; Tang et al., 2021). Since the new era of the oil and natural gas revolution in the Gulf countries, accompanied by rapid economic growth and urbanization activities (Alkaabi, 2014), there has been a substantial increase in the urban population. This population growth is mainly attributed to different nationalities and ethnic backgrounds, resulting in an enormous increase in vehicle demand. Several studies conducted in the Gulf region (Bener et al., 2007; Hammoudi et al., 2014; AlSaeid et al., 2015) revealed an increasing trend of road accidents as well as the different behavior of people of other nationalities.

Over the past years, there have been considered measures taken by the authorities to reduce traffic accidents in the UAE. The UAE witnessed a 10.7 % decrease in traffic accidents during the first eight months of 2014, with 3,170 accidents reported compared to 3,549 in the same period in 2013, along with a 0.2 % reduction in mortality rate (Abu Dhabi Police, 2014). A study conducted for the UAE in 2014 revealed that the cost of a fatal road accident can reach up to 2 million USD, while a severe injury accident can cost between 1 and 1.5 million USD, a medium injury can cost up to 300,000 USD, and even a minor injury can impose a burden of 150,000 USD (Hammoudi et al., 2014). The study

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also revealed that the main factors contributing to road accidents among UAE drivers are unawareness of traffic rules and regulations, a lack of driving skills, poor judgment, a failure to interact, and traffic congestion. The UAE government's aspiration to accomplish the UAE National Smart Mobility Strategy by 2032 (Ministry of Energy and Infrastructure, 2023) highlights the significance of taking essential measures to ensure the success of this campaign and transform Abu Dhabi City into a hassle-free, world-class urban center.

Thus, gaining a comprehensive understanding of the perceptions and experiences of drivers involved in road accidents in Abu Dhabi city, as well as the spatial distribution of traffic and car accidents, becomes crucial for effectively addressing this traffic issue. Therefore, this study conducted a survey to explore the perceptions and experiences of drivers involved in road accidents in Abu Dhabi city. The survey aimed to gather valuable insights into the primary reasons for accidents, understand the impact of age and driving experience on accident probability, and assess drivers' attitudes towards road safety issues. The survey data provided valuable information to support the analysis of traffic accidents in the region.

Additionally, the study applied the Getis-Ord Gi* statistic approach and density map to identify and analyze the hotspots of traffic accidents in Abu Dhabi city during the year 2014. The Getis-Ord Gi* statistic was used to pinpoint areas with significant clustering of high or low values of traffic accidents, indicating the locations of hotspots and cold spots. This spatial autocorrelation analysis helped identify regions with higher accident densities, enabling a more targeted approach to address high-risk areas and implement preventive measures. Overall, this data-driven study offers a comprehensive approach to understanding and addressing traffic accidents in Abu Dhabi, utilizing modern geospatial techniques and survey data to enhance road safety in the region.

Literature review

A considerable regional difference is always reflected in the driving behavior and style of the people, which increases the probability of accidents. The findings of earlier studies (Bener et al., 2008; Yao and Du, 2022) have established a link between road traffic accidents and types of driver behavior among Qatari drivers. The Manchester Driver Behavior Questionnaire (DBQ) is considered one of the essential instruments used in Traffic Psychology for identifying a particular relationship between driving behavior and accident involvement (Reason et al., 1990).

Overall, GCC countries have significantly higher road traffic accident fatality rates than other high-income nations (Abbas et al., 2011; Bener et al., 2008). Road traffic accidents are the second leading cause of death in Abu Dhabi (after cardiovascular disease) and the leading cause of death for young drivers (Alketbi et al., 2020). Since there is an explosion in immigration and population from different countries with different driving skills, their reflexes and skills while driving were mostly affected by their driving environment back home. This mix of various cultures increases the number of road traffic accidents with casualties and fatalities, necessitating targeted research to identify methods of reducing accidents and fatalities.

Previous research has addressed the problems of aggressive behavior and driving offenses, as well as their links to traffic accidents (Parker et al., 1995; Han and Zhao, 2020; Abudayyeh et al., 2021). Although most researchers now agree that attempting to isolate a single leading cause of an accident is inappropriate, early accident studies demonstrated that 90 % of all accidents could be attributed to road user behavior characteristics (Lawton et al., 1997; Moradi et al., 2019; Mokarami et al., 2019). A study conducted in Japan by the Institute of Traffic Accident Research and Data Analysis (ITARDA, 2011) presented that higher car speeds would undoubtedly increase the risk and severity of accidents, but this is not always the case. They found that fatal accidents were most often caused by mid-speed ranges of 30–60 km/hr. The reason was due to the drivers' inattention or distracted behavior, which made them careless in the mid-speed range. The causative factors identified were minimal yet essential, such as staring at something outside the car, taking out or putting back an item, sudden movement of the items inside the car, distraction from other passengers, adjusting the stereo system, lighting a cigarette, and looking at maps. de Albuquerque and Awadalla (2020) conducted a study on road crash severity in the Emirate of Abu Dhabi, UAE, analyzing collisions from 2012 to 2017. Surprisingly, 65 percent of crashes took place on roads with speed limits up to 40 kph, while only 5 percent occurred on roads with higher speed limits of 100–120 kph, contributing to almost 50 percent of fatal crashes.

Even though it is commonly accepted worldwide that wearing seatbelts reduces the risk of fatalities among car occupants during an accident, it has been argued that it has a less significant overall effect on fatalities (Peltzman, 1975; Farooq et al., 2021). However, some researchers do not support this theory and do not find substantial support for the compensating-behavior theory, suggesting that seat belt use has an indirect adverse effect on fatalities by encouraging careless driving (Cohen and Einav, 2003; Zhang et al., 2018). Many studies have been conducted across the world to evaluate the impact of road accidents and have found that public awareness campaigns and proactive law enforcement strategies and policies play an essential role in reducing traffic accidents (Bendak, 2005; Abu Abdo and Al-Ibrahim, 2015; Al-Ghamdi, 2003).

Abu Dhabi serves as the capital of the UAE and stands as one of its highly developed, industrialized, and popular tourist destinations. With the increase in population and income level, the purchasing power of the public has increased; as a result, the vehicle has become common among the public and has been encouraged by the city's insufficient public transportation. Abulibdeh et al. (2018) also assessed the viability of implementing cordon pricing as a strategy to alleviate traffic congestion on Abu Dhabi Island. The study revealed that toll charges play a significant role in prompting certain income groups to modify their travel habits due to the increased financial burden associated with their daily trips.

Traffic safety studies investigate the impact of a variety of factors on safety performance, either qualitatively or quantitatively, such as the influence of various geometric features of road design, weather conditions, lighting factors, or geographical conditions on accident occurrences (Shankar et al., 1995; Khan et al., 2006). Through these earlier researches, some critical factors were identified and categorized to facilitate analysis and suggest recommendations to the authorities. The study and identification of road sections vulnerable to traffic accidents assists road managers in allocating genuine resources to those areas for improving roadway conditions or developing new strategies to avoid losses. Traffic volume, weather, highway network configuration, roadway design, driving behavior, and other factors all play a significant role in the occurrence of traffic accidents and exhibit strong spatial patterns (Xiea and Yanb, 2008).

The Gi* spatial statistics method was introduced by Getis and Ord. It is used to identify a tendency for positive spatial clustering and can strongly distinguish between high and low spatial associations in an accident location area. The proposed statistical method can capture the events' frequency, associated value, and spatial correlation (Ord and Getis, 1995; Getis and Ord, 1992).

GIS-based systems can model relationships between various spatial phenomena that would be extremely difficult to establish with a non-spatial database. This technique has been used by many researchers since 1900 to geocode accident locations, develop maps, and perform database queries. Apart from ranking accident locations with higher accident rates, they can also be classified according to the severity of accidents (Kim and Sul, 2009). Numerous methods have been developed for hotspot analysis and point pattern studies. These can be classified into two categories: a) methods that analyze first-order effects, which calculate the variation in the mean value of processes such as Kernel Density Estimation (K), quadrant count analysis, etc.; and b) methods that examine second-order effects that calculate spatial autocorrelation of points for spatial patterns, like Moran's I Index, Geary C ratio, and

Getis-Ord Gi* statistics, etc. (Manepalli et al., 2011).

Many researchers used Planer K, or simply K, to identify hotspots for various road networks. The major drawback of this technique is its inability to be tested for statistical significance. Spatial patterns of any accident data could be analyzed by spatial autocorrelation statistics, which combine attribute similarities and location proximity into a single index. Getis-Ord Gi* statistic identifies the hot and cold spots where the same values surround features with significant high and low values. The Getis-Ord Gi* statistical method was utilized to detect statistically substantial traffic accident hotspots on various roads and highways (Songchitruksa and Zeng, 2010). Moreover, Mohammed et al. (2023) conducted a comprehensive study employing Time-Space Cube Analysis, Moran's Index, and Getis-Ord Gi* to identify and compare crash hotspots in Qatar for the years 2015 and 2019. Results notably indicated concentrated crashes in Qatar's central-eastern region, primarily attributed to driver behavior. Furthermore, there was an increased clustering of crashes on weekdays in 2019 as compared to 2015.

Many researchers have conducted research on accident studies and road safety improvements for a particular location or stretch of road in a different manner. For example, Singh and Suman (2012) developed a prediction model based on AADT and road conditions to study the monthly and annual variation in accident rate on selected stretches, as well as the effect of traffic volume on the rate of road accidents.

The aim of this paper is to assess and depict the patterns of traffic accidents in urban environments, specifically Abu Dhabi City, UAE. The detection can assist in identifying vulnerable locations and road segments that require remedial measures. A spatial method for visualizing spatial clusters and identifying risky areas is explained in the methodology section. A relative hypothesis is also verified and tested to establish a linkage between accident frequency and places of high density.

Methodology

The methodology used in this study includes variable identification, a sample survey, and a spatial analysis if traffic accidents in Abu Dhabi City. Potential items relevant to the UAE Accident were identified through a literature review and gathered through a designed questionnaire, which was useful in suggesting measures to reduce traffic accidents and raise awareness. The following subsections describe the identification of participating variables and methods used in data collection, analysis, and interpretation.

The analysis of this study depends on the city levels of spatial aggregation. Aggregated area-based data are significant sources of information for many social science disciplines. The calculations were based on data obtained from official sources and public websites. For each area, the number of accident cases was counted, including minor and major crashes with all types of damages to life and property due to vehicle accidents. The study included three analyses: spatial analysis to describe the overall spatial aggregation and dispersion of the road network and important landmarks attracting people; hotspot analysis to detect significant hotspots using a spatial statistical method for crash sites; and population and vehicle density analysis for the detected hotspots.

Identification of variables – identifying accident causes

The research on identifying cause-and-effect variables began by acknowledging that the factors leading to accidents are interlinked and do not exhibit a linear nature. To pursue this study further, the "Complex Non-Linear Model" introduced by Hollnagel (2012) was adopted. This model asserts that the variables leading to an accident are non-linear and mutually interact, culminating in an accident over time. Understanding and mitigating these multiple factors, which may encompass environmental, human activity, technical faults, and socio-economic reasons, can lead to safer traffic outcomes with minimal damages. To facilitate the preparation of a questionnaire survey on the status of traffic accidents in Abu Dhabi City, the survey form was divided into six distinct categories:

1. Driver's behavioral issues.
2. Traffic accidents and fatalities.
3. Driver's speed perceptions.
4. Seatbelt usage.
5. Policy awareness and implementation.
6. General socio-economic questions.

Each of the aforementioned categories was further elaborated into various other variables (dependent or independent) that were utilized in the road-user survey. Table 1 provides an overview of the variables and categories employed in the study.

Sample survey: gathering information

From August to October 2017, a survey was conducted in Abu Dhabi, targeting 1,400 road users with prior experience of a traffic accident in the city. The target population for this study comprised individuals who had encountered traffic accidents. To select participants, 11 undergraduate research assistant students were trained in using a purposive sampling technique, which involved specific criteria and variables. The survey was carried out over an eight-week period, with each of the 11 team members assigned between 50 and 250 hard copy surveys in both Arabic and English versions to improve the response rate from the respondents.

The survey collected information on various factors, enabling the reconstruction of impact events. The research team considered the city's diverse population, aiming to collect responses from people from all continents and linguistic backgrounds. The drivers' participation was voluntary and conducted at their convenience, with public gathering areas like shopping malls, public parks, and among friends and relatives situated in the Abu Dhabi Emirate.

Before conducting the main survey, a preliminary survey (the pilot survey) was carried out with a sample size of 10 individuals. The pilot survey aimed to assess the effectiveness and clarity of the questionnaire. Its purpose was to evaluate the respondents' level of engagement and determine the understandability, relevance, and utility of the questions. Based on the results of the pilot survey, adjustments were made to the questionnaire, including refining certain questions and removing technical jargon and redundancy. The modifications aimed to enhance overall respondent comfort and comprehension for the main survey.

A total of 1,400 survey responses were aimed to be collected, and 1,072 (76.6 %) were obtained. However, 16 % of the responses were disregarded from the sample. The key sections of the survey included questions related to accidents, seatbelt usage, speed, driving behavior, traffic policies, and general socioeconomic aspects. The 16 % discarded sample resulted from incomplete responses, duplicate entries, and inconsistencies in the survey data. Some respondents left questions unanswered, while others provided conflicting information. Duplicated entries and technical issues during data entry also contributed to the sample's exclusion. Removing these unreliable entries ensured data quality and enhanced the survey's credibility in studying traffic accidents in Abu Dhabi.

The study also conducted a comparative analysis of different accident types across various emirates within the UAE for the year 2017. The study highlights the frequency of four distinct accident categories: Shock and Crash, Deterioration, Run Over, and Other. Through data analysis, the study aims to identify the distribution of these accident types across the UAE. The data source is the Ministry of Interior, extracted from the UAE Federal Competitiveness and Statistics Authority (n.d.).

Statistical model used: exploring correlations

The SPSS software statistical package was used to execute the

Table 1
List of Identified Variables related to Traffic Accidents.

S. No.	Main Categories	Variables	Note	Source
1	Traffic accidents and fatalities	Month, Year, Time, Day of the week, Region name, Street name, accident type, Road Classification, Speed Limit, Number of Lanes, Weather, lighting condition, Road surface condition, number of injured, Seating position, seatbelt usage, cause of the injury	This category explores various aspects of traffic accidents and fatalities, including: • Role in the accident • Type of accident happened • Category of the vehicle • Traffic condition at the time of accident • Kind of Injuries happened • Cause of the accident • Punishment put on you • Involved in an accident	Abbas et al. 2011; Bener et al. 2008; Shankar et al., 1995; Khan et al., 2006; Xiea and Yanb, 2008
2	Driver's behavioral issues	Speed violation, lane and traffic violation	This category focuses on driver behavior and traffic violations, such as: • Paid attention to the traffic signboard • Distracted by activity while driving • Following closely with other vehicles • Violating lanes • Wrong passing • Sudden turning • Wrong reversing • Distraction and lack of precaution • Vehicle priority violation • Pedestrian priority violation • Speed limit violation • Red light violation • Stop sign violation • Traffic sign violation • Not securing the car while stopping • Illegal parking or stopping • Not slowing at intersection • Inside reason of accident • Main factor for negligence	Reason et al., 1990; Parker et al., 1995; Han and Zhao, 2020; Abudayyeh et al., 2021; Lawton et al., 1997; Moradi et al., 2019; Mokarami et al., 2019
3	Speed perception	Speed during accident, speeding opinion, speed limit, factors of speed disposition	This category investigates drivers' perceptions regarding the speed of their vehicles, road speed limits, and the potential damage caused by speeding. It also explores drivers' opinions on various aspects related to speeding, including: • Severity of injuries could be reduced by a slower speed • Speed cameras reduce road deaths • More likely to be involved in a Crash if you speed • Difficult to always drive within the speed limit • It is OK to speed if you drive Safely • It is OK to drive up to some km over-speeding • Factors influencing your speed	ITARDA, 2011
4	Seatbelt	Wearing a seatbelt, reasons for carelessness, opinion on seatbelts, Infants' safety	This category assesses seatbelt usage, reasons for not using seatbelts, public opinions on seatbelts, and their effectiveness in enhancing safety, including infants' safety.	Peltzman, 1975; Farooq et al., 2021; Cohen and Einav, 2003; Zhang et al., 2018
5	Driver information	Driver name, nationality, age and gender, profession, education level, years of driving in UAE, total number of driving years, use of alcohol, driving training	This category gathers information about the drivers, including personal details, driving experience, and accidental history.	Alketbi et al., 2020
6	Policy awareness	Current intensity of the traffic law, factors that may reduce traffic, means of traffic education	This category explores the level of awareness of traffic regulations, factors that can improve traffic safety, and the effectiveness of different educational measures for drivers.	Bendak, 2005; Abu Abdo and Al-Ibrahim, 2015; Al-Ghamdi, 2003

research analysis. The software conducted a thorough regression analysis procedure to determine the correlation between various independent or predictor variables and dependent or criterion variables. The suitable model was selected based on the general goodness of fit represented by the coefficient of simple and multiple regression determination (R^2), the significance of individual variables as determined by the *t*-test, the normality of the residual distribution, the consistency of variance, and the standard error of estimation (Obaidat and Ramadan, 2012). Linear regression models are used for further analysis because they have proven statistically better.

Spatial analysis: understanding accident density

The level of spatial aggregation of road crashes in the Abu Dhabi city was assessed by examining a spatial autocorrelation using Global Moran's I statistics with row-standardized inverse distance weights matrices. The method can be used to determine whether the values of neighboring areas are similar. Thus, significant positive spatial autocorrelation implies that the distribution of accident patterns is more spatially aggregated than a random underlying spatial process.

The accident distributions were observed using Inverse Distance Weighted (IDW) interpolation with the annual crash density of Abu Dhabi city. IDW is an interpolation method that creates a crash-density surface. A neighborhood around the interpolated point is identified during the process, and a weighted average of the observation values within this neighborhood is calculated. The weight is a function of inverse distance.

Getis-Ord Gi statistic: identifying spatial clusters*

The Getis-Ord Gi* statistic is a spatial autocorrelation statistic used in geographic information systems (GIS) and spatial statistics. It is a measure that assesses whether there is spatial clustering of high or low values (i.e., hotspots or cold spots) for a specific attribute within a spatial dataset (Esri, n.d.). The collection of events and mapping of clusters using the Getis-Ord Gi* function are two processes involved in identifying the desired hotspots. It generates a new output feature class for each incident location with a P value and Z score associated with it. A statistically significant hotspot was defined by the tool as a location with a high value that is surrounded by highly valued neighbors. The local sum of values of a feature and its neighbors is proportional to the sum of all features. When the calculated local sum significantly deviates from the anticipated local sum, and this deviation is substantial enough to rule out random chance, it leads to a high Z score and a low P value. This, in turn, indicates a statistically significant presence of strong clustering.

In the case of incident point data as acquired in this study, a weighted point feature class with field Icount was created using the ArcGIS toolbox's collect event function. It represents the total number of accidents in a specific geographic location. This weighted point feature was used as the input for the Gi* function, which was used to determine whether features with high or low values tend to cluster in the study area. For this study, the weighted point feature method is used as the data availability limits the extent of analysis to be carried out. Many researchers use another method of severity weighing in which the weighted point features take the severity of accidents into account.

This study employs a GIS statistical approach utilizing the Getis-Ord Gi* statistic to identify the hotspots of traffic accidents in Abu Dhabi City. The crash data utilized in this analysis is from the year 2014 (Ministry of Interior, 2015). The selection of this particular year was based on the availability of comprehensive and relevant data from the Abu Dhabi police. As the study was conducted in 2017, the data from 2014 was relatively close to the survey timeframe, allowing for a reasonable representation of traffic accidents within Abu Dhabi city.

By combining these methodological approaches, this study aimed to gain comprehensive insights into the variables influencing accidents and pinpoint significant accident hotspots in Abu Dhabi City. The robust methodology facilitated an in-depth exploration of traffic safety factors and spatial patterns, providing a basis for evidence-based interventions and policy decisions to enhance road safety in the city.

Results and discussion

Traffic accident factors: analysis of survey responses

The drivers' responses were obtained through voluntary declaration, and since the survey was provided to them conveniently, a response bias cannot be excluded. A responder analysis is carried out to determine the number of respondents and non-respondents, which affects the regression analysis. The return on participation ratio was moderate, with an average of 50 % responses in each category. Tables 2–7 offer a comprehensive overview of various categories, including their associated variables and corresponding participation percentages. These tables provide valuable insights into the factors contributing to traffic accidents. Further details about each category are discussed in the subsequent sections.

Accidental characteristics

Table 2 presents data on the distribution of respondents and non-respondents based on these various variables related to traffic accidents. It provides insights into the role of individuals in accidents, the type of accidents that occurred, the category of vehicles involved, traffic conditions at the time of accidents, the kinds of injuries sustained, the causes of the accidents, punishments imposed, and the overall involvement in accidents. The majority of respondents participated in providing information regarding their involvement in accidents, with percentages ranging from 52.8 % to 94.9 %. This indicates a high level of engagement from the surveyed road users with prior accident experiences in sharing relevant details about the incidents.

Among those who took part in the study, 661 (61.6 %) of the respondents had experienced the situation, out of which 288 (26.9 %) were the originators of the accident. The type of accident was chosen based on previous research (Näätänen and Summala, 1976; Elander et al., 1993), and 664 (61.9 %) people responded to this variable. The analysis also took into account the accident's cause and involvement, and the response rate of the people was excellent.

The categories of Vehicle type and category involved also received a high response rate, with percentages ranging from 60.4 % to 61.9 %. This indicates that respondents from various vehicle categories were forthcoming in providing their data.

In terms of traffic conditions at the time of the accident and causes of accidents, the response rate remains consistent, ranging from 59.7 % to 60.7 %. This demonstrates the willingness of respondents to share information about the traffic conditions and causes of the accidents.

The response rate for the type of injuries that occurred during accidents was 59.9 %, while the punishment imposed on respondents due to their involvement received a relatively lower response rate of 52.8 %. This suggests that some individuals may have been hesitant to disclose

Table 2
Survey Response Distribution of Accidental Characteristics.

Accidental Characteristics	N		
	Respondent	Non-Respondents	%
Role in the accident	661	411	61.7
Type of accident happened	664	408	61.9
Category of the vehicle	647	425	60.4
Traffic condition at the time of accident	642	430	59.9
Kind of Injuries happened	640	432	59.7
Cause of the accident	651	421	60.7
Punishment put on you	566	506	52.8
Involved in an accident	1017	55	94.9

Table 3
Survey Response Distribution of Driving Behavioral Characteristics.

Driving Behavioral Indicators		N		
		Respondent	Non-respondents	%
Paid attention to the traffic signboard		660	412	61.5
Distracted by activity while driving		632	440	58.9
Driver's common mistakes	Following closely with other vehicles	601	471	56
	Violating lanes	596	476	55.5
	Wrong passing	599	473	55.8
	Sudden turning	597	475	55.6
	Wrong reversing	594	478	55.4
	Distraction and lack of precaution	594	478	55.4
	Vehicle priority violation	590	482	55
	Pedestrian priority violation	589	483	54.9
	Speed limit violation	592	480	55.2
	Red light violation	591	481	55.1
	Stop sign violation	591	481	55.1
	Traffic sign violation	593	479	55.3
	Not securing the car while stopping	579	493	54
	Illegal parking or stopping	579	493	54
	Not slowing at intersection	579	493	54
Inside reason of accident	593	479	55.3	
Main factor for negligence	602	470	56.2	

Table 4
Survey Response Distribution of Seatbelt Characteristics.

Seatbelt Indicators		N		
		Respondent	Non-respondents	%
Status on seatbelt wearing		618	454	57.6
Reasons for not wearing your seatbelt	It is not comfortable	531	541	49.5
	I do not think about it	529	543	49.3
	Feel safe with airbag	520	552	48.5
	Strong vehicle to feel safe	526	546	49.1
	Might get trapped in Seatbelt	532	540	49.6
	Seatbelt is not cool to wear	530	542	49.4
	Not to wear in short distances	530	542	49.4
	Not to wear if with friends	513	559	47.9
Opinion for wearing seat belts	Seat belts reduce the risk of injury	664	408	61.9
	Feel vulnerable when not wearing a seat belt	657	415	61.3
	Seat belts can be dangerous	656	416	61.2
	Do not bother to wear a seat belt	656	416	61.2
	Seat belts are necessary even if you drive carefully	659	413	61.5

Table 5
Survey Response Distribution of Speed Characteristics.

Speed Indicators		N		
		Respondent	Non-respondents	%
Opinion on Speeding	Severity of injuries could be reduced by a slower speed	651	421	60.7
	Speed cameras reduce road deaths	655	417	61.1
	More likely to be involved in a crash if you speed	653	419	60.9
	Difficult to always drive within the speed limit	633	439	59
	It is OK to speed if you drive Safely	633	439	59
	It is OK to drive up to some km over-speeding	628	444	58.6
Factors influencing your speed	640	432	59.7	

Table 6
Survey Response Distribution of Traffic Policy Opinion and Implementation Characteristics.

Traffic Policy and Implementation Indicators		**N**		
		Respondent	**Non-respondents**	**%**
Traffic rules and penalties in UAE		1009	63	94.1
Factors that may help in reducing traffic accidents	Intensifying supervision	927	145	86.5
	Financial penalties	926	146	86.4
	Increasing traffic culture concept	924	148	86.2
	Non-traditional penalties like community Service	924	148	86.2
	Expanding public transport	923	149	86.1
	Promoting public transport usage	918	154	85.6
	Tightening driving license testing	921	151	85.9
	Control on Fake auto parts	918	154	85.6
	Traffic signs redesigning	919	153	85.7
	Shifting working hours	917	155	85.5
	Congestion Pricing on certain roads	916	156	85.4
Most effective public education method	1007	65	93.9	

the punitive measures they faced. The last column, "Involved in an accident," shows a remarkably high response rate of 94.9 %. This indicates that almost all respondents were directly involved in traffic accidents, validating the relevance of their experiences and insights.

Overall, the high response rates in most categories reflect the dedication of the surveyed road users to sharing their accident-related data. The data collected from the respondents can serve as valuable information for understanding the patterns and factors contributing to traffic

Table 7
Survey Response Distribution of Socio-economic Factors.

Socio-economic Factors	N		
	Respondent	Non-respondents	%
Years of driving in the UAE	962	110	89.7
Age of respondent	1005	67	93.8
Gender of respondent	1007	65	93.9
Marital status of respondent	1004	68	93.7
Qualification of the respondent	1004	68	93.7
How did you learn to drive	1006	66	93.8

accidents in the study area. It also highlights the importance of further encouraging respondents to share crucial details to gain a comprehensive understanding of road safety and traffic accident dynamics in Abu Dhabi.

Driver's behavioral issues

Both driving skills and driving style contribute to the crash risk. It becomes more intense when behavior is introduced as a new dimension—in the former case, hazard-perception latency appeared to be one of the essential factors that led to the misidentification of complex visual targets and careful attention on roads. The latter refers to faster driving and a willingness to commit violations while driving, both of which may be explained by personality and careless driving habits (Lajunen and Summala, 1995). The behavior is then associated with failing to follow rules and regulations, as well as being distracted by any internal or external entity (Table 3).

Seatbelt issues

Research carried out across the world has shown that wearing a seatbelt in both the front and rear seats can significantly reduce road traffic injuries in the event of an accident. In countries such as the UAE, the use of safety belts for both the driver and the passengers, as well as the use of child safety seats and booster seats, is strictly enforced, and policies are in place (Durbin et al., 2005; Zhu et al., 2007; Barss et al., 2008). This component is included in the study to examine the current status of the situation following the newly amended traffic law and its implementation in 2017. The survey highlights that more than half of the respondents (60 %) were concerned about the topic, and around 50 % expressed concern about not wearing a seatbelt (Table 4).

Speeding factors and opinion

Speeding is one of the critical elements contributing to the high number of road accidents, along with other factors. As a public perception, it is being studied that high speed is the leading cause of crashes, but recent studies suggest that moderate speed dispositions are equally responsible as they make the driver more careless and inattentive towards the road (ITARDA, 2011). This is included in the research to examine any significance between the number of accident experiences and the speed factor. The respondents were sensitive to this factor and responded well (60 %) as per their opinion (Table 5).

Policy opinion

Many traffic policy implementations occur every few years as per the data gathered by the traffic authorities, including drunk driving and speeding, road safety evaluation systems, and traffic education programs (Staubach, 2009; Yang and Kim, 2003). Multiple policy interventions are used to reduce the number of injuries and fatalities associated with road traffic accidents. This research includes policy implications and law enforcement initiatives, which are incorporated into factors that may help reduce traffic accidents. The response rate was excellent (more than 85 %), indicating that people are aware of these factors and that the authorities are effectively reaching out to the public through various educational methods (93.9 %) (Table 6).

Socio-economic factors

As expected, the response rate was estimated to be more than 90 % in this category (Table 7). The factors included in this category in the survey relate to various hypotheses developed in previous research that age, gender, qualification, and years of driving experience are some of the significant factors in road crashes (Matthews and Moran, 1986; McKnight and McKnight, 2003; Özkan and Lajunen, 2006; Chang and Wang, 2006).

The age variable is divided into three categories: 18–25 years, 25–50 years, and above 50 years. In contrast to other research studies, this survey found that 45 % of drivers were involved in accidents at a young age (18–25 years) and 52.8 % of drivers had an accident at a comparatively older age (25–50 years) (Fig. 1). It highlights that middle-aged drivers account for more traffic crashes than young drivers. The experience factor is divided into three categories: 1–3 years, 3–10 years, and more than 10 years. More than half of the respondents who experienced a traffic accident situation in Abu Dhabi were 3–10 years old with driving experience (53.5 %) at the time, while less experienced drivers (25.6 %) were accounted for the traffic accident (Fig. 1). Since the two variables were independently analyzed, it was possible to conclude that as drivers' age and experience increase, they become more careless and casual about driving.

Exploring correlations and hypothesis testing in traffic accident analysis

In this section, a bivariate correlation analysis was conducted to assess relationships between independent variables and accident involvement, utilizing the Spearman correlation coefficient index with accident involvement as the dependent variable. Correlation is a unit-free measure of finding a relationship between two variables with values in the range $[-1, +1]$, where r is close to $+1$ (-1). It indicates a strong positive (or negative) linear relationship, whereas a correlation coefficient of 0 indicates no linear relationship between the two variables. Table 8 presents correlations between independent variables and the dependent variable. The symbol (**) denotes that a correlation is significant at the 0.01 level, while the symbol (*) indicates significance at the 0.05 level. Table 8 incorporates variables that are assumed to exhibit potential correlations, whether positive or negative, and can be subsequently utilized for regression analysis. The correlation table analysis is used to test the hypothesis for the overall significance of the model.

- Null Hypothesis (1): There is no significant relationship between road traffic accidents and the behavior of the drivers.
- Null Hypothesis (2): There is no significant relationship between road traffic accident causalities and seatbelt implementation.
- Null Hypothesis (3): There is no significance between speeding behavior and the chances of road traffic accidents.
- Null Hypothesis (4): There is no significance between the contingency plan taken by the authority and its effect on road traffic accidents.
- Null Hypothesis (5): There is no significance between implementing stricter policies and traffic accidents.
- Null Hypothesis (6): There is no significance between age and years of experience in driving and the chances of traffic accidents.

The correlation coefficients, along with their significance levels, offer a glimpse into the potential relationships between different categories, such as Behavioral, Seatbelt, Speeding, Accidental, Policy implementation, and Socio-economic factors. The p-value reported in the correlation analysis within Table 8 indicates significance levels of

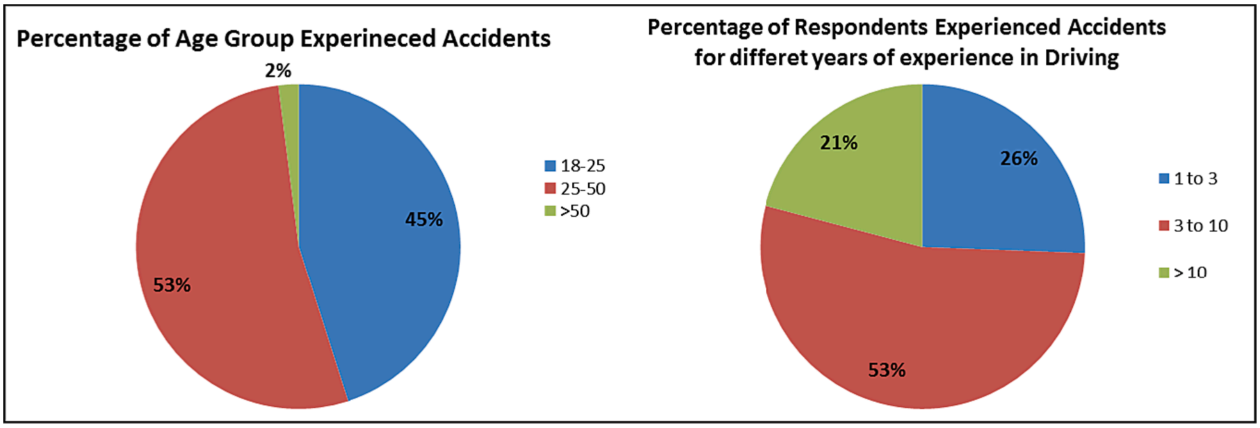

Fig. 1. Percentage of Respondents who Experienced Accidents.

Table 8
Correlation Analysis of Accident Involvement Factors.

Categories	Spearman's rho	Accident Involvement		
		Correlation Coefficient	Sig. (2-tailed)	N
Behavioral	Common driver mistakes	0.1*	0.015	580
Seatbelt	Reasons for not wearing a seatbelt	−0.087*	0.047	511
Speeding	Opinion on speeding	0.093*	0.019	620
Accidental	Factors in reducing traffic accidents	0.069*	0.038	909
Policy implementation	Traffic rules and penalties in UAE	0.085**	0.008	985
Socio-economic	Years of driving in the UAE	0.052**	0.000	947
	Age of respondent	0.048*	0.015	984
	Gender of respondent	−0.221**	0.063	985
	Marital Status of respondent	0.080*	0.068	983
	Qualification of the respondent	0.061	0.056	982
	How did you learn driving	0.072	0.208	992

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

0.05 and 0.001. Therefore, the null hypothesis was rejected, leading to the study's conclusion that there is a significant relationship between traffic accidents and the factors associated with them.

Analyzing driver accident experience: a binary logistic regression approach

In this section, a binary logistic model is employed to examine the connection between a driver's traffic accident experience and various pre-identified categories and variables. These factors encompass common driver errors, reasons for seatbelt non-compliance, speeding tendencies, accidental occurrences, policy perspectives, and general socio-economic data (such as age, gender, marital status, qualification, and method of learning to drive). These specific variables were chosen based on their robust correlation with the dependent variable—prior accident involvement. A statistical significance level of $P \leq 0.05$ was employed, along with a 95 % confidence interval, to measure their impact. The binary logistic regression model was selected due to the dichotomous nature of the dependent variable. This model estimates the likelihood of accident involvement using the maximum likelihood method. The binary logistic regression is utilized in this study since the dependent variable, denoted as Y, can exclusively take two values: $Y = 1$, representing no accident involvement, and $Y = 2$, representing accident involvement. Furthermore, the Hosmer-Lemeshow test was utilized to evaluate the goodness-of-fit (Hosmer and Lemeshow, 1989). All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 24.0, developed by SPSS Inc., Chicago, IL, USA.

Which factors should be considered most influential in the traffic accident study?

The results addressing this question are presented in Table 8. It's important to highlight that the variables included in this study were selected based on their significance to the dependent variable, and cases with any indication of non-collinearity between dependent and independent variables were excluded. Regarding information collected from participants' past experiences in traffic accidents, it was observed that among the valid cases involving their role in accidents (61.7 %), the majority played the role of the opponent (34.8 %), while a smaller percentage (26.9 %) accepted responsibility for the accident. The analysis of accident types revealed that rear-end collisions (34 %) were the most dominant, followed by side collisions (15.4 %), and roundabout accidents (11.4 %). The main reason for rear-end collisions was attributed to closely following the preceding vehicle (56 %), which exhibited a strong relationship with a higher probability of accidents ($p = 0.011$).

The behavioral statistics collected in this study also reveal noteworthy insights. While driving, drivers paid careful attention to traffic signboards (61.5 %), but they often got distracted by various activities (58.9 %), both outside (e.g., observing other vehicles, shops) and inside (e.g., phone use, makeup, chatting with passengers) the vehicle. It's important to highlight that factors contributing to driver negligence (56.2 %) included oriented and false expectations, misjudgment of speed and distance, and getting nervous in congestion. While some of these factors have been significant in previous studies, their impact was not significant in this study ($p = 0.75$). Concerning seatbelt usage, over half of the drivers (57.6 %) stated that they wear seatbelts, and 55.3 % of the respondents indicated consistent usage. Nonetheless, there is a large proportion of people who indicated wearing it sometimes (34.8 %), rarely (7.1 %), or never (2.8 %). This demonstrates that a significant amount of effort is required to reduce the percentage of people who have a situational attitude toward wearing seatbelts. Some of the main reasons for such behavior included a fear of being trapped in the vehicle by the seatbelt in the event of an accident (49.6 %), not being comfortable (49.5 %), not being cool to wear (49.4 %), and a preference for not wearing it for shorter distances (49.4 %). This demonstrates the carelessness of the drivers in the city, even though they understand that it will reduce the risk of injury (61.9 %) and is necessary while driving carefully (61.5 %). Even though the authorities have taken measures by increasing fines and monitoring the road, more public awareness initiatives are needed.

Another important factor to consider in any traffic accident study is speed temperament. It is carried out in this research, which also highlights people's opinions and the factors that influence the driver's speed. The question was included in the survey to gain insight into people's speed dispositions and the likelihood of being involved in an accident. The null hypothesis was rejected due to the strong significance in the regression analysis of the driver's awareness and knowledge of the probability of an accident. As shown in Table 5, the majority of drivers (61.1 %) agreed that speed cameras are important in reducing road deaths because they cause people to be more cautious on the road. They also shared their views that it is difficult for them to always drive within the speed limit (60.9 %). This is acceptable, as maintaining a constant speed is always tricky, but the authorities always recommend driving in a controllable manner within the speed limits.

The views on traffic rules and penalties were taken into account in order to estimate the current situation in the UAE. The public submitted their responses, highlighting that the penalties are too severe (56.9 %), but also recommending that traffic rules be strictly enforced to control the aggressive behavior of Abu Dhabi drivers (18.7 %). It will help in maintaining discipline on the road and reducing traffic incidents. Apart from the drivers' age and experience at the time of the accident, no other factor was found to be significant in relation to the accident experience. People responded strongly to income (response rate: 88.9 %), gender (response rate: 91.9 %), marital status (response rate: 91.7 %), qualification (response rate: 91.6 %), and driving education (response rate: 92.5 %), but these variables did not show any significance in the regression model and were thus ignored.

How high is the comparative risk among various identified variables contributing to a traffic accident in Abu Dhabi city?

A logistic regression model is applied to identify the risk parameters involved with the variables participating in an accident. Factors with less significance are excluded from the analysis, and only those with a strong impact are considered for this model. A study conducted in the USA identified driver's mistakes to be the most probable cause of the accident (Treat et al., 1979). They categorized the driver errors into three types: recognition errors, decision errors, and performance mistakes. This study found that following too close to the other vehicle is the most common mistake that comes under decision errors (Table 9), as mentioned by Treat et al. (1979). The variable is highly correlated with an increased risk of an accident because it prevents the driver from stopping in time in case of an emergency ($n = 601$; $p = 0.011$). The other variables are also considered important, but they are not included here due to their lower significance in the analysis. It should be noted that the most significant variable in the analysis is avoiding seatbelts when traveling with friends ($p = 0.024$) (Table 10), and this attitude makes them more vulnerable to an accident. Although speed proposition is important in traffic accident research and people's opinions matter in accident probability, it did not form a strong relationship with the chances of a person being involved in an accident in the statistical model (Table 11).

As per the policy opinion gathered (Table 12), only 8.7 % of the residents in Abu Dhabi city are concerned about monitoring traffic rules. Accidents have increased as a result of common mistakes made on the road by the other driver, such as lane violations, wrong passing, sudden turning, speed limit violations, stop sign violations, and vehicle priority violations. Although not all factors attained a significant level in correlating public opinion on factors that may help in reducing traffic accidents and the accident experience gained by them, intensifying supervision ($p = 0.046$) and control on fake parts ($p = 0.045$) crossed the mark (Table 13), and it is important to include them to understand the public's suggestions. Most respondents recommended intensifying supervision on the road (86.5 %) and increasing the financial penalties for violators (86.4 %). It should be noted that the authorities were already aware of their suggestions, allowing them to decide on increased penalties and stricter measures in 2017 (Abu Dhabi Digital Portal, 2017). A large number of respondents (85.6 %) selected the control of fake parts to be used in the vehicle as one of the major issues that could reduce traffic accidents, as these lead to sudden malfunctioning of the vehicle and create an accident.

A research review conducted by Mayhew and Simpson (1990) to determine the relationship between driver age and experience in traffic collision involvement. The studies reported mixed results. For example, some found that age was an essential factor to be considered. In contrast, others showed that the accumulation of driving experience is more important to be studied. Nevertheless, some argue that both factors are equally responsible for the collision rate. The legal driving age in the UAE is 18 years (Abu Dhabi Digital Portal, 2017). These two factors were considered necessary as they showed a high number of responses and were also significant in the Spearman coefficient analysis. The crash rate of Abu Dhabi drivers of different ages and with different driving experiences is considered a critical factor. The findings revealed that both experience and age play a significant role in the respondents' accident experiences. Many studies have found that teenage drivers with less experience have a dramatically higher crash rate than older drivers (McCartt et al., 2009; Mayhew et al., 2003; Ray et al., 1998). The data gathered for age ($p = 0.048$) and experience ($p = 0.052$) are included in the analysis due to their high significance based on their age and driving experiences at the time of the accident (Table 14).

Overall, the study found a significant relationship between road accidents experienced by the drivers in Abu Dhabi and factors such as behavior, seatbelt use, speed, policies associated with them, age, and

Table 9
Behavioral Mistakes.

Common driver behavioral mistakes	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for EXP(B)	
							Lower	Upper
Following closely to another vehicle	0.152	0.060	6.450	1	0.011	1.164	1.035	1.308
Violating lanes	−0.037	0.071	0.275	1	0.600	0.964	0.839	1.107
Wrong passing	−0.055	0.070	0.613	1	0.434	0.946	0.824	1.086
Sudden turning	−0.022	0.072	0.097	1	0.756	0.978	0.849	1.126
Wrong reversing	−0.095	0.069	1.904	1	0.168	0.910	0.795	1.041
Distraction and lack of precaution	0.004	0.062	0.004	1	0.947	1.004	0.889	1.135
Vehicle priority violation	0.081	0.068	1.412	1	0.235	1.084	0.949	1.239
Pedestrian priority violation	−0.026	0.062	0.173	1	0.677	0.974	0.863	1.101
Speed limit violation	0.085	0.061	1.955	1	0.162	1.089	0.966	1.227
Red light violation	−0.046	0.061	0.580	1	0.446	0.955	0.847	1.076
Stop sign violation	−0.008	0.069	0.014	1	0.905	0.992	0.867	1.135
Traffic sign violation	−0.016	0.069	0.053	1	0.818	0.984	0.860	1.127
Not securing car while stopping	0.015	0.072	0.043	1	0.837	1.015	0.881	1.169
Illegal parking or stopping	0.020	0.076	0.068	1	0.795	1.020	0.880	1.182
Not slowing at intersection	−0.015	0.066	0.054	1	0.816	0.985	0.866	1.120

Table 10
Seatbelt Opinion Analysis.

Seatbelt opinion	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for EXP(B)	
							Lower	Upper
It is not comfortable	0.172	0.105	2.700	1	0.100	1.187	0.967	1.457
I do not think about it	0.036	0.120	0.089	1	0.765	1.037	0.819	1.312
Feel safe with airbag	0.239	0.136	3.095	1	0.079	1.270	0.973	1.658
Strong vehicle to feel safe	−0.090	0.133	0.465	1	0.495	0.914	0.705	1.185
Might get trapped in Seatbelt	−0.175	0.131	1.777	1	0.182	0.839	0.649	1.086
Seatbelt is not cool to wear	0.142	0.129	1.208	1	0.272	1.153	0.895	1.485
Not to wear in short distances	0.057	0.109	0.277	1	0.599	1.059	0.855	1.312
Not to wear if with friends	0.287	0.127	5.128	1	0.024	1.333	1.039	1.709

Table 11
Speed Proposition Analysis.

Speed proposition	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for EXP(B)	
							Lower	Upper
Severity of injuries could be reduced by slower speed	−0.113	0.200	0.318	1	0.573	0.893	0.604	1.321
Speed cameras reduces road deaths	−0.122	0.192	0.408	1	0.523	0.885	0.608	1.288
More likely to be involved in a crash if you speed	0.552	0.307	3.227	1	0.072	1.737	0.951	3.171
Difficult to always drive within the speed Limit	0.131	0.214	0.378	1	0.539	1.140	0.750	1.733
It is OK to speed if you drive safely	0.203	0.232	0.767	1	0.381	1.225	0.778	1.929
It is OK to drive up to some km over speeding	0.052	0.204	0.064	1	0.800	1.053	0.706	1.570

Table 12
Penalties Opinion Analysis.

Opinions on Penalties	B	Std. Error	Wald	df	Sig.	Exp(B)	95 % CI for Exp(B)	
							Lower Bound	Upper Bound
Traffic rules should be stricter	1.985	1.040	3.643	1	0.056	7.282	0.948	55.939
Traffic rules are not being checked	1.990	1.053	3.567	1	0.059	7.313	0.928	57.639
Penalties are too severe	1.726	1.032	2.797	1	0.094	5.620	0.743	42.493

Table 13
Opinion on Measures to be Taken.

Traffic Accident Reduction Measures	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for EXP(B)	
							Lower	Upper
Intensifying supervision	1.852	0.929	3.977	1	0.046	6.375	1.032	39.365
Financial penalties	0.815	1.424	0.328	1	0.567	2.259	0.139	36.799
Increasing traffic culture	2.040	1.510	1.826	1	0.177	7.691	0.399	148.292
Penalties like community services	0.970	1.470	0.435	1	0.509	2.637	0.148	46.992
Expanding public transport	3.133	1.796	3.043	1	0.081	22.933	0.679	774.446
Promoting public transport usage	0.337	1.453	0.054	1	0.817	0.714	0.041	12.323
Tightening driving license testing	0.722	1.568	0.212	1	0.645	2.060	0.095	44.483
Control on fake auto-parts	3.989	1.987	4.031	1	0.045	54.020	1.099	73.829
Traffic sign redesigning	2.717	2.181	1.552	1	0.213	15.141	0.211	1088.915
Shifting working hours	0.082	1.416	0.003	1	0.954	0.922	0.057	14.788
Congestion pricing on certain roads	0.133	2.054	0.004	1	0.948	1.142	0.020	64.050

Table 14
Socio-economic Analysis.

Factors	Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for EXP(B)	
								Lower	Upper
Age	18–25 years	1.847	1.398	0.000	1	0.088	6.341	0.409	98.296
	25–50 years	0.188	1.229	0.023	1	0.048	0.829	0.075	9.213
	Above 50 years	0.753	1.202	0.393	1	0.531	0.471	0.045	4.964
Driving experience	1–3 years	1.360	1.173	1.344	1	0.064	2.257	0.026	2.557
	3–10 years	1.403	1.217	1.328	1	0.036	0.249	0.023	2.673
	More than 10 years	0.474	1.185	0.160	1	0.689	1.606	0.158	16.376

experience within different groups. Some of the elements could be resolved simply by enhancing driver awareness and implementing effective measures. Based on the statistics collected from the survey, the dominant behavioral mistake among drivers in the city involves not adhering to the minimum distance between vehicles while driving. This practice leads to accidents caused by sudden braking, misjudgment, or a lack of attention on the road. Although the speed factor had no positive significance in this study, policymakers should consider it in order to maintain control and monitor the situation. Regression analysis shows that strict penalties do not correlate with the risk of an accident. The most prominent measures to reduce accidents, as suggested by the respondents, were intensifying supervision and controlling fake parts used in vehicles. The study also identified a noteworthy correlation between the age and driving experience of drivers who were involved in accidents. Notably, drivers of middle-age were found to have a higher likelihood of causing or being part of an accident compared to younger drivers. Additionally, the findings indicated that as individuals gain more experience, there is a tendency for them to become more careless, which increases their involvement in both minor and major accidents.

Comparative analysis of accident types across UAE Emirates, 2017

Fig. 2 presents a comparative analysis of different accident types across various emirates in the UAE for the year 2017. The data highlights the occurrence of four distinct accident types: Shock and Crash, Deterioration, Run Over, and Other. In the UAE as a whole, a total of 4,103 accidents were recorded in 2017. Among these, "Shock and Crash" incidents constituted the highest number, followed by "Run Over" and "Deterioration." Abu Dhabi recorded the highest number of shock and crash accidents among the emirates, with 1054 occurrences. Following closely, Dubai reported 919 cases, while Sharjah documented 311 incidents in this category.

Abu Dhabi saw the highest instances of deterioration accidents, with 186 reported cases (Fig. 2). Dubai had 65 of these accidents, while Sharjah and Fujairah reported 40 and 37 instances respectively. Abu Dhabi maintained its lead in run over accidents, reporting 280 cases. Dubai followed with 354 run over accidents, and Sharjah documented 156. Umm Al Quwain had the lowest count once again, with only 9 run over accidents.

Overall, the 2017 data in Fig. 2 demonstrates variations in the frequency of different accident types across the various emirates. Abu Dhabi consistently showed the highest figures in most categories, followed by Dubai, Sharjah, and the others. These findings can contribute to understanding accident patterns and implementing tailored safety measures in each emirate.

Exploring urban accident patterns: spatial analysis and hotspot detection

The collected accident locations were transformed into spatial data, creating a statistically significant local aggregation of activity spaces. The Getis-Ord Gi* method, a spatial statistical approach integrated into ArcGIS (Ver. 10.2, ESRI Inc., CA, USA), was employed to identify hotspots of accident sites. Gi* statistics calculate the ratio of the local sum of values in the vicinity of an incident to the total sum of all values.

Identified significant hotspots indicate areas with either high or low values, surrounded by other features exhibiting similar tendencies. Breaks were established at Z scores of 1.65, 1.96, and 2.58, corresponding to statistical significance levels of 0.10, 0.05, and 0.01. Three confidence interval levels (90 %, 95 %, and 99 %) were employed, with higher confidence levels indicating more likely hotspot aggregation. Hotspots were considered crash incidents with a confidence interval exceeding 90 %. The analysis scale was determined through Incremental Spatial Autocorrelation (ISA). This method calculates the Global Moran's I statistic at varying distances, assessing clustering intensification for each distance. The analysis scale was defined as the distance at which ISA yielded its initial Z-score peak, indicating pronounced spatial aggregation. An initial ISA distance of 250 m was chosen, ensuring that all features had at least one neighbor. Within this study, priorities were categorized into four groups based on their corresponding accident densities: low, medium, high, and very high priorities.

Through the hotspot analysis of Abu Dhabi city using Gi* statistics, it becomes evident that the central district area is significantly impacted by road traffic accidents (Fig. 3). Areas with high positive Gi* scores on the map indicate the presence of concentrated road accidents. These hotspots serve as indicators of increased risk zones, which are frequently influenced by factors including dense traffic flow, complex intersections, or other conditions that promote accidents. For instance, the Madinat Zayed, Markaziyah East, and Baladiya areas have encountered

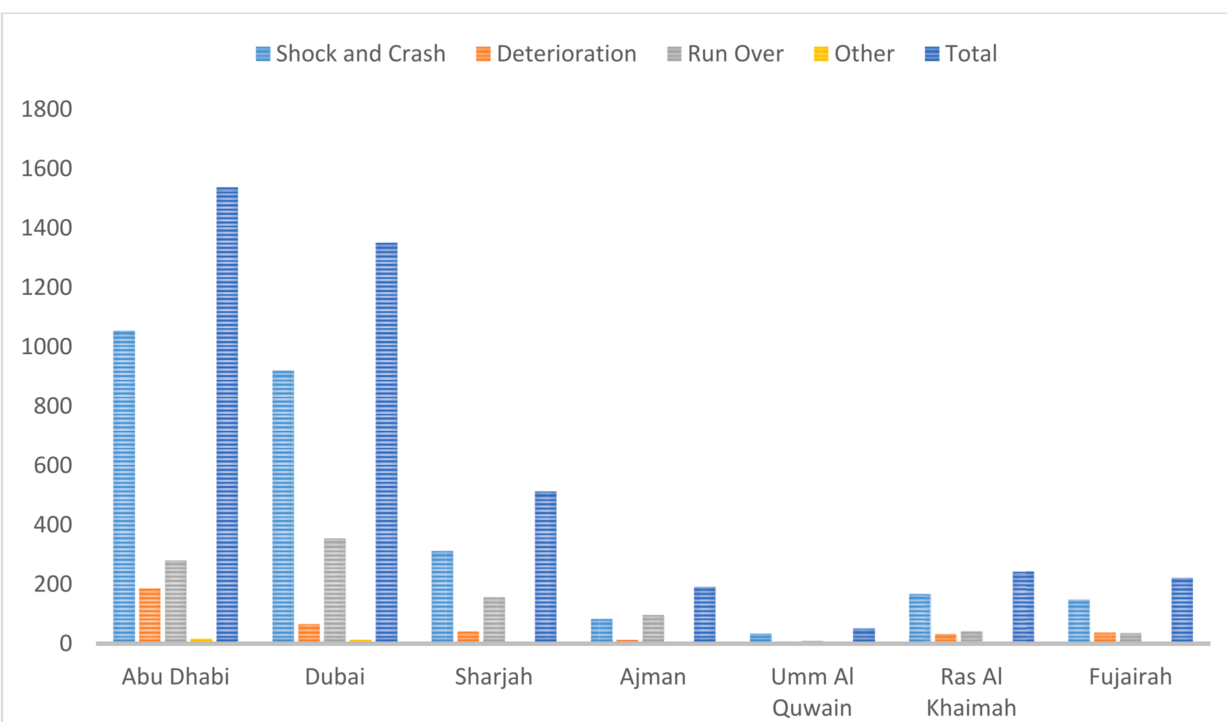

Fig. 2. Number of Accident Types across UAE Emirates, 2017. Source: Data retrieved from UAE Federal Competitiveness and Statistics Authority. (n.d.).

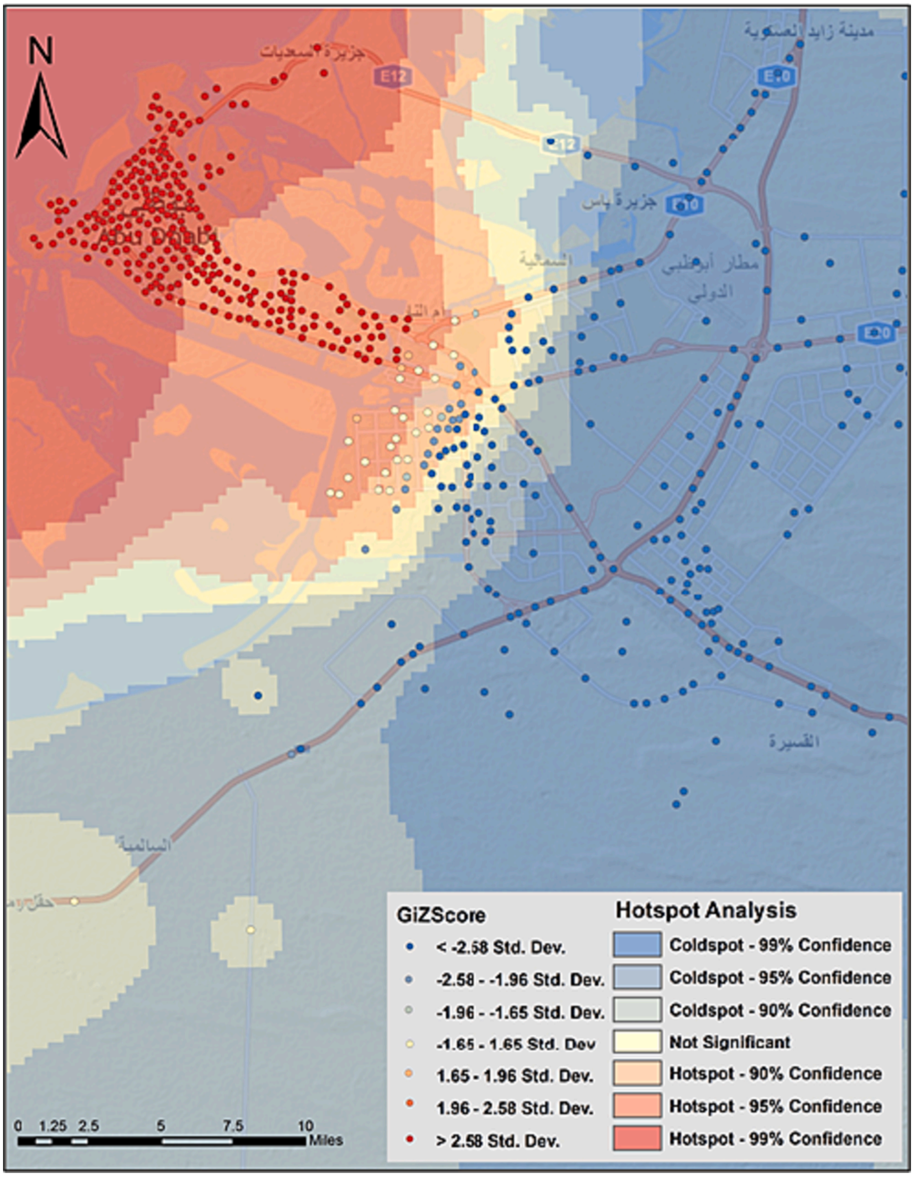

Fig. 3. Accident hotspot Map of Abu Dhabi City, UAE, 2014.

substantial challenges with road crashes. This could potentially be attributed to the presence of nearby shopping areas, mosques, and business centers, which attract a considerable volume of vehicles and pedestrians. The hotspot map in Fig. 3 also shows that approximately 16.1 % of the accidents fall under the category of severe crashes with high casualties. Notably, more than half of these accidents occur in the city's red zone, characterized by densely populated business areas.

After extrapolating the data acquired, some locations have been categorized as high-risk accident density zones, whereas others have been classified as zones with moderate to low risk, as shown in Fig. 3. For example, areas such as Al Markaziyah, Al Zaab, and Al Hosn are predominantly classified as high-risk zones, primarily due to heightened business activities in these areas (Fig. 4). Additionally, a high density of road accidents was found in the Al Danah district, a densely populated commercial zone housing various public establishments such as shopping malls, hospitals, and offices. Al Markaziyah and its adjacent regions emerged as the second most accident-prone zone, even though they have a relatively low population density, resulting in a significant number of casualties. However, as we move farther from the city center and extend towards the neighboring districts of Al Mushrif, Al Aman, and Al Bateen, the frequency of accidents declines noticeably.

Overall, the comprehensive spatial analysis results for Abu Dhabi city demonstrate a strong correlation with a higher likelihood of accidents occurring near the central district. This suggests a direct link between the accident risk zone and public gathering areas. The factors leading to these traffic accidents are varied and can significantly vary from one area to another.

Conclusion

This study showcases the potential of GIS technology in analyzing accident data and conducting complex spatial and statistical analyses, including hotspot identification through tools like Moran's I and Getis-Ord Gi. The research demonstrates a significant correlation between road accidents in Abu Dhabi and various factors, indicating that accident-causing factors are more prevalent in central business areas and locations with large gatherings. Furthermore, the study highlights the effectiveness of using Getis-Ord Gi statistics in conjunction with IDW for hotspot identification. Overall, these findings emphasize the importance of utilizing GIS technology to identify and mitigate factors contributing to road accidents in Abu Dhabi.

The findings of this study demonstrate that the proposed approach is

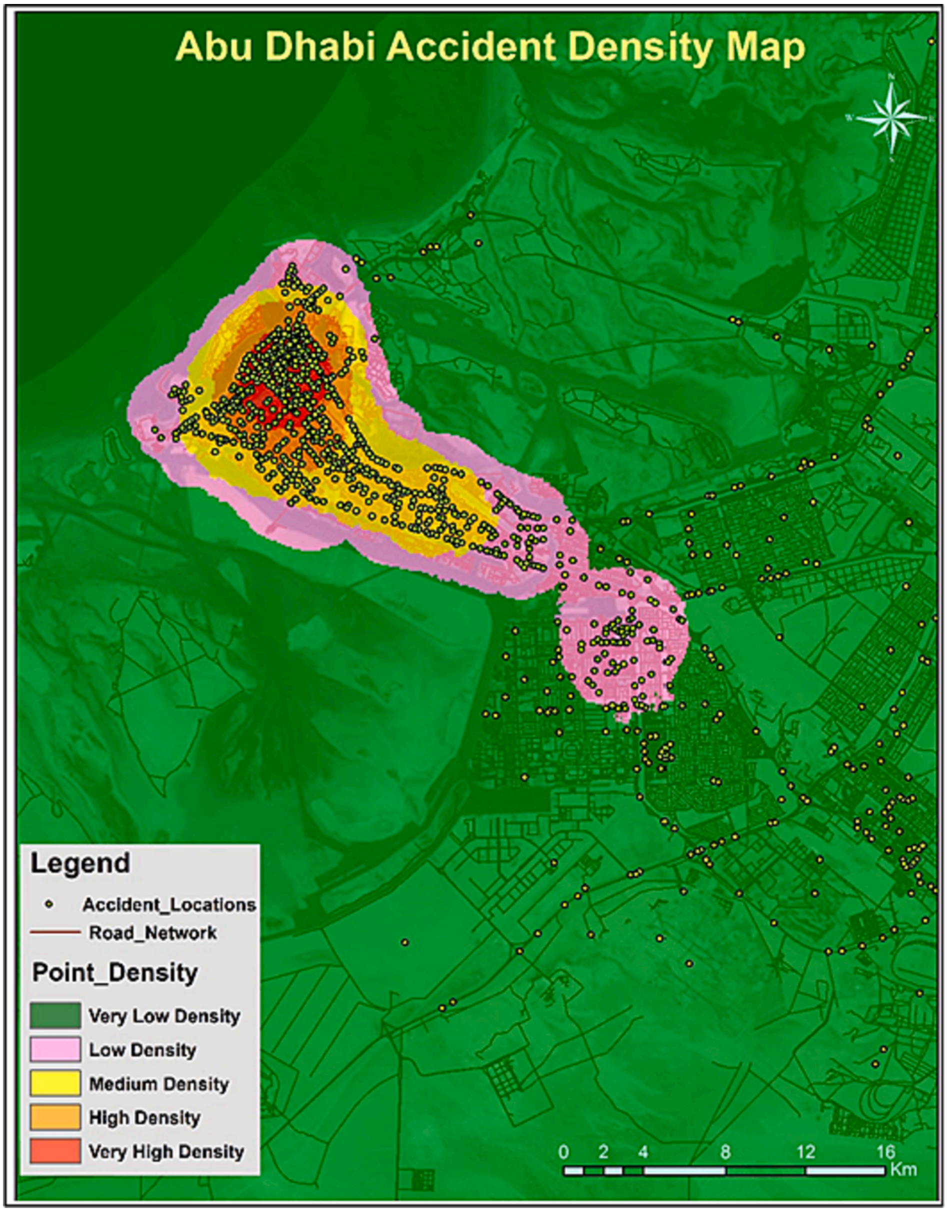

Fig. 4. Accident Density Map of Abu Dhabi City, UAE, 2014.

effective in detecting significant spatial patterns in vehicle accident data and accurately identifying hotspot areas. By utilizing proven spatial statistics that consider both the location of points and their attributes, such as severity and casualties, the identification of vehicle crash hotspots for Abu Dhabi city is reliable. Spatial analysis of raw data locations can provide further insight into capturing safety indicators. The study highlights the issues of vehicle crashes in the mid-block locations of the city, which can largely be attributed to high turning movements and poor adherence to traffic regulations. Overall, this research provides a framework for identifying crash hotspots and prioritizing unsafe zones for further study of causal factors and the implementation of effective countermeasures.

This study also provides valuable insights into the factors contributing to road accidents in Abu Dhabi City, including careless driving, age, and driving experience. Through the examination of responses from 1,072 drivers, the study highlights the need for preventive measures to improve traffic safety within the city. The 2017 comparison of accident types across UAE emirates indicates that shock and crash incidents were common, especially in Abu Dhabi. Additionally, higher run over incidents in Abu Dhabi and Dubai.

To improve road safety and reduce the incidence of accidents, it is important to implement a comprehensive awareness program that educates the public on traffic regulations and safe driving practices. This program can be supported by various entities, such as SAEED, RTA, and the police, along with dissemination through various media channels. Additionally, organizing more training programs, induction courses, and seminars can help drivers learn the art of safe driving. Although the most significant gains in driving experience occur after licensure, education and training programs are still beneficial in preparing drivers for the numerous risky driving situations they may encounter. To enhance road safety and reduce traffic accidents, the UAE may further embrace the implementation of intelligent transportation systems, improve public transportation infrastructure, and enforce traffic laws to encourage drivers to adopt safe driving practices. These measures can collectively contribute to creating safer and more efficient roadways across the country.

The survey conducted among drivers involved in road accidents in Abu Dhabi City has certain limitations that should be acknowledged.

Firstly, the sample size of 1,072 responses might not fully represent the entire population of drivers who experienced accidents during the study period. Additionally, the reliance on self-reporting by the drivers introduces the possibility of recall bias, potentially affecting the accuracy of reported accident details. The study's use of survey and crash data from 2014 provides a snapshot of accidents during a specific period, but longitudinal data could offer deeper insights into trends over time. Moreover, the findings and policy implications are specific to Abu Dhabi City, and caution should be exercised when applying them to other regions or cities with different traffic patterns and infrastructure. Furthermore, the study does not account for external factors such as weather conditions, road maintenance, or sudden emergencies that may have contributed to accidents. Considering these limitations is essential when interpreting and applying the research results for policy development and traffic safety improvement initiatives. Continuous research and monitoring of road safety measures are critical to ensuring the effectiveness of preventive strategies.

CRediT authorship contribution statement

Khaula Alkaabi: Conceptualization, Methodology, Formal analysis, Validation, Data curation, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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