The Pattern of Road Accidents in Fog and the Related Factors in North of Iran in 2014-2018

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Original Contribution

Keywords: Trauma, Traffic Accidents, Weather, Fog

Posted Date: September 16th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-73501/v1

Abstract

Objectives: Road fog can form suddenly which necessitates more caution by the researchers as well as drivers due to low vision and related morbidities and mortalities. This study aimed at determining the pattern of accidents in fog and the relationship between driver, road, and accident with injury level in Guilan, Iran from 2014 to 2018.

Methods: This is a retrospective descriptive-analytical study that investigated all accidents that had occurred in Guilan from 2014 to 2018. All of the data were entered into STATA software. The time-series estimators were used as the multivariate regression model for the presence or absence of any relationship between variables.

Results: In fog, the fatality rate of traffic accidents was significantly higher than other climatic conditions (IRR = 1.471). The likelihood of fatalities in fog decreased with age while it increased when drivers were female (p = 0.001). Most of the accidents in fog condition had occurred in December (p=0.000), February (p=0.001) and November (p=0.012). The number of related injuries at 2 AM (p = 0.032), 3 AM (p = 0.019), and 2 PM (p = 0.02) significantly reduced. Moreover, the rate of mortality at 2 AM (p = 0.005), 9 AM (p = 0.012), 11 AM (p = 0.004), 13 PM (p = 0.008) and 19 PM (p = 0.003) were significantly lower. The rate of injuries was significantly higher in Anzali (P = 0.042) and Rasht (P = 0.018), respectively.

Conclusion: In the fog, the fatality rate was significantly higher than that of other conditions. The pattern of accidents in fog decreased with age and increased in accidents involving female drivers. Most of the fatal accidents had occurred in fog in November, January and February, respectively. Road accidents in Anzali and Rasht cities were more fatal.

Introduction

Weather condition may not be a major factor in causing road traffic accidents (RTAs) but it is undoubtedly one of the important environmental components (1, 2). According to the NHTSA reports, the weather condition is responsible for 22% of damages, 19% of injuries and 16% of RTAs between 2005 and 2014 (3). Fog is one of the most important atmospheric hazards which directly affects transportation safety (4, 5). In China, the analysis of the data from 2005 to 2014 showed that the average financial cost of RTAs was highest on foggy days compared with that of other bad weather conditions (6). In Korea, the results of the statistical analysis of RTAs in 2014 suggested that 0.5% of all RTAs occurred in foggy weather, which seems to be low compared with the occurrence of accidents on sunny days (80.3%), rainy days (9.6%) and snowy days (1.1%) (7). In another study, the rate of fatality was 6.9% on foggy days which was the highest rate compared with 1.9% on sunny, 2.5% on rainy, and 2.5% on snowy days (7). Furthermore, according to reports, the mortalities due to multi-vehicle chain crash are more likely to occur in foggy and snowy conditions (7), with a risk ratio (RR) of 6 times for rainy, 158 for snowy and 171 for foggy weather (8).

Reduced visibility in fog condition can be a real threat since the findings of the Transport Laboratory Research have shown that visibility less than 150 meters is very dangerous for drivers (9). Compared with other weather conditions, fog disturbs drivers due to sudden and irregular occurrence, increasing the likelihood of occurrence of accidents (1) particularly accidents with higher severity. According to the CRII, in foggy weather, the risk of accidents has a 40% increase (10). In sudden fog, drivers are usually unprepared for fog. Moreover, the foggy condition may affect the driver's perception and according to reports, there is up to 60% overestimation of distances in the fog (11). Under this weather condition, especially in thick fog, images and distances are blurred which may cause a slowdown in traffic volume and an increased risk of RTAs occurrence. Moreover, the reduced speed of vehicles and the resulting delay can increase stress and mental pressure during driving. These important factors may lead to increased road hazards in foggy weather (1, 4, 11). In addition to perception, the driver's behavior and performance are also affected by low vision (1). Some drivers slow down their speed while some others may increase it. This behavioral difference in response to low vision disrupts the traffic flow (10). In clear weather condition, people tend to drive faster due to good visibility and clear weather than in fog (1). Lane-keeping performance in the foggy condition is another example of the driver's behavior in fog. Drivers in low visibility have a higher standard deviation in lane-keeping (poor keeping of the lane in which they drive), i.e. drivers in fog compared to drivers who drive in good weather condition with high visibility always change lanes concerning low visibility of traffic signs. This is extremely dangerous and multiples the risk of collision with vehicles coming from the front in the opposite direction (1, 12, 13). Other behaviors include headway distance control in the foggy and misty condition which can be a vital factor. Most drivers tend to reduce their headway distance in this situation because it is easier to notice them (14). A simulated study found that drivers have a shorter headway space in fog, most of whom are unaware of this. Dense fog increases the perception of risk and uncertainty of the environment which makes the drivers reduce their headway distance for more safety. Therefore, shortening the headway distance in fog is not mainly a result of slowing down but probably due to the mental sense of safety in drivers (2). As a result, this behavior increases the likelihood of a rear-end collision (2, 15, 16). Drivers' skills in fog vary according to their individual characteristics. Elderly drivers may be at greater risk of injury due to reduced ability to predict possible accidents in foggy weather (14). More experienced drivers tend to significantly reduce their speed in the fog more than novice ones (17). There is also evidence that usually older drivers get close to the front car 21% less than novice drivers to have a better vision but they do not have enough time to react appropriately if accident occurs (14). Most of these accidents occurred in the morning in December and February. Front to head and rear-end collisions were the most common types of accidents in fog condition (18).

The limited number of epidemiological studies on the fatal accidents in foggy weather in Iran as well as the differences between our country and other countries in related dimensions such as different scientific views (19–21) and different safety levels emphasize the need for undertaking such studies. These remarkable differences include vehicle type, availability and use of seatbelt and airbag, features of road design, driving styles and response time of emergency services (EMS) (22–24). Despite the frequent fog in some roads in northern Iran (Guilan province) and its high risk of accident, few studies have been

conducted in this area. The hotspots of RTAs need to be identified in the fog so with greater knowledge, the number of these accidents can be minimized through efficient traffic management in hazardous areas. The purpose of this study was to determine the pattern of crashes in fog and to detect the relationship between factors related to driver, road and accident with injury levels in Guilan from 2014 to 2018.

Methods

This is a retrospective descriptive-analytical study. Inclusion criteria were the occurrence of RTAs during the period of 2014 to 2018 in Guilan province in fog condition. RTAs with incomplete recorded data in the database were not entered into the study.

After approval of the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1398.202), samples were collected from databases in the Iran Meteorological Organization and Traffic Police of the Islamic Republic of Iran of Guilan. The accidents which had occurred in foggy weather were compared with those occurring in normal weather condition.

The data required for this study were collected from two sources:

1. Meteorological data: This data included daily information about maximum, minimum and average temperature in Celsius, mean daily rainfall, and mean daily air pollution which were obtained from Guilan Meteorological Organization and from Guilan meteorological stations in https://www.wunderground.com website. This center has appropriate and up-to-date technical equipment to measure and record the related data. The data were sorted based on days from March 21, 2014 to March 20, 2018. Foggy days were found according to meteorological station data.
2. Data related to traffic accident variables: Data on the number of accidents with vehicle damages, as well as the number of accidents with mortalities and morbidities/injuries were collected and entered into Excel software which were then determined and sorted on a daily basis, using the PivotTable command (mortality, morbidity, and vehicle damage).

For a descriptive assessment of the status of road accident on foggy days, the accidents which had occurred in fog were separated from normal weather and the differences in the severity of accident, the time of accident, the age and sex of the driver at-fault, the time and day and month of the accident, the city of the accident, the situation of the road, geometrical status of the road and the type of vehicle were identified and compared. The number of deaths, injuries and accidents were collected daily. After data collection, all of the data were entered into STATA software and analyzed by multivariate regression model for the presence or absence of any relationship among variables. P and Z were used to examine the significance between dependent and independent variables. R2 statistic was used for studying goodness of fit.

Results

A total of 467 accidents occurred in the foggy weather in the cities of Guilan during 2014–2018. Most of the accidents occurred in Rasht, Astara, and Talesh, respectively, and no accidents occurred in Lahijan in foggy weather. However, in per thousand accidents, the highest number of accidents belonged to Astara, Talesh, and Rasht, respectively (Fig. 1).

Red color shows hot spots around Rasht and Talesh (Fig. 2).

The mean age of the drivers at-fault in non-foggy (normal) compared with foggy weather was 35.95% versus 37.03%. However, there was no significant difference between the two groups (p = 0.11). The fatalities of male drivers in normal compared with fog was 87.53% versus 91.6%. The difference was statistically significant (p = 0.005). In regression model, considering death rate due to road accidents in foggy weather in Guilan between 2014 and 2018, in terms of age, sex, road type and road geometry, IRR = 0.935 and p = 0.039 indicated that with increasing age, the likelihood of death in traffic accidents could significantly reduce. Whereas there was a significant increase in death rate (P = 0.001) in accidents involving a female driver (Table 1).

Table 1
Regression model of the fatalities due to traffic accidents in foggy weather based on age, sex, road type and road geometry in Guilan from 2014 to 2018

Death	Odd ratio	Standard error	z	p-value	Upper limit	Lower limit
Age	0.937	0.0292	-2.06	0.039	0.881	0.996
Sex	0.136	0.084	-3.23	0.001	0.040	0.457
Type of road						
Highway	1					
Mainway	0.079	0.062	-3.2	0.001	0.016	0.375
Side road	1					
Geometry of road	0.256	0.276	− 1.26	0.207	0.031	2.124

The Poisson regression model of cross-sectional showed that most of the accidents occurred in January with IRR = 2.723 and p = 0, in February with IRR = 2.031 and p = 0.001 and in November with IRR = 1.690 and p = 0.012, respectively. However, in June, July, August and September, the fatality rate in foggy weather was significantly lower. In other months, no significant relationship between the month and the occurrence of accidents was noticed (Table 2).

Table 2
Regression model of the relationship between accidents in foggy weather and month of accident and vehicle type in Guilan in 2014–2018

Fog	Odd ratio	Standard error	Z	p-value	Lower limit	Upper limit
Type of Vehicle Accident						
Pedestrian	0.67	0.144	-1.86	0.063	0.44	1.021
Motorcycle & bicycle	0.768	0.123	-1.64	0.101	0.561	1.052
Heavy vehicles	1.684	0.548	1.6	0.109	0.889	3.188
Month of accident						
May	0.64	0.177	-1.6	0.109	0.372	1.104
June	0.239	0.092	-3.7	0	0.112	0.510
July	0.081	0.048	-4.2	0	0.025	0.262
August	0.155	0.063	-4.55	0	0.069	0.346
September	0.260	0.088	-3.96	0	0.134	0.507
October	0.461	0.142	-2.5	0.013	0.251	0.847
November	1.690	0.353	2.51	0.012	1.121	2.548
December	0.711	0.190	-1.27	0.204	0.42	1.203
January	2.723	0.528	5.17	0	1.862	3.983
February	2.031	0.419	3.43	0.001	1.354	3.046
March	1.011	0.253	0.05	0.962	0.619	1.653

After controlling for the variables of age, sex, road type and geometry in the regression model, IRR = 1.03 and p = 0.616 indicated no significant difference in the rate of injuries in foggy and normal weather conditions (Table 3).

Table 3
Regression model of foggy weather and the extent of injuries due to traffic accidents in Guilan from 2014 to 2018

Variable	IRR	Standard error	p-value	Lower limit	Upper limit
Fog	1.033	0.068	0.616	0.908	1.176
Age of driver at-fault	0.996	0.0003	0	0.995	0.997
Sex of driver at-fault	1.07	0.02	0	1.03	1.112
Type of road					
Mainway	0.787	0.04	0	0.712	0.869
Side road	1.193	0.06	0	1.081	1.318
Geometry of road (Straight)	1.229	0.016	0	1.198	1.261
Road surface					
Dry	0.903	0.012	0	0.88	0.927
Icy	0.612	0.068	0	0.492	0.761

Considering the foggy condition and mortality rate of IRR = 1.47 and P = 0.078, the regression model showed that the mortality rate was higher in foggy weather in 90% confidence interval (Table 4).

Table 4
The regression model of foggy weather and mortality rate due to road accidents in Guilan from 2014 to 2018

Variable	IRR	Standard error	p-value	Lower limit	Upper limit
Fog	1.471	0.322	0.078	0.957	2.261
Age of driver at-fault	0.997	0.001	0.081	0.994	1.000327
Sex of driver at-fault	1.331	0.113	0.001	1.126	1.573
Type of road					
Mainway	0.656	0.108	0.011	0.474	0.906
Side road	0.679	0.111	0.019	0.492	0.937
Geometry of road	1.348	0.069	0	1.219	1.491
Road surface					
Wet	0.755	0.042	0	0.676	0.842
Icy	0.304	0.176	0.04	0.0981	0.946

There was no significant relationship between the variables of age, sex, road type and road geometry in the regression model of injuries in road accidents in the foggy weather.

The regression model of the fatalities in traffic accidents based on the year of the accident displayed no significant difference between the year of the accident and the death rate. Yet, the highest mortality rate in traffic accidents dedicated to the year 2015 with IRR = 2.283. There was no significant difference in the rate of injuries in different years, though the highest rate of injuries with IRR = 1.01 belonged to 2015.

The regression model of deaths due to road accidents in fog at different hours in Guilan between 2014 and 2018 revealed that the mortality rate at 2 AM (IRR = 0.05 and p = 0.005), 9 AM (IRR = 0.06 and p = 0.012), 11 AM (IRR = 0.045 and p = 0.004), 13 (IRR = 0.230 and p = 0.008) and 19 PM (IRR = 0.04 and p = 0.003) were significantly lower. Hours 1, 3, 4, 5, 6, 7, 8, 10, 12, 14, 15, 16, 17, 18, 21, 22, 23, and 24 could not be investigated due to the incomplete information. Also, the same model indicated a remarkable decrease in the rate of injuries at 2 AM (IRR = 0.2 and p = 0.032), 3 AM (IRR = 0.075 and p = 0.019) and 2 PM (IRR = 0.1 and p = 0.02). There was no significant association in the rest of the hours (complete information was not available for accurate evaluation at 4 AM, 5 AM and 6 AM).

The regression model of mortalities due to traffic accidents in Guilan from 2014 to 2018 proposed no statistically significant relationship between the site of accident and mortality rate. However, the highest mortality rate belonged to Someh Sara with IRR = 1.5% (insufficient data on the exact number of fatalities in foggy weather in the cities of Astara, Anzali, Langrud, Talesh, Fouman, Roudbar, Masal, Amlash, Siahkal, and Shaft). Moreover, the assessment of injuries in the model showed that the rate of injuries due to accidents which had occurred in the aforementioned period was significantly higher in Anzali (IRR = 5.923 and p = 0.042) and Rasht (IRR = 2.432 and p = 0.018), respectively (sufficient data on the extent of injuries due to road accidents from 2014 to 2018 in the cities of Langroud, Some Sara and Amlash were not available).

Discussion

A notable finding of this study was that although the rate of injuries was significantly higher in Anzali and Rasht, accidents occurring in foggy condition caused huge damages and injuries in most of the cities. A study of all areas of the United States except Northwest and New England reported similar results (25). In an Iranian three-year study on the Firouzkooh-Sari road, 930 road crashes were identified over a distance of 131 kilometers. The highest risk of fatal accidents belonged to the distance of 98, 100, 106, 109 and 110 kilometers, and due to the installation of fog lights at 9 to 18 kilometers (before and after the mountain pass or road curve), these types of accidents were prevented to a huge extent (26). Therefore, it is likely that the differences in the magnitude and severity of accidents be due to the installation of lighting and fog lights and other road facilities in different cities of Guilan with varying numbers and qualities.

According to the results of the present study, the mortality rate due to RTAs decreased significantly with age. In fact, this type of accidents in northern Iran follows a specific age pattern in terms of rate of

mortality of drivers. In a similar research which scrutinized the relationship between all certain weather conditions including rain, fog, dust, etc. and traffic accidents, significantly less number of RTAs were observed in older drivers (40–60) (27). There are various reports insisting that older drivers may be at greater risk of injury due to the reduced ability to detect impending events and fail to maintain a safe headway distance (14). If we assume age and experience as two similar concepts, a study reported that more experienced drivers compared with novice drivers were significantly less likely to lower their speed (17). Experienced drivers are also less likely to approach the front vehicle than novice drivers, which gives them enough time to respond appropriately (14). However, these differences may be related to the different age range included in each study.

The pattern of RTAs in the foggy condition was significantly associated with the male sex. That is, men were more likely to have accident than women in such condition, however, the likelihood of death dramatically increased in accidents where a female driver was at-fault. In a similar study, female drivers were more likely to deviate from the straight path in fog and involved in a single-vehicle accident in dense fog. It is noteworthy that male drivers usually drive at high speeds in foggy conditions since they usually have more confidence in their driving skills than female drivers (28). But in a study in Pakistan's urban areas, men were more likely to be involved in traffic accidents than women in all types of weather (27). Also, according to a logistic model, sex was the only characteristic associated with the deceleration of the vehicle in foggy weather. Evidence suggests that the average speed of women is more affected by fog than men at speeds of up to 10 mph. This means that women are probably more cautious when driving in foggy conditions and have a more responsible attitude than men because male drivers are more likely to risk speeding when the immediate dangers are unclear (29, 30). Still, more detailed studies are required.

In the present study, there were no significant differences in the number of injuries in foggy weather compared with other conditions, but the mortality rate was significantly higher than other climatic conditions. In one Iranian study, however, the number of accidents in rainy weather (73.8%) which led to damages was higher than the number of accidents leading to death, which was due to the slower speed of vehicles in such conditions compared with sunny weather (31). In a time series analysis in northern Iran, the first day of rainfall after several dry periods was significantly associated with morbidities and mortalities due to accidents (32). This may imply that fatal accidents in fog are so severe that they lead to immediate death because of the severity of the injuries.

Most of the fatal accidents related to foggy weather occurred in the autumn (November) and winter (January and February) whereas the number of these accidents was significantly lower in warm months including June, July, August and September. A study on accidents in the USA in cold weather in winter season published similar findings according to which the highest rate of deaths due to RTAs dedicated to cold days of winter (33). Furthermore, Abdel-Atyet al. (2011), found similar results where the highest number of accidents had been recorded for smog weather occurring during winter (34). According to the data obtained from the FARS database, 40% of fatalities occurred in fog, smoke, dust storm and sand storm, with most of them occurring in December, March, and April (35). In an Iranian study, dense fog

(less than 40 meter vision sight) was highest in February (31). Therefore, in the present study, the pattern of RTAs in the fog had a seasonal pattern and had a significant increase in winter compared with summer. However, previous studies have reported that drivers tend to go faster in clean weather due to good visibility so they usually speed up in clear weather in foggy weather (1, 5). Although the dense fog is often observed during the winter when the average speed of vehicles is slower and the number of tourists is remarkably lower than that of other times of the year (36), the number of accidents under foggy weather is surprisingly high which needs more investigations.

Studying the mortality rate of RTAs in foggy weather at different hours of the day in Guilan province from 2014 to 2018 revealed that the mortality rate significantly decreased at 2 AM, 11 PM, 13 PM and 19 PM. The number of injuries decreased dramatically at 2 AM, 3 AM and 2 PM. In the study by Black and Mote (2015), the highest number of fatalities in fog due to RTAs belonged to evening time (33), and in another study, the most frequent fatalities were in smog condition in the morning in winter (34). However, due to the lack of available data related to certain times of the day/night, an accurate analysis was not possible.

Examining the mortality and injury rates of RTAs in the fog revealed that the incidence of these accidents did not change significantly in Guilan from 2014 to 2018. Thus, it can be concluded that with advances in knowledge, technology and resource development, etc., there has been no reduction in these types of accidents within this time and there is a need for more effort to prevent such accidents. However, it should be noted that atmospheric phenomena can only exacerbate the cause of accidents and they should not be accounted for as the mere causes of these events. A study on bad weather conditions (snow, ice, rain, and fog) in Iran specified that these conditions caused a total increase in the risk of accidents by 6.6% (26).

Although natural phenomena such as fog, snow, cold weather, etc. cannot be prevented, some variables can be interfered with. For example, the driver's information on safe driving in such weather conditions can be improved by installation of not only the common road warning signs but also some signs containing brief messages about driving skills in foggy weather in hot spots with a higher likelihood of fog (37).

One of the limitations of this study was that the information obtained from traffic police about several variables such as the hour of accidents leading to mortality or morbidity and the city where accidents took place were incomplete. Moreover, the accidents which involved animals or hitting a traffic sign and the accidents not being reported by the driver were excluded from the study. Therefore, the number of recorded accidents may not showcase the actual number of accidents (under-report). However, our findings were similar to those of related conducted studies in other countries.

Conclusion

In the fog weather, the mortality rate was significantly higher than that of other climates, and with increasing age, the likelihood of fatalities due to accidents in fog condition decreased while the likelihood of death increased significantly among female drivers. Most of the fatal accidents occurred in November,

January, and February, respectively. The incidence of injuries due to accidents in Anzali and Rasht cities was significantly higher. In addition, our investigation on the fatalities and injuries due to traffic accidents in foggy weather demonstrated that the number of accidents in Guilan has not seen a significant change from 2014 to 2018. This indicates a low attention to this important, life-threatening issue in northern Iran. Therefore, according to our findings, it seems that some predictive factors such as age and sex can be effective in reducing fatalities due to road accidents in Rasht and Anzali during November, January and February.

Abbreviations

NHTSA: [1] National Highway Traffic Safety Administration, CRII: Crash Risk Increase Indicator

Declarations

Acknowledgment

The authors would like to offer their special thanks to Ms. Fatemeh Javadi for translating the manuscript.

Authors' contributions

N KH designed the study, E HR performed the analyses and drafted the manuscript, H SK collected the data, L KE contributed to the interpretation of the results and writing the manuscript. All authors read and approved the final manuscript.

Funding

None

Availability of data and material

The data used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study has been approved by The Ethics Committee of Guilan University of Medical Sciences, Rasht, Iran (IR.GUMS.REC.1398.202).

Consent for publication

Not applicable

Competing interests

The authors declare that they have no conflict of interest

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Figures

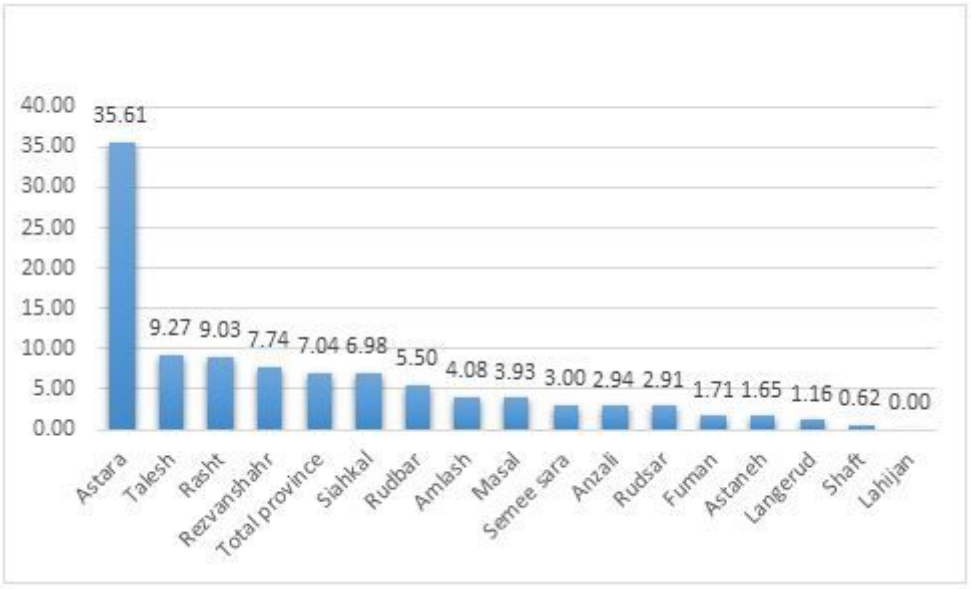

Figure 1

Frequency of traffic accidents in each city per 1000 accidents in foggy weather in Guilan from 2014 to 2018

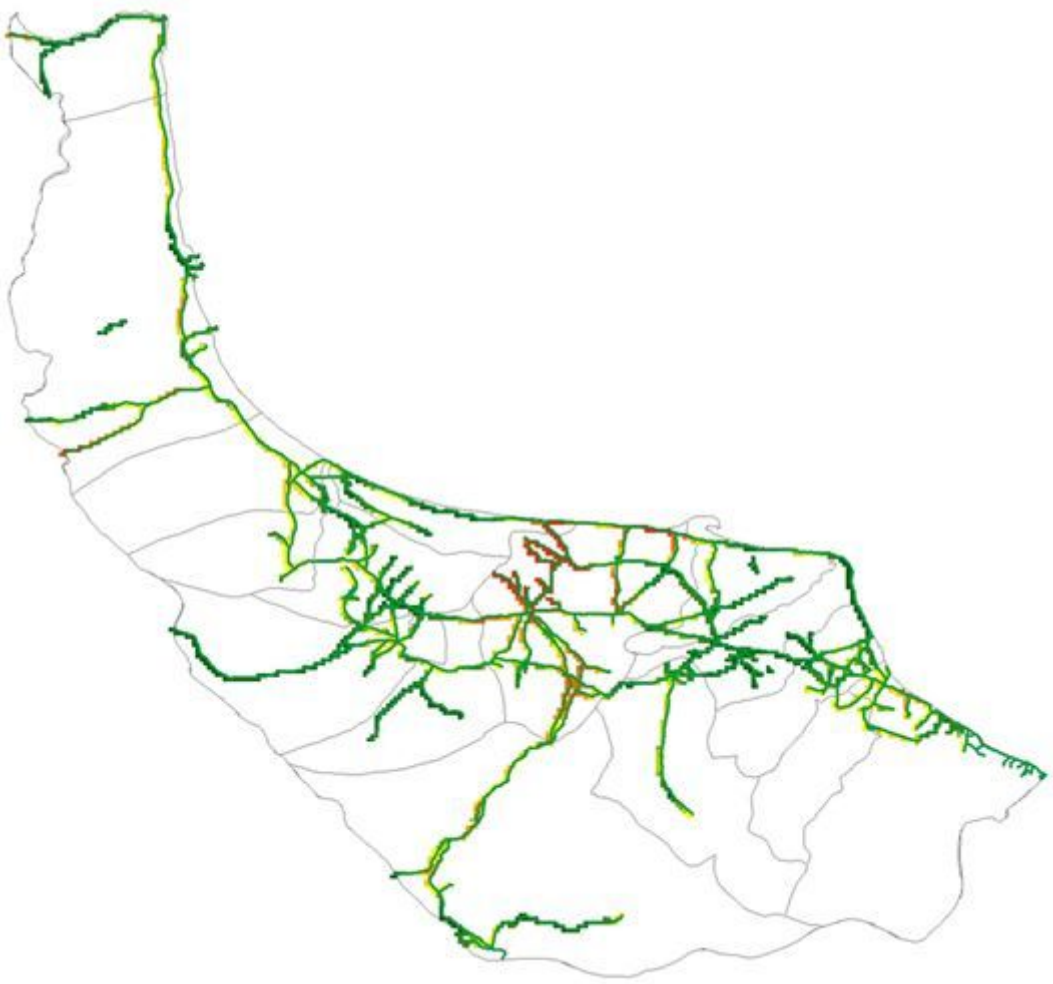

Figure 2

GIS report of accidents in foggy weather in Guilan from 2014 to 2018: from green to red color showing hot spots