ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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Identification of Traffic Accident Hot Spots and Their Characteristics by Using Geographical Information System in İstanbul: Cross-Sectional Study

İstanbul'da Trafik Kazası Sıcak Noktalarının ve Özelliklerinin Coğrafik Bilgi Sistemi Kullanılarak Belirlenmesi: Kesitsel Çalışma

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ABSTRACT Objective: One of the leading social problems all over the world is deaths and injuries caused by traffic accidents. Identification of accident hotspots and sources by Geographical Information System has been popular tool to provide road/travel safety. In this study, it was aimed to analyze the trends and characteristics of traffic accidents by presenting a system with geographically referenced data on a district basis, taking into account various variables such as accident type, accident result, time period (day/night) and intervals of the accident, and in which days or months the accident occurred. **Material and Methods:** All the statistical results of accidents were obtained by expert reports issued in 2017 by İstanbul Council of Forensic Medicine, Traffic Specialization Department. Although the accidents, that are the subject of this study, occurred between 2005 and 2017, they were sent to the Forensic Medicine Council and reported in 2017 due to the length of legal processes and the inconsistency of forensic expert reports. **Results:** In this way, 1,568 accidents occurred in İstanbul, which were submitted to the judicial authorities as a result of the disputes arising after a traffic accident, were determined and examined. Since accident reports are prepared in textual format, this situation makes difficult to analyze data. This study includes data on traffic accidents within the provincial borders of İstanbul to investigate trends and characteristics. According to the obtained data, it was possible to determine the accidents which have occurred on the European Side were doubled the ones on the Anatolia Side. Küçükçekmece district was the highest number of accident in both fatal and injured. June (148 accidents-9.4%) and September (144-9.1%) were the months with the highest number of accidents occurred on a monthly basis. The majority of traffic accidents have occurred at the 16.00-19.59 interval hours. **Conclusion:** The identification of potential accident hotspots is effective and practical for management decision-making, reducing traffic accidents and improving safety operation management.

Keywords: Traffic accident; İstanbul; accident trends; traffic model

ÖZET Amaç: Trafik kazalarından kaynaklanan ölüm ve yaralanmalar, tüm dünyada önde gelen sosyal sorunlardan biridir. Coğrafik Bilgi Sistemi ile kara yolunda kaza noktalarının ve kaynaklarının belirlenmesi, yol/seyahat güvenliğini sağlamak için popüler bir araç olmuştur. Bu çalışmada, ilçe bazında coğrafi referanslı veriler içeren bir sistem sunarak kaza tipi, kaza sonucu, kazanın gerçekleştiği zaman dilimi (gündüz/gece) ve saat aralıkları, kazanın hangi gün veya aylarda meydana geldiği gibi çeşitli değişkenler dikkate alarak trafik kazalarının eğilimlerinin ve özelliklerinin analiz edilmesi amaçlanmıştır. **Gereç ve Yöntemler:** Kazaların tüm istatistiksel sonuçları, İstanbul Adli Tıp Kurumu Trafik İhtisas Daire Başkanlığı tarafından 2017 yılında düzenlenen bilirkişi raporları ile elde edilmiştir. Bu çalışmaya konu olan kazalar, 2005-2017 yılları arasında meydana gelmesine rağmen yasal süreçlerin uzunluğu, adli bilirkişi raporlarının uyuşmazlığı nedeniyle adli tıp kurumuna gönderilip 2017 yılında raporlanmıştır. **Bulgular:** Kara yolunda çıkan anlaşmazlıklar sonucu mahkemeye intikal eden raporlar arasında İstanbul ili sınırları içinde 1.568 kaza meydana geldiği belirlenmiştir. Kaza raporlarının metin formatında hazırlanması, verilerin analizini zorlaştırmaktadır. Bu çalışma eğilimleri ve özellikleri araştırmak için İstanbul il sınırları içindeki trafik kazalarına ilişkin verileri içermektedir. Elde edilen verilere göre, Avrupa Yakasında meydana gelen kazaların Anadolu Yakasındakileri 2'ye katladığı, Küçükçekmece ilçesinin hem ölümlü hem de yaralamalı kazaların en fazla görüldüğü ilçe olduğu, Haziran (148 kaza-%9,4) ve Eylül (144-%9,1) aylarında en fazla kazanın meydana geldiği ve kazalarının büyük çoğunluğunun 16.00-19.59 saatleri arasında meydana geldiği belirlenmiştir. **Sonuç:** Olası kaza noktalarının belirlenmesi, şehir yönetiminin karar almasında, trafik kazalarının azaltılmasında ve güvenlik yönetiminin iyileştirilmesinde etkili ve pratik bir yöntemdir.

Anahtar Kelimeler: Trafik kazası; İstanbul; kaza trendleri; trafik modeli

Thousands of people die or injured in traffic accidents every day around the world. On the other hand, millions of survivors go through the hospital processes that require heavy treatments, such as organ loss or failure, or have to take under care for many years.[1] The increase in national income makes

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people and goods to move more in both developed and developing countries, thus it leads to investing more in both vehicles and transport infrastructure.

Traffic congestion occurs as a result of existing vehicles and pedestrians where the demand for space on the road is higher than the current capacity of the road. The narrowing of the road at a certain point or distance, the increase in the number of vehicles, weather conditions, and traffic accidents can be given as examples that cause an increase in traffic density.[2]

It is reported that the increase in the tendency to use private vehicles in urban transportation is the most important cause of traffic congestion. There are many reasons for the increase in this tendency, such as pandemic, the inadequacies in the public transportation system, the comfort and convenience provided by the private vehicle.[3] As of 2015, the city of İstanbul ranked first in the world with a traffic density of 58%, especially due to inadequate transportation infrastructure.[4] In terms of population, the city ranks first in Europe and fifth in the world, according to the ranking made by considering municipal boundaries. Due to its economic and socio-cultural importance, this city constantly receives immigrant and its population also increases day-to-day.[5]

As of the end of July 2021 in Türkiye, the number of registered vehicles was on average 25 millions and it has reached on average 5 million in İstanbul. This number corresponds to the total population of 22 under populated provinces on Türkiye and also represents one-fifth of all motor vehicles in Türkiye.[6,7]

There are the 2 main indicators used to compare level of traffic safety of the countries: traffic deaths per person and per vehicle. Since the number of vehicles is in related to both levels of development and frequency of exposure to traffic, the traffic deaths per vehicle of countries are considered as an important indicator that reflects the real risk of accident and death. Accordingly, there were 58 traffic deaths per 100,000 vehicles in Türkiye in 2010, and an average of 11 traffic deaths among 28 European Union member states. In this sense, Türkiye ranks 69th in 175 World Health Organization countries. In addition, when it is compared with 28 European Union member countries, it is seen that Türkiye has the highest number of traffic deaths per vehicle.[8]

Road traffic and driving safety aims to reduce all kinds of damage (death, injury and property damage) caused by the interaction of road vehicles traveling on public roads. Although there are many factors that affect driving safety, the most important ones are environmental conditions, road geometry and infrastructure, vehicle, and people.[9]

Since accident reports are prepared in textual format, this situation makes it difficult to analyze accident results.[10] Geographical Information System (GIS) technology has been a popular tool to create, manage, and analyze the hotspots of the accidents in highways through patterns, relationships, and geographic context.[11] Accident analyses provide information about the reasons of the accidents and suggest corrective measures at potential locations. At this point, traffic officials are needed for implementing precautionary measures and provisions for traffic safety.

From this point of view, in this study, it was aimed to obtain a GIS-supported evaluation of the statistical data of fatal and injured traffic accidents which occurred in İstanbul province in 2017 and were issued by the report of İstanbul Traffic Specialization Department of the Council of Forensic Medicine.

MATERIAL AND METHODS

STUDY FIELD

According to the 2017 data of the Turkish Statistical Institute, the population of İstanbul was approximately 15 million people.[12] Moreover, İstanbul province has an area of approximately 5,461 square kilometers, bounded by the coordinates 41.09 norths and 29.42 easts. It is the most populated city in Türkiye with a total of 39 districts, which are fourteen on the Anatolian Side and 25 on the European Side.

DATA COLLECTION

In this study, the data were examined and reviewed based on the issued reports about the traffic accidents that occurred within the provincial borders of İstanbul in 2017 with the approval of the Forensic

Medicine Council dated March 5, 2019 and numbered 21589509/2019/119. Although the accidents that are the subject of this study occurred between 2005 and 2017, they were sent to the Forensic Medicine Council and reported in 2017 due to the length of legal processes and the inconsistency of forensic expert reports. The study was performed in accordance with the principles stated in the Declaration of Helsinki.

GIS ANALYSIS

Data sets were created by using Microsoft Office Excel program, taking into account particularly the spatial data, daylight conditions, time intervals, accident type and the characteristics of the accidents that issued in the reports. Thus, the created data sets were saved in Excel as a separate file with different variations depending on the criteria, and these criteria were stored to be evaluated as GIS supported.

Arc View GIS Version 10.6.1 program (Esri; Redlands, California) was used to evaluate the GIS data. The distribution of the accident cases were obtained on the İstanbul province map, whose report was issued by the relevant specialization office in İstanbul in 2017.

The evaluation of accident cases distributions was conducted according to day time intervals by dividing the day into 6 hour intervals (04.00-07.59; 08.00-11.59; 12.00-15.59, 16.00-19.59; 20.00-23.59, and 00.00-03.59). The situations such as starting time of working/school; rush hours; entertainment hours were taken into account. If there is no correlation between the 2 variables, aforementioned data set in the excel column is excluded.

RESULTS AND DISCUSSION

Based on the available data, traffic accidents were analyzed considering several variables including accident type, accident results, and time intervals (day/nighttime, time periods, day or month of the accident) on a district basis.

Traffic accident reports were issued with 11,162 files that were submitted to the court as a result of disagreement among the Türkiye in 2017, by the Council of Forensic Medicine, Traffic Specialization Department, and it was found that 1,568 accidents occurred within the provincial borders of İstanbul from these reports.

It is seen that 494 (32.39%) of the accidents occurred on the Anatolian Side and 1,031 (67.61%) occurred on the European Side. The accidents which have occurred on the European Side were found 2 times higher than in Anatolia Side as depicted Figure 1.

When the population of both sides has evaluated from Turkish Statistical Institute (TUIK) data in 2017, it was obviously seen that the population in European Side has doubled than in Anatolian Side.[12] It can be considered that this situation is influenced by the fact that the administrative buildings of official institutions are located more often on the European Side, and the residential area is more common besides population rates.[3]

According to the obtained data, it was possible to determine districts of 1,324 accident cases. The hotspots of accidents in 1,251 districts have demonstrated on İstanbul map (Figure 2). The districts with the highest number of accidents were found as Küçükçekmece with 89 accidents, Kadıköy and Esenyurt with 58 accidents. Küçükçekmece district seems to have doubled its closest followers. Çatalca and Şile districts were found as the fewest number of accidents.[7,8]

The number of accidents in Küçükçekmece was determined as 6.72% compared to the overall İstanbul. It is shown that the population ratio of this district was 5.12% in TUIK 2017, so it was the second district with the highest population.[12] D-100 State Highway and the E-80 Highway passes from the south and north of Küçükçekmece district respectively and could contribute to the increase of accidents.

The traffic load to be created by large housing projects, shopping malls and hospitals concentrated around these roads cause traffic density because the traffic load was not taken into account while they built.[2]

On the other hand, it is known that the population increase in parallel with the developing welfare level increases the demand for housing. It is not surprising that dense housing brings along the transportation problem. Although public transportation

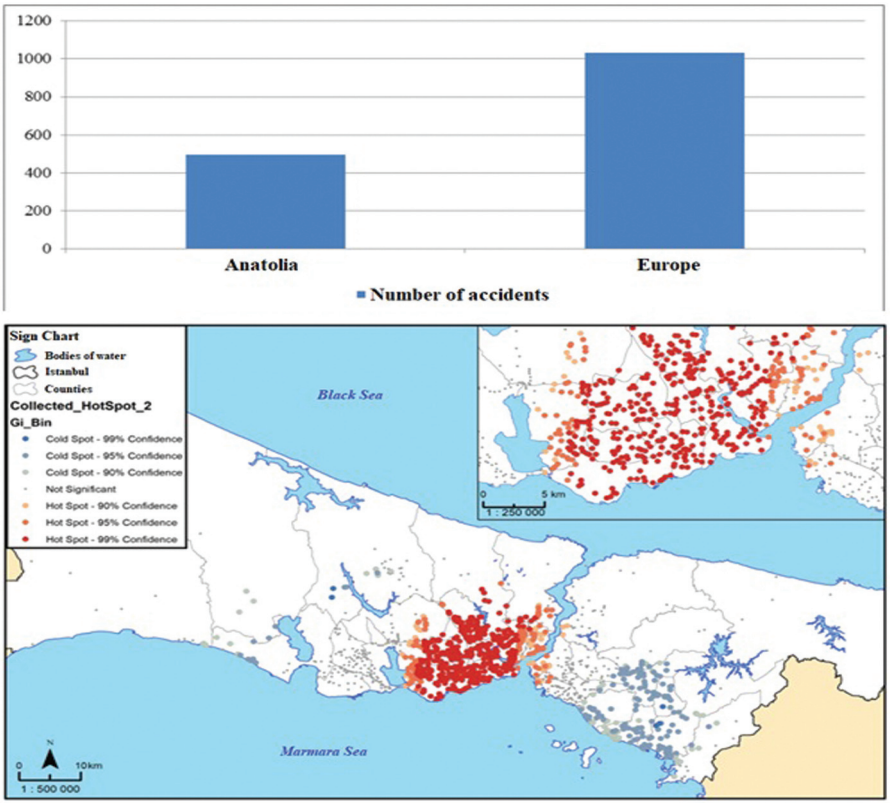

FIGURE 1: Display of accident numbers on the chart and map according to the region where the accident occurred.

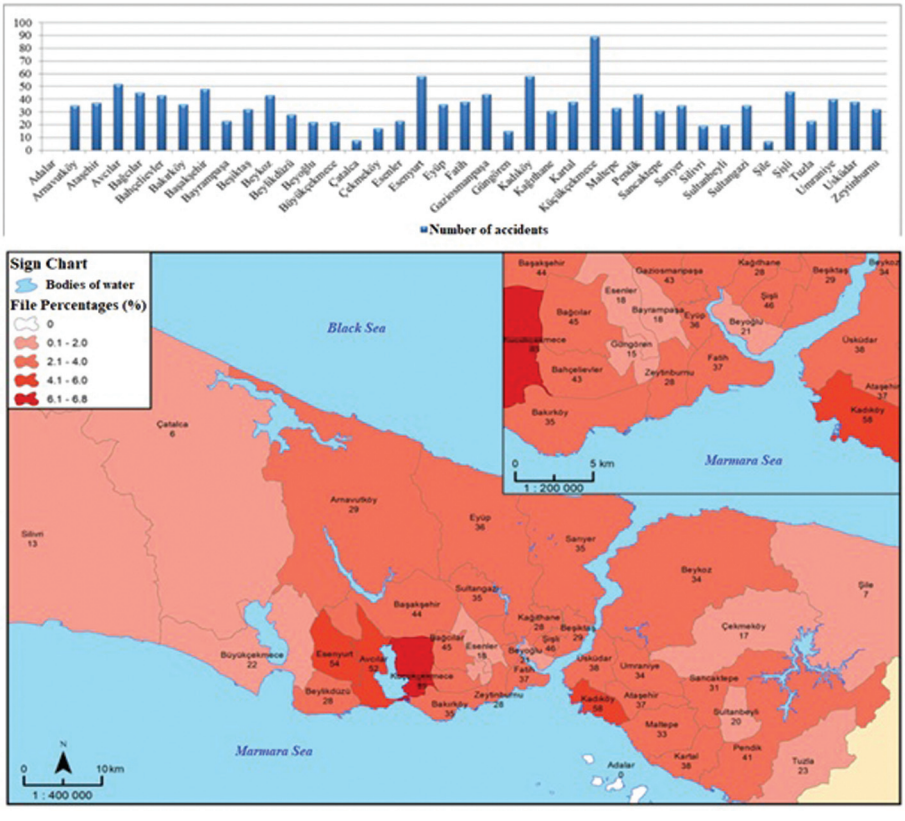

FIGURE 2: Graphic and map view of accident numbers by district.

projects such as metro, tram or metrobus partially solve the traffic problem, they cannot be effective in solving the problem completely.

It was determined that the highest number of accidents occurred in June (148 accidents-9.4%) and September (144 accidents-9.1%), the least number of accidents occurred in January (110 accidents-7.0%) and February (107 accidents-6.8%) according to monthly distribution of all cases.

This situation represents the beginning and end of summer, and for many people, it can be considered as a rush to go on a vacation and come back. It is also thought that the coinciding of Ramadan Feast and Eid al-Adha with these months in 2017 could also played a role. There was no difference between the days, either on weekdays or weekends according to the distribution of the accident day.

There are 2 distinguish studies related to day of the accidents. The first one, in Jordan, shows the majority of traffic accidents have occurred on thursdays, followed by sundays which represent the last and first working days respectively in Jordan. Another study in USA where most of fatal accidents occur in saturdays followed by fridays which represents the end of the week in US were many outdoor activates took place at these days.[13]

As a result of the hour intervals evaluation, it was found that the highest number of accidents occurred in the time zone of 16.00-19.59 with 415 accidents, and the least accident occurred in the time zone of 04.00-07.59 with 103 accidents. The distribution of the obtained statistical information by districts in terms of hour intervals is also shown in Figure 3 with a map.[14]

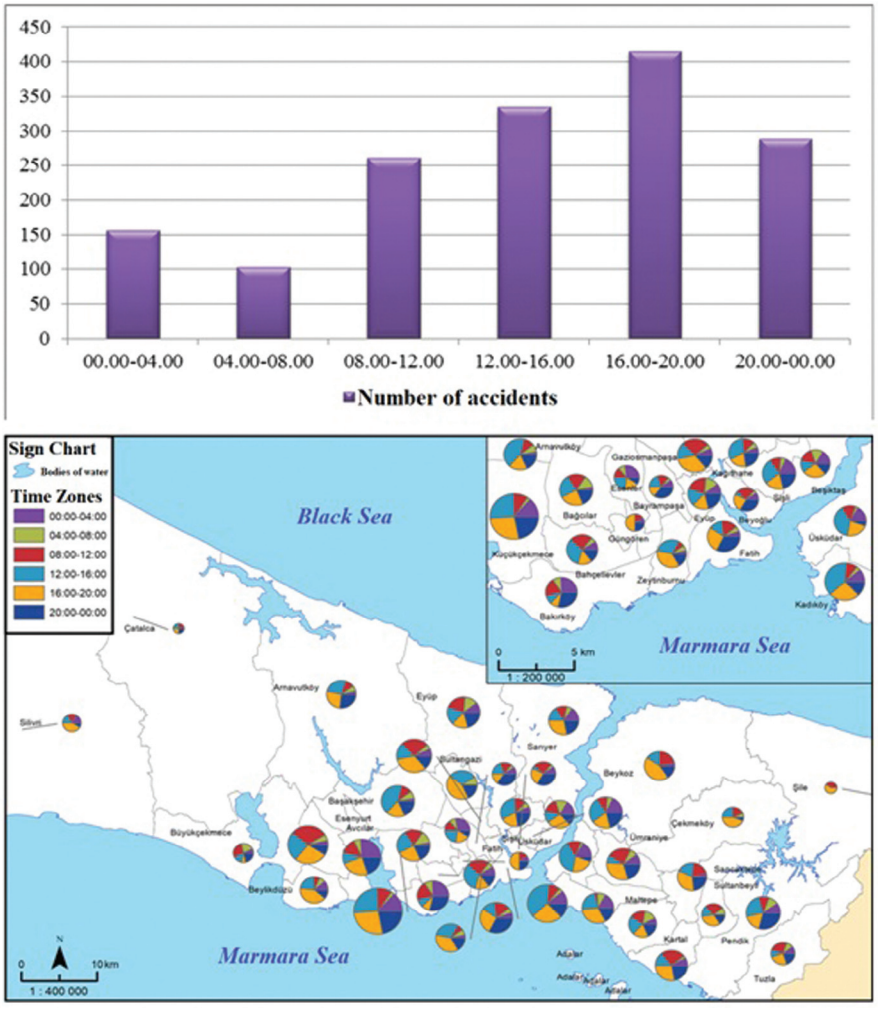

FIGURE 3: The view of the accident numbers on the graphic map according to the time zones in which the accident occurred.

It can be considered that the 16.00-19.59 hour interval covers the rush hours, whereas the 12.00-15.59 hour interval demonstrates intense transportation activities.

The related articles indicate that the largest numbers of traffic accidents have occurred during the time period 12.00-14.59 followed by the time period 15.00-17.59. This may be referred to the working end hours for schools and most of the public and private agencies. This is also compatible with data from other countries like USA where most of the fatal accidents occurred during the time period from 04.00 to 08.00 PM (end of the work day).[13-15]

Regarding the day and night differences, it was determined that 962 accidents (61.70%) occurred during the day, 547 (35.08%) at night, and 50 (3.21%) accidents occurred during sunset or sunrise, which is defined as twilight (Figure 4).

It has concluded that crash risk is higher for nighttime compared with others by related articles.[16,17] Especially time of day has also appeared to be associated with crash severity, as drivers are more likely to sustain a fatal injury due to nighttime crashes compared to daytime crashes, particularly among the younger age groups.[18,19]

According to the accident type, 672 (42.85%) cases were found as vehicle-vehicle accidents which were occurred in the form of collisions of two or more vehicles. The number of vehicle-pedestrian accidents occurring in the form of a vehicle hitting pedestrian(s) is 763 (48.66%) cases, and the number of vehicle-vehicle-pedestrian accidents occurring vehicles colliding with one or more pedestrians is 48 (3.06%) (Figure 5).

In addition, 27 (1.72%) cases have been determined as vehicle-passenger accidents that occur in the form of a passenger falling inside or outside the vehicle during driving.

It was found that the number of single vehicle accidents occurring in the form of hitting an object, going off the road, or overturning was 58 (3.70%). It has been observed that the location information (hotspot) of 317 accident cases were not suitable for detecting on the map.

Another study from USA has taken into account 5 situations such as side impact collisions, crashing during merging, rear-end accidents, head-on crashes, multi-vehicle collisions for types of road accidents.[20] It was concluded that type of side-impact collision called T-bone crash were common. In this type, one

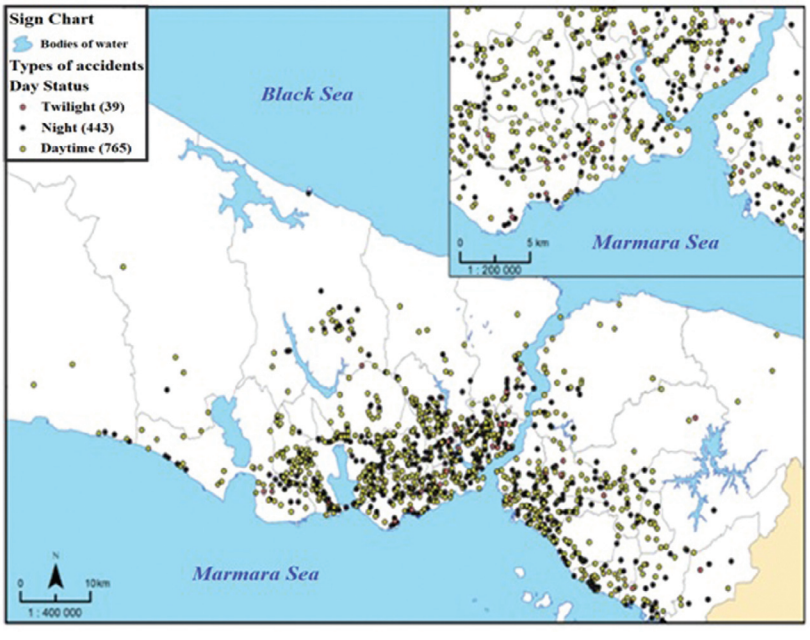

FIGURE 4: The view of the accident numbers on the chart and map according to daylight factor.

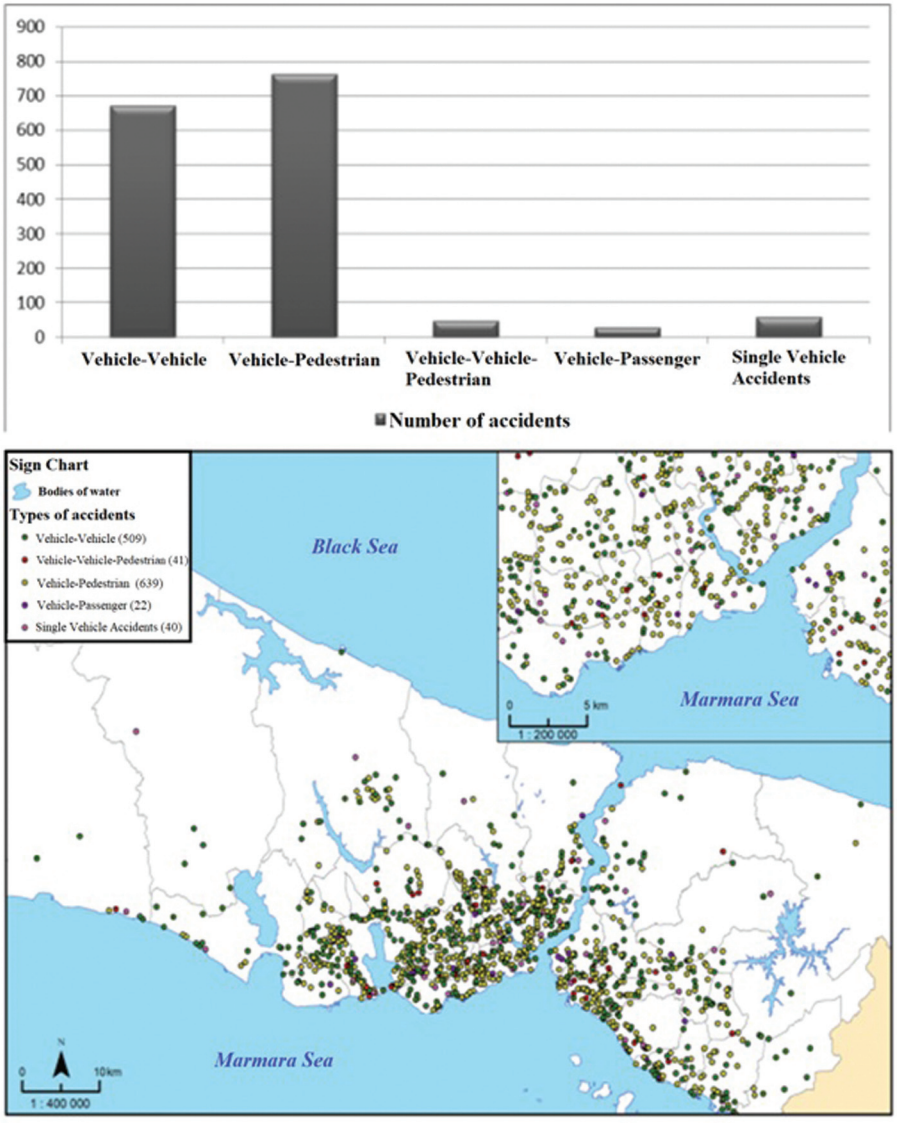

FIGURE 5: Graphical and map view of accident numbers by accident type.

vehicle perpendicularly impacts the side of another vehicle. These collisions are generally caused by drivers attempting to merge, because they fail to check their blind spots as they are changing lanes.

The rear-end collisions are the most frequent type of collision that occurs on U.S. roads, making up %29 of all accidents. These crashes often occur because one car follows another too closely, known as tailgating.[21]

Single vehicle crashes; these types of crashes include running off the road, slipping on ice and spinning out of control, hitting stationary objects, and many other situations.

Besides, low speed impact crashes may not be the worst, but they can still do damage. These fender-benders, bumps, parking lot collisions, and other crashes under the speed of 10 miles per hour can often happen in parking lots and residential areas, risking pedestrian lives.[22]

According to evaluation of the accident results, it was determined that 438 of the (30.43%) cases were fatal, 923 of them were injuries (64.15%) and

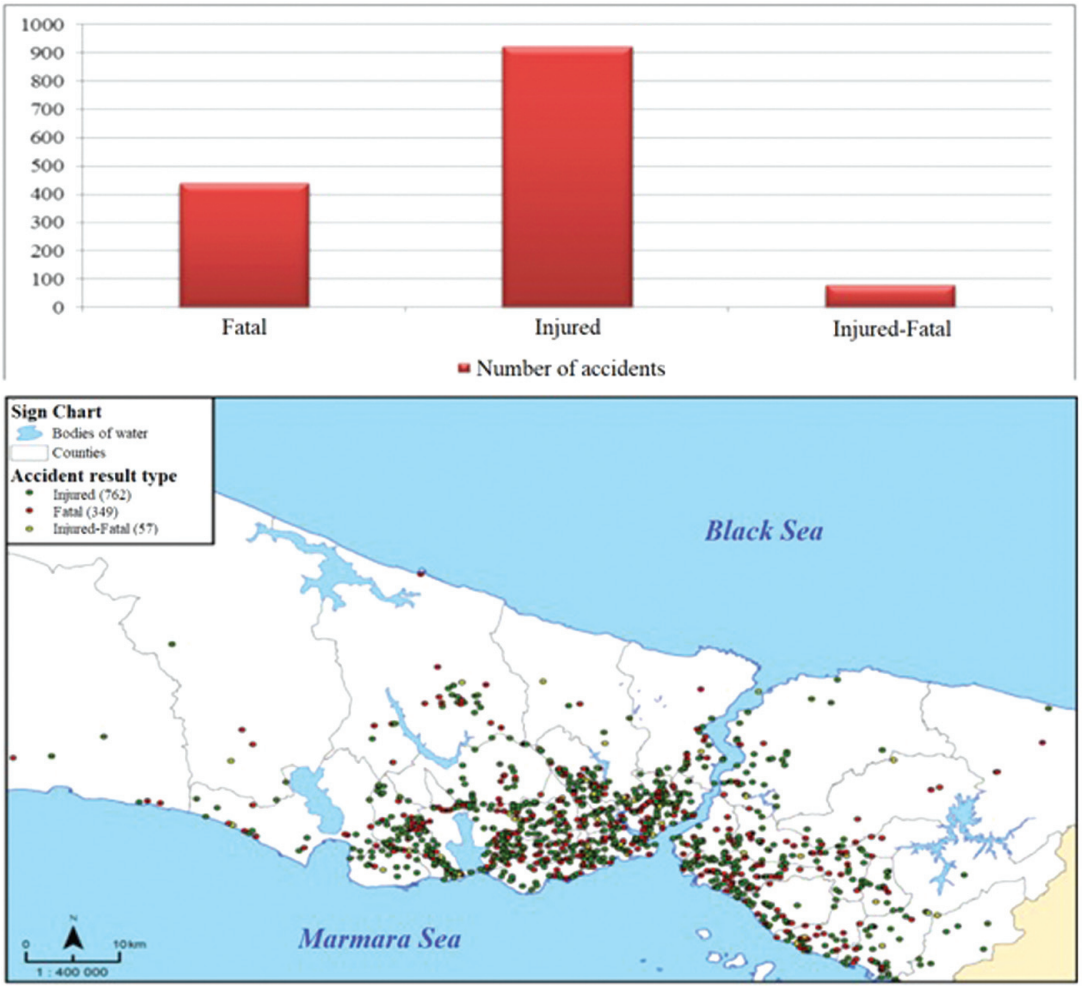

FIGURE 6: Graphical and map view of accident numbers according to accident results.

5.42% of them were death and injury occurred together (Figure 6).

In the evaluation of fatal accidents distribution by districts, Küçükçekmece ranks first with 21 accidents, followed by Kadıköy with 20 accidents, Esenyurt, Avcılar and Ataşehir districts with 14 accidents, respectively, and Çatalca and in Şile district with 3 accidents have the least number of accidents cases (Figure 7).

It is seen that Küçükçekmece ranks first with 58 injured accidents in the determined locations, followed by Esenyurt with 3 accidents, Kadıköy and Avcılar with 35 accidents. The least injuries occurred in Çatalca and Şile with 3 accidents each, followed by Silivri with 4 accidents and Çekmeköy with 5 accidents (Figure 8).

There are similar studies in this field with GIS in our country. In a recent and very similar study, 3,105 fatal or injured traffic accidents between 2010-2017 in Sarıyer district of İstanbul, Türkiye's largest city in terms of population, were discussed.[23]

Another study, which was conducted the most intense tourism city, Antalya, data on traffic accidents that resulted in death and injury in the city center between 2009 and 2010 were examined and analysis data were processed using World View satellite image and ArcGIS10 software (Esri; Redlands, California). According to these data, hotspots were detected at 41 junction points in 2009 and 57 in 2010.[24]

In another study, it is concluded that a significant number of hotspots were determined mostly at

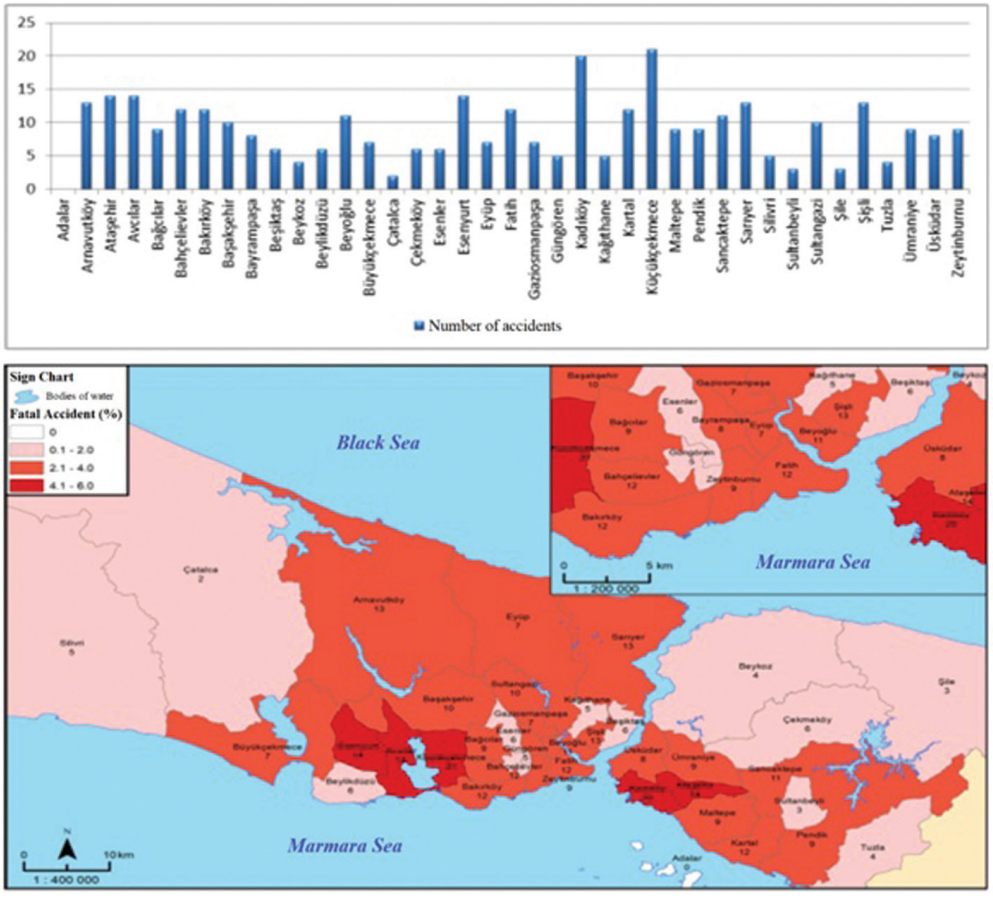

FIGURE 7: Graphic and map view of the distribution of fatal accidents by districts.

the intersection or 100 m away from the intersections in the settlement of Ankara (in the urban area), and these areas were marked risky for pedestrians.[25]

In a similar study, Afyon province, which is at a cross roads of both Antalya and İzmir ports and has a critical temperature drop in winter, was analyzed by GIS. It has been found that fatal accidents occur frequently in the summer months data recovering a 10-year period between 1996 and 2006.[10]

According to the accident statistics covering the years 2008-2017, organized by the General Directorate of Highways together with TUIK and General Directorate of Security, it is seen that there has been a 25% increase in the total number of accidents within 10 years, while the number of fatal and injury accidents has increased by 75%.[8]

Finally, although the data obtained in this study are limited due to the fact that the accidents spread over a wide period of time are based on their reports produced in 2017; the results are considered to be significant because it is a provincial-wide study conducted in a city like İstanbul, which is very crowded and has a high accident rate. Considering the limitations of the study, some solutions were proposed according to the results obtained by evaluating the hot spots and changing factors in order to reduce the number of traffic accidents in İstanbul. It is anticipated that this preliminary study will lead to many other studies in this field of legal medicine and traffic safety.

CONCLUSION

Based on the investigated traffic accidents data over one-year period of İstanbul, which is the most popu-

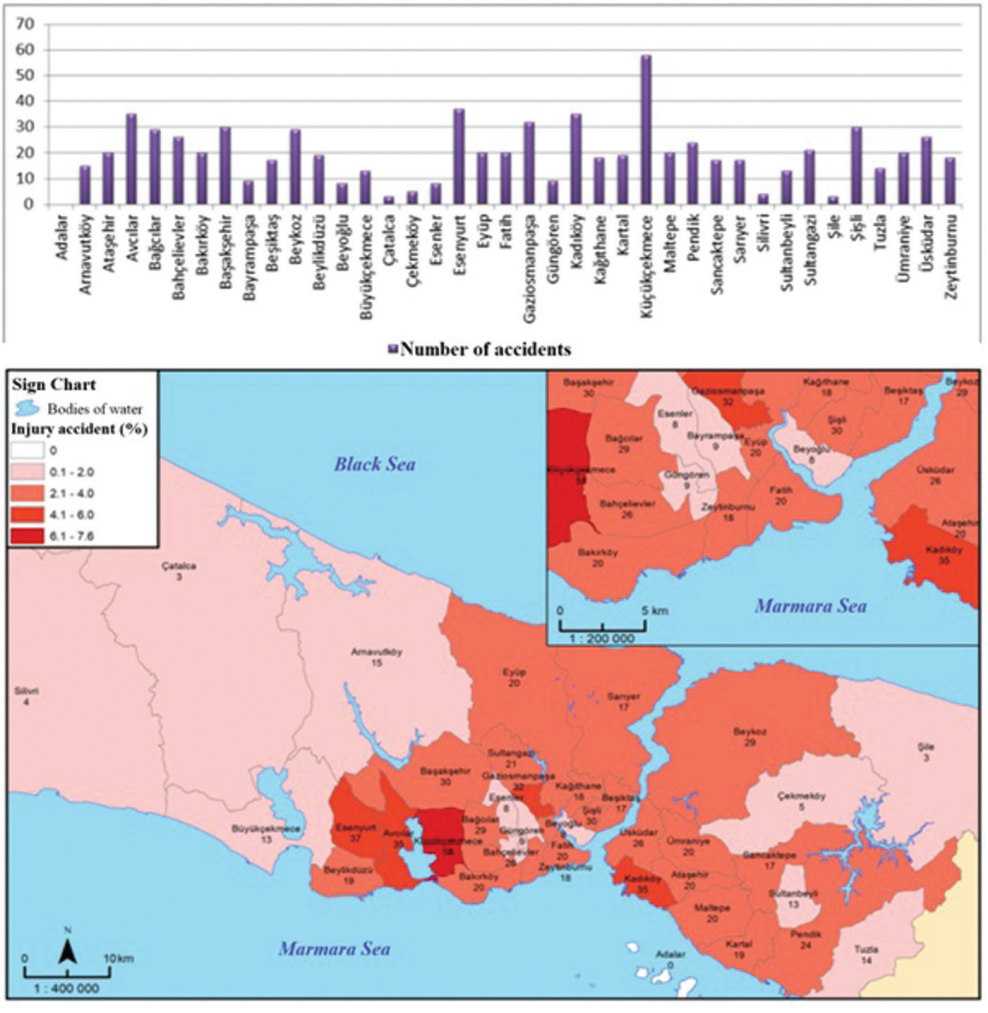

FIGURE 8: Graphic and map view of the distribution of injured accidents by districts.

lated city in Europe, the following conclusions can be drawn:

1. It has been observed that traffic accidents on the European Side are twice as high as on the Anatolian Side.

2. Küçükçekmece district was the highest number of accident in both fatal and injured.

3. The majority of traffic accidents have occurred at the 16.00-19.59 interval hours, which is compatible with other international studies.

4. The negative effects of religious holidays, which last long, on traffic were once again revealed in this study.

5. As a result of the data analyzes on a monthly basis, it has been concluded that traffic controls should be increased for the beginning and end of summer season (June and September) in the city.

6. The majority of traffic accidents have occurred in daylight, so this data is not compatible with other related studies which were concluded that crash risk is higher for nighttime.

7. It has been concluded that Kadıköy district, since especially the Moda region has grid road type (t-bone strike), has the second highest number of fatal accidents in traffic accidents.

8. Küçükçekmece and Esenyurt districts, which adjacent to both sides of the lake, were ranks on the top with injured accident cases. It is concluded that this situation is related with demand for space on the road is higher than the current capacity.

9. While approving new mass housing projects, it should be taken into account that the traffic problem in the region will increase in case of private vehicle use.

Further research on this topic is necessary to have a strong conclusion of the above findings. This study results have to be updated by recent traffic accidents data, so more accurate accidents prediction models may be well developed. This study is a pilot study for the adoption of more effective strategies, policies and measures to improve general traffic safety within the framework of forensic sciences, and also provides a different research infrastructure in which the capability of the GIS tool can be evaluated.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Zeynep Türkmen, Ahmet Özgür Doğru;* ***Design:*** *Emre Kayabaşı, Zeynep Türkmen, Ahmet Özgür Doğru;* ***Control/Supervision:*** *Zeynep Türkmen, Ahmet Özgür Doğru;* ***Data Collection and/or Processing:*** *Emre Kayabaşı, Ahmet Özgür Doğru;* ***Analysis and/or Interpretation:*** *Emre Kayabaşı, Ahmet Özgür Doğru;* ***Literature Review:*** *Zeynep Türkmen, Emre Kayabaşı; Writing the Article: Zeynep Türkmen, Emre Kayabaşı, Ahmet Özgür Doğru;* ***Critical Review:*** *Faruk Aşocıoğlu, Hızır Aslıyüksek;* ***References and Fundings:*** *Zeynep Türkmen, Emre Kayabaşı.*

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