Research Article

Investigation of traffic accidents in Şişli district with geographic information systems

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Abstract: Traffic accidents occurring are one of the most important issues that cause loss of life and property of the people. With the increasing population, the number of vehicles increasing in use creates traffic density. For this reason, studies aimed at reducing traffic accidents are of vital importance. In this study, a total of 3833 fatal and injured traffic accidents that occurred between 2010-2017 in Şişli district were analyzed with the help of geographical information systems and Kernel density method. In this study, various maps were created according to the accident type, time zone and the type of vehicles that had the most accident, and the locations of the accidents were examined. It is aimed to help reduce the number of possible accidents by taking necessary precautions in locations that are determined to be risky according to the accident intensities obtained. It has been observed that the accidents intensify differently according to the changing time zones, especially on the streets. In the study, it is also aimed to help the units that make traffic planning by making separator maps of the types of vehicles that have the most accidents on these streets, according to the accident types, days of the week and time zones.

Keywords: Traffic accidents, accident analysis, geographic information systems, Kernel density method

Şişli ilçesindeki trafik kazalarının coğrafi bilgi sistemleri ile incelenmesi

Özet: Trafik kazaları, insanların can ve mal kaybına neden olan en önemli konulardan biridir. Artan nüfusla birlikte kullanımı artan araç sayısı beraberinde trafik yoğunluğunu meydana getirmektedir. Bu nedenle trafik kazalarını azaltmaya yönelik çalışmalar hayati önem taşımaktadır. Bu çalışmada Şişli ilçesindeki 2010-2017 yılları arasında meydana gelmiş toplam 3833 ölümlü ve yaralanmalı trafik kazası coğrafi bilgi sistemleri ve çekirdek yoğunluk yöntemi yardımıyla analiz edilmiştir. Bu çalışma ile kaza türü, saat dilimi ve en çok kaza yapan araç türlerine göre çeşitli haritalar oluşturularak kazaların oluş lokasyonları incelenmiştir. Elde edilen kaza yoğunluklarına göre riskli olduğu tespit edilen lokasyonlarda gerekli önlemler alınarak olabilecek kaza sayılarının azaltılmasında yardımcı olmak amaçlanmıştır. Özellikle caddelerde değişen saat dilimlerine göre kazaların farklı olarak yoğunlaştığı görülmüştür. Çalışmada ayrıca bu caddelerde en çok kaza yapan araç cinslerinin kaza oluş türleri, haftanın günleri ve saat dilimlerine göre ayrıştırıcı haritaları yapılarak trafik planlaması yapan birimlere yardımcı olunması amaçlanmıştır.

Anahtar Kelimeler: Trafik kazaları, kaza analizi, coğrafi bilgi sistemleri, çekirdek yoğunluk yöntemi

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1. Introduction

The fact that traffic accidents are not known in advance where and when they will occur makes it necessary for accident analysis studies to be based on statistical data. In today's world where science and technology are developing rapidly, the prevalence of the use of geographic information systems, which provide the management and presentation of map-based information, is increasing rapidly and its importance is better understood. The most important convenience brought by geographic information systems regarding traffic accidents is the easier detection of areas (black spots) where accidents occur frequently (Erdoğan et al., 2008). The determination of these points is done by "accident mapping". Making visual maps of accidents helps people who have never visited the relevant area before to have information about the subject. Spatial analysis of traffic accidents provides decision-makers with simple, understandable and guiding visual information at important accident points where traffic safety must be ensured (Kaygısız et al., 2012).

In a study conducted with spatial analysis, it is very important to determine the locations of the events under investigation and to reveal the relationship between these events (Ersen et al., 2021; Xie and Yan, 2008; Tuncuk, 2004). With the help of the results found as a result of the application of geographical information systems, which are a powerful technological tool, traffic accidents can be examined (Saplıoğlu and Karaşahin, 2006; Söylemezoğlu, 2006; Özmal, 2016). Kernel density method is used to determine the places where the accident points are spatially dense and to evaluate the spatial clustering at these black points (Dereli and Erdoğan, 2017; Karaman, 2013).

Although the measures taken regarding traffic accidents are not the same everywhere, they do not lead to the same result everywhere (Bil et al., 2013). For this reason, in order to develop effective road safety measures to reduce traffic accidents, it is necessary to identify the areas where accidents are frequently experienced (black spots). It is extremely important to analyze the causes of similar accidents that occur in the same location in order to ensure the safety of people in traffic and to prevent accidents (Mohaymany et al., 2013).

In this study, in order to examine the fatal and injury traffic accidents, the Şişli district of Istanbul was taken into consideration and maps were prepared according to the accident type, time zone and the type of vehicle that had the most accidents. In the study, first of all, the Kernel density method map was given, with the occurrence types of the accidents in Şişli district added. With this map, the streets with the most traffic accidents in this district and the types of accidents were determined. Then, it is aimed to make a separate map of the types of accidents where the most accidents occur and to make solutions according to the causes of the accidents and the black points where they occur. Also, in order to obtain a planned transportation policy, accidents were analyzed according to time zones. In addition, the accidents made by the most accidental vehicle types are examined according to the types of accidents, days and time zones and it is aimed to help the units that will regulate traffic.

2. Materials and methods

In this study, temporal and spatial analyses of traffic accidents were performed with the help of the results obtained as a result of the application of geographic information systems technology. Kernel density method was used to determine the places where the accident points are spatially dense and to evaluate the spatial clustering at these black points.

2.1. Kernel density method

In the Kernel density method, a circular area is drawn around each point in the sample, not on each cell. A mathematical function is then applied that moves from 1 to 0 from the place where the point is located to the boundary of the circular field (Atalay and Say, 2022). In Figure 1, an example of the implementation of Kernel density estimation for a study area is given.

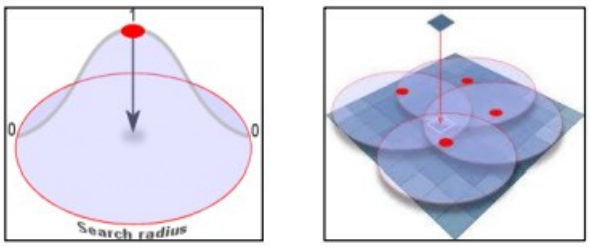

Figure 1. Kernel density estimation method (Atalay and Say, 2022).

The Kernel density estimation method is performed by weighting the accident intensities in a defined impact area. The accident intensity values in the cells in the entire study area are calculated by considering cells of a certain size in the study area. In this type of analysis, it is possible to analyse the accidents by giving weight points (Xie and Yan, 2013).

Kernel density is involved in spatial analysis studies within geographic information systems. This method gives illuminating information for the determination of hot spot or cold spot regions. Kernel density analysis refers to the density of the points falling into the circle with a defined radius and the point density that changes as they move away from this source (Thakali et al., 2015).

2.2. Kernel estimator

The series $(x_1, x_2, ...x_n)$ is allowed to be an independent and uniformly distributed sample of n observations from a population X whose probability distribution function f (x) is unknown. The Kernel estimate of the original f(x) f^(x) assigns to each i'th sample data point a function K(x, t), called the Kernel function. Its mathematical representation is given in equation 1 (Atalay and Say, 2022).

$$\hat{f}(t) = \frac{1}{n}\sum_{i=1}^{n} K(x_i, t) \tag{1}$$

K(x, t) is not negative and is bounded for all x and t: $0 \leq K(x, t) < \infty$ for all real x, t and for all real x as shown in equation 2 (Atalay and Say, 2022).

$$\int_{-\infty}^{\infty} K(x,t)dt = 1 \tag{2}$$

Equation (3) normalizes the Kernel density estimate to Equation (2):

$$\begin{aligned}\int_{-\infty}^{\infty} \hat{f}(t)dt &= \frac{1}{n}\sum_{i=1}^{n}\int_{-\infty}^{\infty} K(x_i,t)\,dt = 1\ K(t) \\ &= f(x) \\ &= \begin{cases}\dfrac{15}{16} & for\,|t|<1 \\ 0 & for\,|t|>1\end{cases}\end{aligned} \tag{3}$$

In other words, the Kernel transforms the "sharp" (point) position of x_i into an interval (symmetrically or unsymmetrically) centered around x_i. This transformation is given in equation 3. The formula used to determine the search radius, also known as the bandwidth, is explained in equation 4 (Atalay and Say, 2022):

$$h = 0.9 * \min(SD, \sqrt{\frac{1}{In(2)}} * D_m) n^{-2} \quad (4)$$

In equation (4); h is bandwidth, D_m is weighted average; is the weighted median distance from the center. Also, n is the number of points when the population field is not used or a population field is provided, and n is the sum of the population field values. SD is the standard distance (Atalay and Say, 2022).

The smaller of the $(\sqrt{\frac{1}{In(2)}} * D_m)$ value in the equation and the SD value is used.

$$SD_W = \sqrt{\frac{\sum_{i=1}^{n} w_i (x_i - \bar{X}_i)^2}{\sum_{i=1}^{n} w_i} + \frac{\sum_{i=1}^{n} w_i (Y_i - \bar{Y})^2}{\sum_{i=1}^{n} w_i} + \frac{\sum_{i=1}^{n} w_i (Z_i - \bar{Z}_i)^2}{\sum_{i=1}^{n} w_i}} \quad (5)$$

In equation (5), wi is the weight in the feature i.{ x w , y w , z w } represents the weighted average center (Atalay and Say, 2022).

In this study, accident point map was produced on a digital map by using accident location information. With the help of spatial analysis tools in ArcGIS/ArcMap software, Kernel density method analysis was applied and the sections where the accidents were intense were determined.

3. Results

In this study, Şişli district, which is known to have a high number of fatal and injury accidents, was examined with the help of geographic information systems and Kernel density method. It is aimed to offer solutions to the points where the accidents are intense by creating separation maps according to the accident type, time zone and the type of vehicle that has the most accidents. In addition, it has been tried to help the traffic problem for Şişli to some extent by creating separator maps according to the accident type, days of the week and time zone for the types of vehicles that have the most accidents. The variables used in this study are given in Table 1.

Table 1. Variables used in accident data

Variable Name	Coding	Value Names
Accident Day	AD	AD1 (Monday), AD2 (Tuesday), AD3 (Wednesday), AD4 (Thursday), AD5 (Friday), AD6 (Saturday), AD7 (Sunday)
Accident Time Zone	ATZ	ATZ1 (00:00-04:00), ATZ2 (04:00-08:00), ATZ3 (08:00-12:00), ATZ4 (12:00-16:00), ATZ5 (16:00-20:00), ATZ6 (20:00-24:00)

Table 1 (continued). Variables used in accident data

Accident Type	AT	AT1 (Head on collision), AT2 (Rear impact collision), AT3 (side impact collision), AT4 (side to side collision), AT5 (hitting a stationary vehicle), AT6 (multiple vehicle collision), AT7 (multiple hitting), AT8 (hitting fixed objects), AT9 (hitting pedestrian), AT10 (animal impact), AT11 (vehicle's rolling over), AT12 (run off road), AT13 (falls from vehicles)
Vehicle Type	VT	VT1 (bicycle), VT2 (moped), VT3 (motorcycle), VT4 (automobile), VT5 (minibus), VT6 (pickup truck), VT7 (truck), VT8 (towing vehicle), VT9 (bus), VT10 (tractor), VT11 (land vehicle), VT12 (special purpose vehicles), VT13 (heavy duty vehicles), VT14 (ambulance), VT15 (tanker), VT16 (tram), VT17 (other)

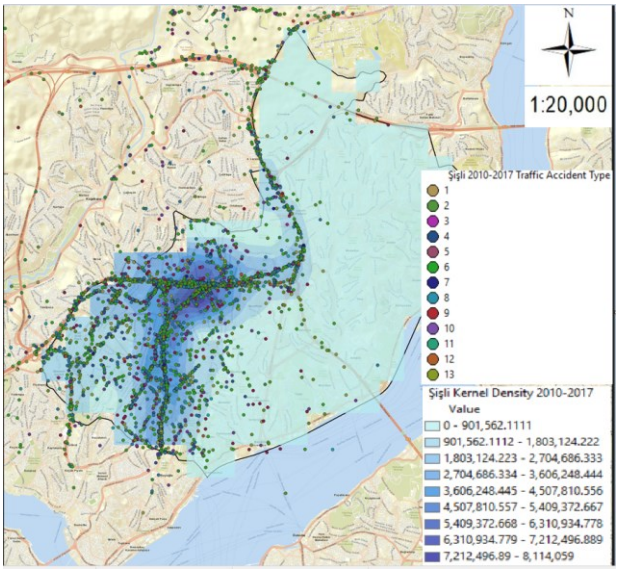

Figure 2. Kernel density method map of traffic accidents occurred in Şişli district.

In Figure 2, when the types of accidents for all accidents between 2010 and 2017 in Şişli district were added and the Kernel density method map was examined, it was seen that the streets where the accidents were high were Büyükdere, Halaskargazi and Cumhuriyet streets. When we examine these accidents according to the types of accidents, it is seen that the most accidents are in the form of side-impact collisions, followed by hitting pedestrian and rear impact collisions. Where side impact collision, pedestrian collision and rear impact collision are more common, are analyzed with detailed

maps made in Figure 3, Figure 4 and Figure 5. The meaning of the accident type label values in these accidents is the label values between 1 and 13 in Table 1.

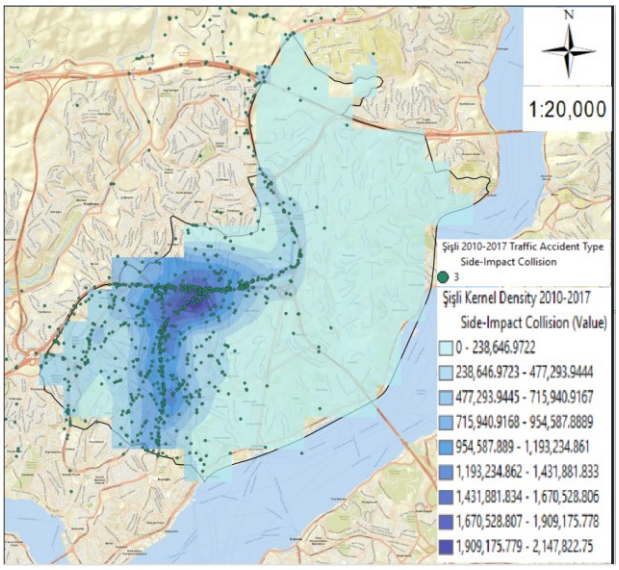

Figure 3. Kernel density method map of traffic accidents in the form of side-impact collision in Şişli district.

In Figure 3, the Kernel density method map of the accidents in the form of a side impact collision in Şişli district is given. It has been observed that the accidents that occur in the form of side impacts are mostly on Cumhuriyet and Büyükdere streets. It has been concluded that accidents in the form of side-impact collisions are high in areas where there are event areas such as congress and theater on Cumhuriyet Street. On the other hand, Büyükdere Street is a region that is heavily used by large masses due to its business centers, shopping malls and public transportation transfer areas. For this reason, it has been found that accidents in the form of side collisions are high, especially in the region where there is heavy vehicle traffic, especially in the area of the Ortaklar junction.

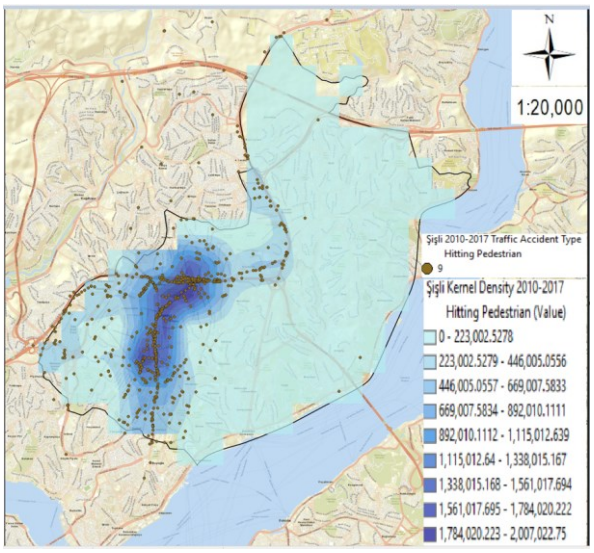

Figure 4. Kernel density method map of traffic accidents in the form of hitting pedestrian in Şişli district.

In Figure 4, the Kernel density method map of the pedestrian crashes in Şişli district is given. It has been observed that most of the accidents that occur in the form of hitting the pedestrian are on Halaskargazi Street. It is thought that the pedestrian lines on the streets leading to Şişli Hamidiye Etfal

Training and Research Hospital on Halaskargazi Street are faulty and this situation causes a high number of pedestrian crashes.

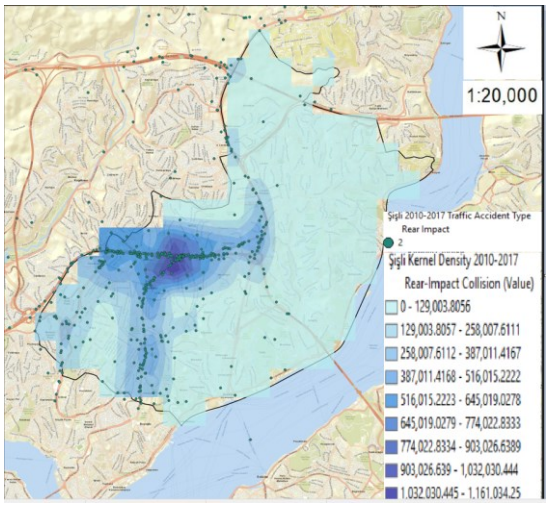

Figure 5. Kernel density method map of traffic accidents in the form of rear impact collision in Şişli district.

In Figure 5, the Kernel density method map of accidents in the form of a rear impact collision in Şişli district is given. It has been observed that most of the accidents in the form of rear impact collisions occur on Cumhuriyet Street. It has been found that accidents in the form of rear impact collisions are high in this region, especially at the points where the activity areas are high.

By adding the accident types given in Table 1 to the Kernel density method maps (Figure 6, Figure 7, Figure 8, Figure 9, Figure 10 and Figure 11) obtained according to time periods, it has been tried to determine which types of accidents are more common in the places where the accidents are concentrated according to the time periods. The label color representations of accident types have been changed in some time periods because of the fact that the colors cannot be seen clearly due to the differences in the locations where the accidents occur.

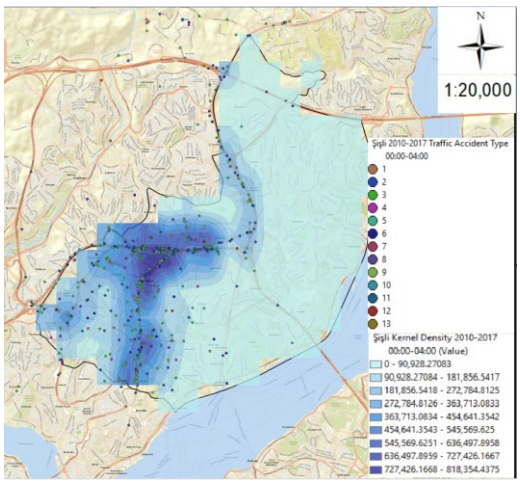

Figure 6. Kernel density method map of traffic accidents occurred between 00:00-04:00 time zones in Şişli district.

In Figure 6, Kernel density method map of traffic accidents occurred between 00:00-04:00 time zones in Şişli district is given. It was observed that the accidents that occurred between 00:00-04:00 were concentrated in Halaskargazi, Abidei Hürriyet, Mecidiyeköy Road, Center, Piyalepaşa Boulevard, Sıracevizler, Büyükdere, Cendere, Cumhuriyet and Darülaceze streets. In the accidents that occurred between 00:00 and 04:00, it was concluded that the accidents in the form of a side impact collision in

Halaskargazi, Abidei Hürriyet, Mecidiyeköy Road, Center, Büyükdere and Cumhuriyet streets, hitting fixed objects in Sıracevizler Street and hitting a stationary vehicle on Cendere Street were high. On the other hand, in the accidents between 00:00 and 04:00, it was observed that there were equally most accidents in the form of side impact collision and hitting fixed objects on Piyalepaşa Boulevard. On Darülaceze Street, it was seen that there were more accidents in the form of a side impact collision, hitting a stationary vehicle, hitting fixed objects and hitting pedestrian.

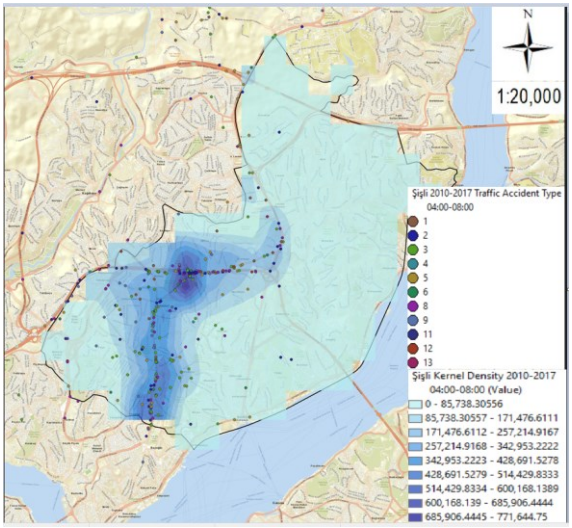

Figure 7. Kernel density method map of traffic accidents occurred between 04:00-08:00 time zones in Şişli district.

In Figure 7, Kernel density method map of traffic accidents occurred between 04:00-08:00 time zones in Şişli district is given. It has been observed that there are no accidents in the form of multiple collisions and animal strikes between 04:00 and 08:00, and the accidents are concentrated in Halaskargazi, Abidei Hürriyet, Piyalepaşa Boulevard, Tem Connection Road, Ayazağa, Büyükdere, Cendere, Cumhuriyet and Darülaceze streets. It has been observed that accidents such as side collisions on Halaskargazi, Abidei Hürriyet, Ayazağa, Büyükdere and Cumhuriyet streets, hitting fixed objects and hitting a vehicle on Piyalepaşa Boulevard are more common. Accidents occurred to the vehicle standing on the TEM Connection Road and the pedestrian crash on the Darülaceze Street. In addition, it was observed that side collisions and collisions with a stationary vehicle were equally common on Cendere Street.

In Figure 8, Kernel density method map of traffic accidents occurred between 08:00-12:00 time zones in Şişli district is given. It was found that the accidents that occurred between 08:00-12:00 were concentrated in Halaskargazi, Abidei Hürriyet, Kadırgalar, Mecidiyeköy Road, Piyalepaşa Boulevard, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze, Dereboyu, Dolapdere and Ergenekon streets. In accidents between 08:00-12:00, hitting pedestrian on Halaskargazi, Abidei Hürriyet, Mecidiyeköy Road, Darülaceze and Ergenekon streets, side impact collision on Kadırgalar, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Dereboyu and Dolapdere streets, rear impact collision on Piyalepaşa Boulevard and it has been found that accidents in the form of multiple hitting are high in Governor's Mansion Street.

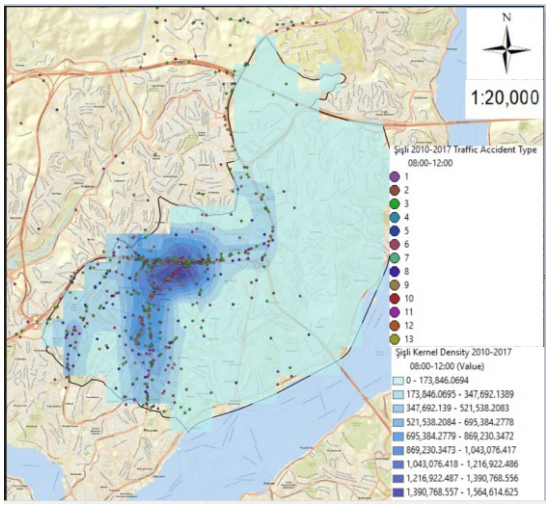

Figure 8. Kernel density method map of traffic accidents occurred between 08:00-12:00 time zones in Şişli district.

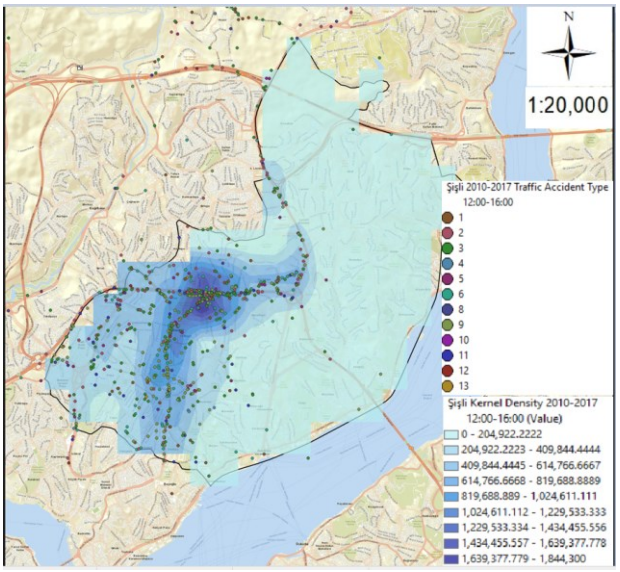

Figure 9. Kernel density method map of traffic accidents occurred between 12:00-16:00 time zones in Şişli district.

In Figure 9, Kernel density method map of traffic accidents occurred between 12:00-16:00 time zones in Şişli district is given. It was seen that there were no accidents in the form of multiple hitting's in the accidents between these hours. It has been concluded that the accidents between 12:00- 16:00 are concentrated on Halaskargazi, Abidei Hürriyet, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet and Darülaceze streets. In the accidents that took place between 12:00-16:00, it was seen that there were more accidents such as hitting pedestrian in Halaskargazi, Abidei Hürriyet and Center streets, side impact collision on Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet and Darülaceze streets, multiple vehicle collision on Ortaklar Street and run off road on Piyalepaşa Boulevard. In addition, between 12:00-16:00, it was found that there were more accidents in the form of side impact collision, multiple vehicle collision and hitting pedestrian equally in Kurtuluş Street and in the form of rear impact and hitting pedestrian equally on Mecidiyeköy Road Street.

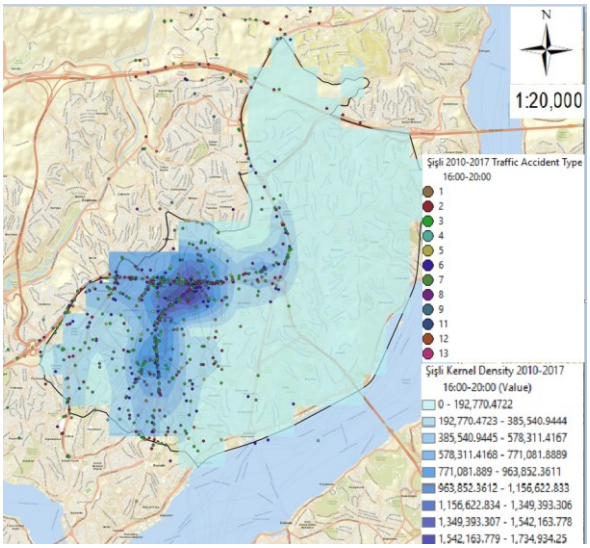

Figure 10. Kernel density method map of traffic accidents occurred between 16:00-20:00 time zones in Şişli district.

In Figure 10, Kernel density method map of traffic accidents occurred between 16:00-20:00 time zones in Şişli district is given. It was seen that there were no accidents in the form of animal impact in the accidents between these hours. It was observed that the accidents between 16:00-20:00 were concentrated in Hakkıyeten, Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Governor's Mansion, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze, Dereboyu and Ergenekon streets. In the accidents that took place between 16:00-20:00, it was seen that there were more accidents in the form of hitting pedestrian in Halaskargazi, Kurtuluş, Mecidiyeköy Road, Center and Büyükdere streets, in the form of side impact collision in Abidei Hürriyet, Kadırgalar, Piyalepaşa Boulevard, Governor's Mansion, Ayazağa, Darülaceze and Dereboyu streets and in the form of multiple vehicle collision on Cumhuriyet Street. In addition, between 16:00-20:00, it was observed that there were more accidents in the form of head on collision and rear impact collision equally on Hakkıyeten Street, side impact collision and multiple vehicle collision equally on Ortaklar Street and side impact collision and hitting pedestrian equally on Ergenekon Street.

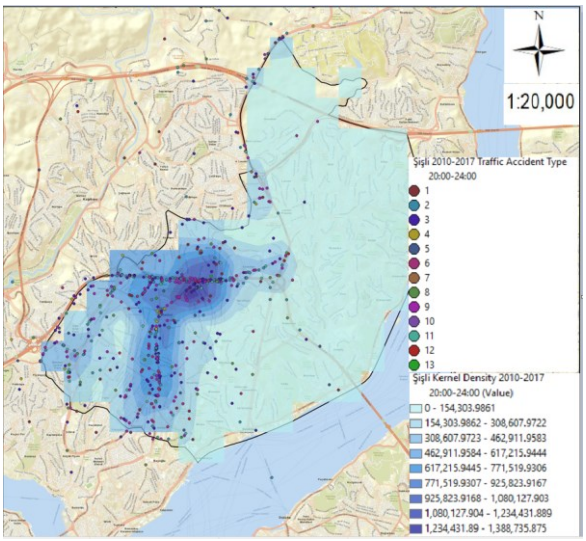

Figure 11. Kernel density method map of traffic accidents occurred between 20:00-24:00 time zones in Şişli district.

In Figure 11, Kernel density method map of traffic accidents occurred between 20:00-24:00 time zones in Şişli district is given. It was concluded that the accidents between 20:00-24:00 were

concentrated in Halaskargazi, Abidei Hürriyet, Hasret, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Martyr Ertuğrul Kabataş, Talatpaşa, Taşkışla, Büyükdere, Cumhuriyet, Darülaceze, Dereboyu and Dolapdere streets. In the accidents that occurred between 20:00-24:00, it was found that there were more accidents in the form of side impact collision in Halaskargazi, Abidei Hürriyet, Ortaklar, Martyr Ertuğrul Kabataş and Dereboyu streets, in the form of hitting pedestrian in Kurtuluş, Mecidiyeköy Road, Center, Taşkışla, Büyükdere and Darülaceze streets, in the form of rear impact collision in Hasret and Piyalepaşa Boulevard streets and multiple vehicle collision in Cumhuriyet Street. In addition, between 20:00- 24:00, it was observed that there were more accidents in the form of head on collision, rear impact collision and hitting pedestrian equally on Talatpaşa Street and head on collision and side impact collision equally on Dolapdere Street.

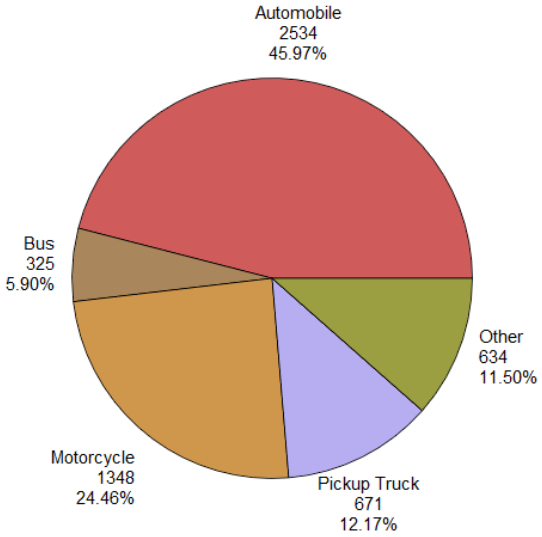

Figure 12. Pie chart of traffic accidents in Şişli district by vehicle type.

In Figure 12, the pie chart of traffic accidents in Şişli district is given according to the type of vehicle. When we interpret the 3833 fatal and injured traffic accidents that occurred between 2010-2017 in Şişli district according to the type of vehicle, it was found that the highest number of accidents was made by automobile vehicles with 2534 accidents, followed by motorcycle accidents with 1348 accidents. On the other hand, it has been observed that most of the accidents in Şişli district are caused by motorcycles, automobiles, pickup trucks and buses.

For this reason, accidents caused by these vehicles have been tried to be analyzed with separate maps made according to accident types, days and time zones in order to create a planned transportation policy.

First of all, in Figure 13, Figure 14 and Figure 15, Kernel density method maps of accidents with motorcycle vehicles are given according to the types of accidents, days and time zones. The label values for accident types, days, and time zones are given in Table 1.

In Figure 13, Kernel density method map with added types of accidents of traffic accidents occurred with motorcycle vehicles in Şişli district is given. It was found that the accidents caused by motorcycles were concentrated in Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Talatpaşa, Tem Link Road, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze, Dereboyu and Dolapdere streets. Motorcycles; Halaskargazi, Abidei Hürriyet, Kadırgalar, Mecidiyeköy Road, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Talatpaşa, Tem Link Road, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze Dereboyu and Dolapdere streets in the form of side impact collision, in the form of hitting pedestrian on the Center Street and in the form of side impact collision and in the form of hitting pedestrian on Kurtuluş Street were observed to have the highest number of accidents.

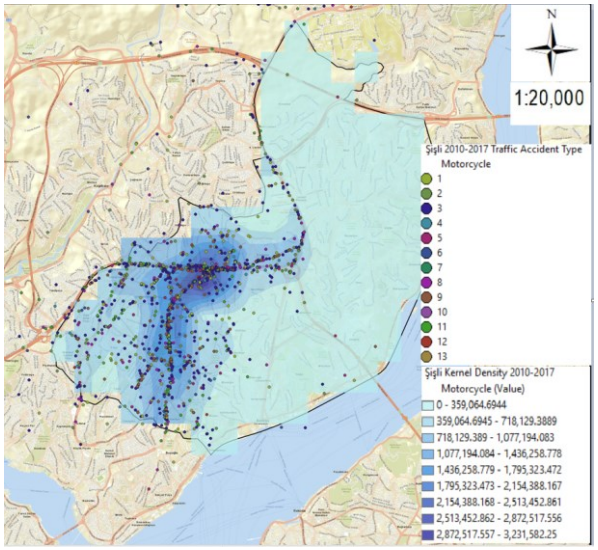

Figure 13. Kernel density method map with added types of accidents of traffic accidents occurred with motorcycle vehicles in Şişli district.

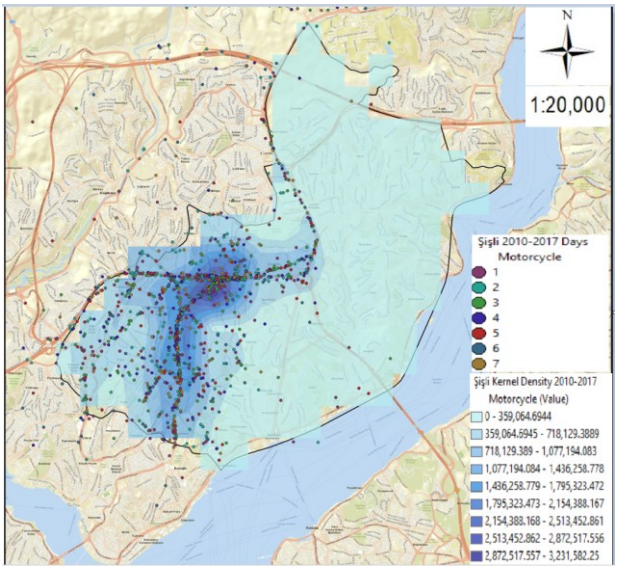

Figure 14. Kernel density method map with added days of the week of traffic accidents occurred with motorcycle vehicles in Şişli district.

In Figure 14, Kernel density method map with added days of the week of traffic accidents occurred with motorcycle vehicles in Şişli district is given. With this map, the accidents made by motorcycles in Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Talatpaşa, Tem Link Road, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze, Dereboyu and Dolapdere streets were examined according to the days. On these streets, it was observed that the most accidents by motorcycle vehicle occurred on Tuesday and the least accidents occurred on Saturday.

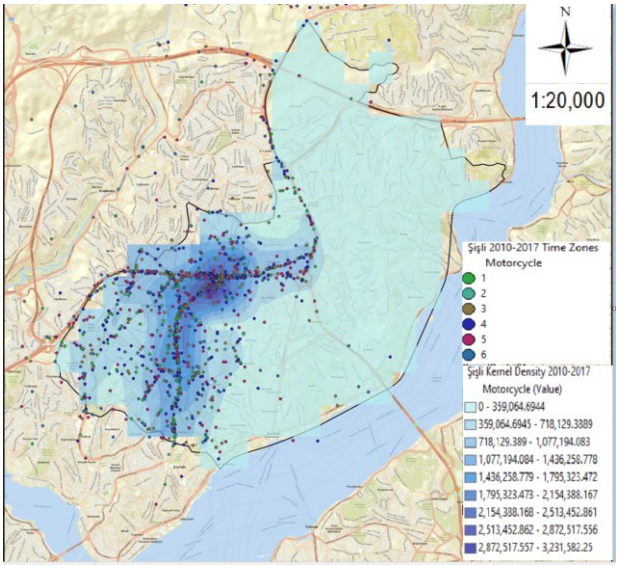

Figure 15. Kernel density method map with added time zones of traffic accidents occurred with motorcycle vehicles in Şişli district.

In Figure 15, Kernel density method map with added time zones of traffic accidents occurred with motorcycle vehicles in Şişli district is given. With this map, the accidents made by motorcycles in Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Talatpaşa, Tem Link Road, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze, Dereboyu and Dolapdere streets were examined according to time zones. It was found that the most accidents with motorcycle vehicles on these streets were between 16:00-20:00, followed by accidents between 12:00- 16:00. It is understood that the accidents with motorcycles occurred between 04:00-08:00 at least.

In Figure 16, Figure 17 and Figure 18, Kernel density method maps of accidents with automobile vehicles are given according to the types of accidents, days and time zones. The label values for accident types, days, and time zones are given in Table 1.

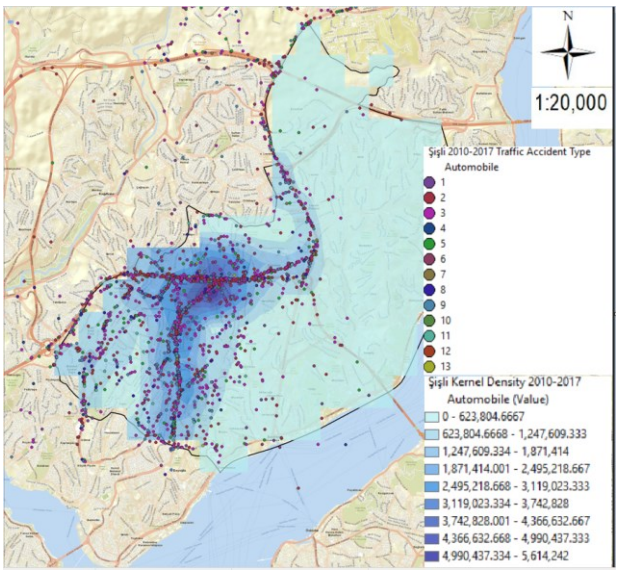

Figure 16. Kernel density method map with added types of accidents of traffic accidents occurred with automobile vehicles in Şişli district.

In Figure 16, Kernel density method map with added types of accidents of traffic accidents occurred with automobile vehicles in Şişli district is given. It was concluded that the accidents caused by the

automobiles were concentrated in Galata Creek, Hakkıyeten, Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze and Dereboyu streets. It has been observed that cars mostly crash on these streets in the form of side impact collisions.

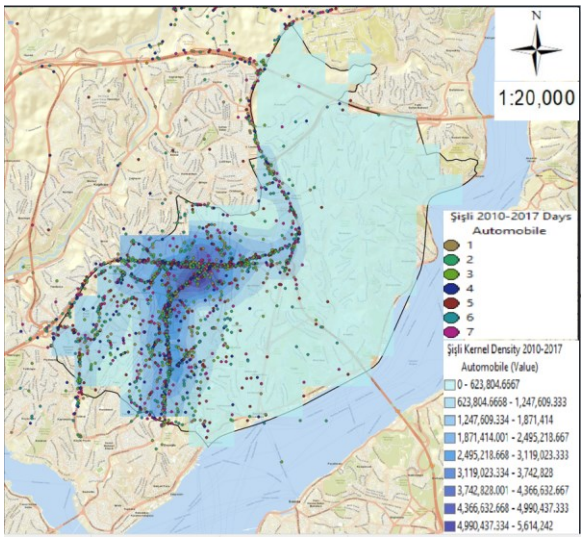

Figure 17. Kernel density method map with added days of the week of traffic accidents occurred with automobile vehicles in Şişli district.

In Figure 17, Kernel density method map with added days of the week of traffic accidents occurred with automobile vehicles in Şişli district is given. With this map obtained, the accidents made by cars in Galata Creek, Hakkıyeten, Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road, Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze and Dereboyu streets were examined according to the days. It has been observed that accidents with automobile vehicles are more common on weekends on these streets.

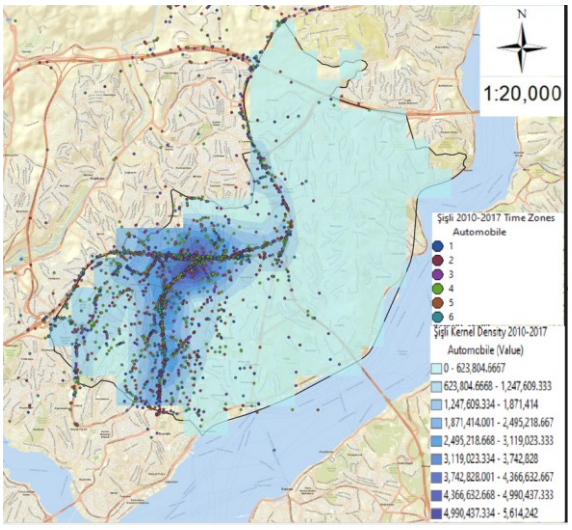

Figure 18. Kernel density method map with added time zones of traffic accidents occurred with automobile vehicles in Şişli district.

In Figure 18, Kernel density method map with added time zones of traffic accidents occurred with automobile vehicles in Şişli district is given. With this map obtained, the accidents made by the cars in Galata Creek, Hakkıyeten, Halaskargazi, Abidei Hürriyet, Kadırgalar, Kurtuluş, Mecidiyeköy Road,

Center, Ortaklar, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze and Dereboyu streets were examined according to time zones. It was observed that the accidents with the automobile vehicle on these streets occurred most between 12:00-16:00, followed by the accidents that occurred between 16:00-20:00. It was observed that the time zone with the least number of accidents with automobile vehicles was between 04:00-08:00.

In Figure 19, Figure 20 and Figure 21, Kernel density method maps of accidents with pickup truck vehicles are given according to the types of accidents, days and time zones. The label values for accident types, days, and time zones are given in Table 1.

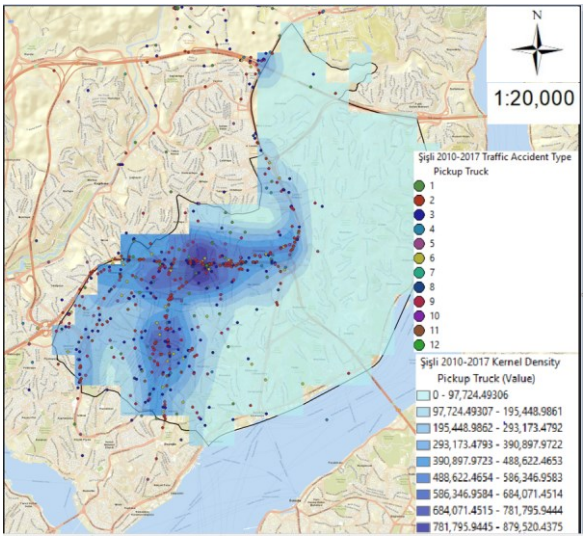

Figure 19. Kernel density method map with added types of accidents of traffic accidents occurred with pickup truck vehicles in Şişli district.

In Figure 19, Kernel density method map with added types of accidents of traffic accidents occurred with pickup truck vehicles in Şişli district is given. Since only 12 types of accidents occur in accidents involving pickup truck, the ArcGIS software has given a color representation of the first 12 types of accidents in Table 1. It was seen that the accidents caused by the pickup truck were concentrated in Halaskargazi, Abidei Hürriyet, Mecidiyeköy Road, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze and Dereboyu streets. Pickup trucks; It has been observed that there are more accidents in the form of hitting pedestrian in Halaskargazi, Mecidiyeköy Road streets, in the form of side impact collision in Piyalepaşa Boulevard, Governor's Mansion, Ayazağa, Cendere and Dereboyu streets, and in the form of rear impact collision in Büyükdere and Cumhuriyet streets. In addition, it was found that the pickup trucks had the most accidents in the form of multiple vehicle collision and hitting pedestrian on Abidei Hürriyet Street, in the form of side impact collision and hitting pedestrian in Sıracevizler Street, in the form of rear impact collision and side impact collision on Tem Link Road and in the form of side impact collision and hitting pedestrian on Darülaceze Street.

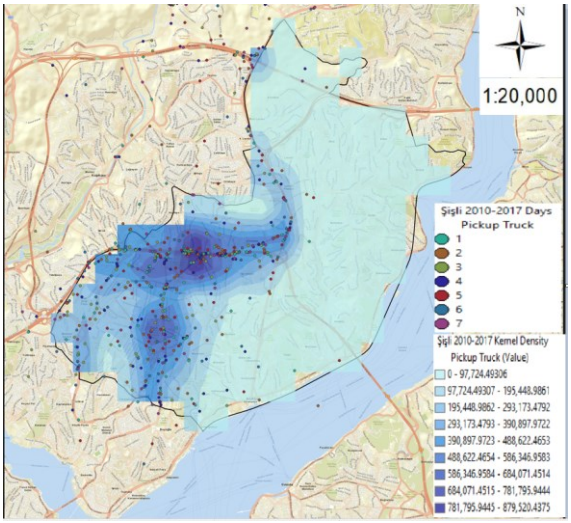

Figure 20. Kernel density method map with added days of the week of traffic accidents occurred with pickup truck vehicles in Şişli district.

In Figure 20, Kernel density method map with added days of the week of traffic accidents occurred with pickup truck vehicles in Şişli district is given. With this map obtained, the accidents made by the pickup trucks in Halaskargazi, Abidei Hürriyet, Mecidiyeköy Road, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze and Dereboyu streets were examined according to the days. It was found that the most accidents with pickup trucks on these streets occurred on Thursday, followed by accidents that occurred on Friday. It is understood that the accidents with the pickup truck occurred at least on Sunday.

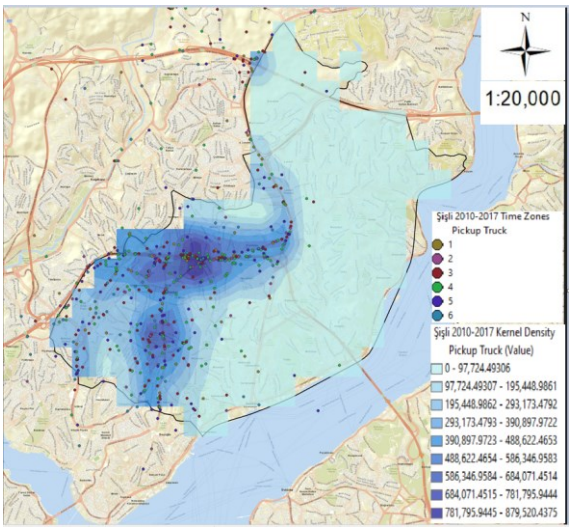

Figure 21. Kernel density method map with added time zones of traffic accidents occurred with pickup truck vehicles in Şişli district.

In Figure 21, Kernel density method map with added time zones of traffic accidents occurred with pickup truck vehicles in Şişli district is given. With this map obtained, the accidents made by the pickup trucks in Halaskargazi, Abidei Hürriyet, Mecidiyeköy Road, Piyalepaşa Boulevard, Sıracevizler, Tem Link Road, Governor's Mansion, Ayazağa, Büyükdere, Cendere, Cumhuriyet, Darülaceze and Dereboyu streets were examined according to time zones. It was found that accidents with pickup trucks on these streets occurred most often between 12:00-16:00, followed by accidents

that occurred between 08:00-12:00. It is understood that the accidents with the pickup truck occurred between 04:00-08:00 at least.

In Figure 22, Figure 23 and Figure 24, Kernel density method maps of accidents with bus vehicles are given according to the types of accidents, days and time zones. The label values for accident types, days, and time zones are given in Table 1.

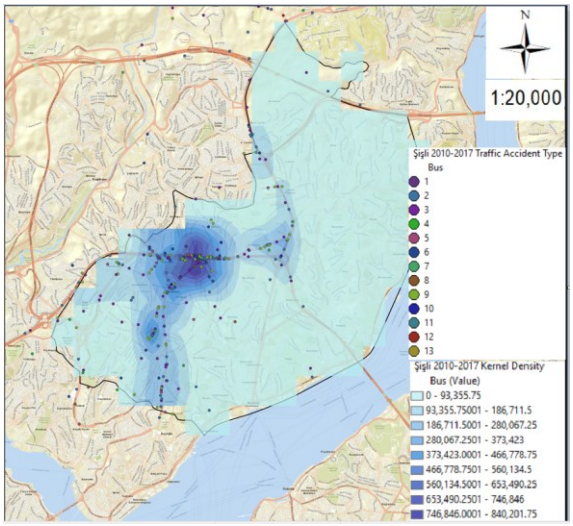

Figure 22. Kernel density method map with added types of accidents of traffic accidents occurred with bus vehicles in Şişli district.

In Figure 22, Kernel density method map with added types of accidents of traffic accidents occurred with bus vehicles in Şişli district is given. It was observed that the accidents caused by the buses were concentrated in Halaskargazi, Abidei Hürriyet, Kurtuluş, Mecidiyeköy Road, Center, Piyalepaşa Boulevard, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze and Ergenekon streets. Buses; It was concluded that they had the most accidents in the form of side impact collision in Halaskargazi, Center and Ayazağa streets, in the form of hitting pedestrian in Abidei Hürriyet, Mecidiyeköy Road, Darülaceze and Ergenekon streets, and in the form of rear impact collisions in Büyükdere and Cumhuriyet streets. In addition, it was seen that accidents with buses occurred the most in the form of side impact collision and multiple vehicle collision on Kurtuluş Street and side to side collision and hitting a stationary vehicle on Piyalepaşa Boulevard.

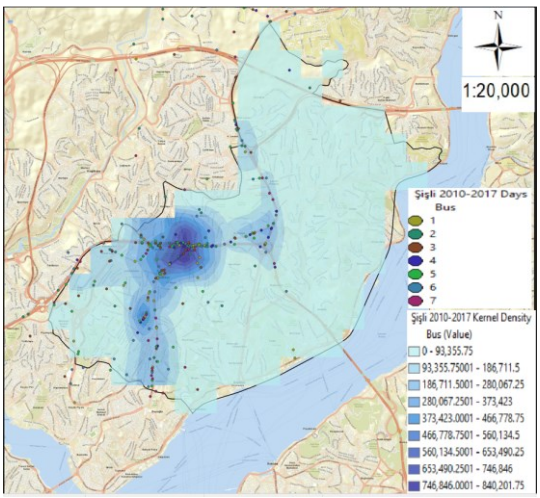

Figure 23. Kernel density method map with added days of the week of traffic accidents occurred with bus vehicles in Şişli district.

In Figure 23, Kernel density method map with added days of the week of traffic accidents occurred with bus vehicles in Şişli district is given. With this map, the accidents made by buses in Halaskargazi, Abidei Hürriyet, Kurtuluş, Mecidiyeköy Road, Center, Piyalepaşa Boulevard, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze and Ergenekon streets were examined according to the days. It was found that the most accidents with bus vehicles on these streets occurred on Tuesday. It is understood that the accidents by bus occurred at least on Sunday.

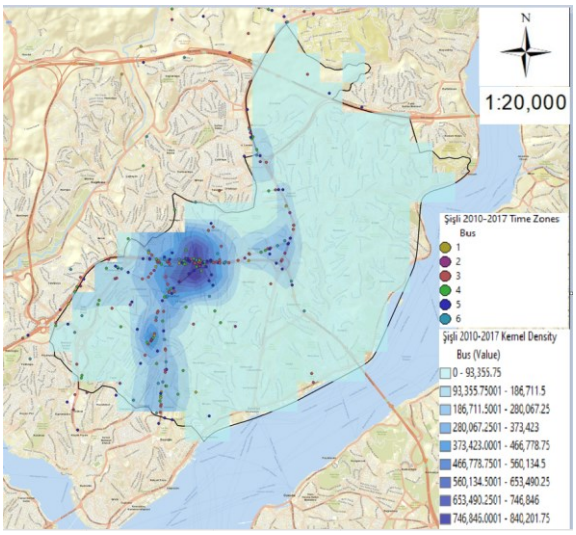

Figure 24. Kernel density method map with added time zones of traffic accidents occurred with bus vehicles in Şişli district.

In Figure 24, Kernel density method map with added time zones of traffic accidents occurred with bus vehicles in Şişli district is given. With this map obtained, the accidents made by buses in Halaskargazi, Abidei Hürriyet, Kurtuluş, Mecidiyeköy Road, Center, Piyalepaşa Boulevard, Ayazağa, Büyükdere, Cumhuriyet, Darülaceze and Ergenekon streets were examined according to time zones. It was observed that the accidents made by bus vehicles on these streets were most common between 08:00-12:00, followed by accidents that occurred between 16:00-20:00. It is understood that the accidents with the bus occurred between 00:00-04:00 at least.

4. Discussion and conclusion

Factors such as the advancement of technology and the rapid increase in the world population cause the urban traffic to be negatively affected. With the increase in traffic, the problems in this regard increase rapidly. Traffic accidents and traffic safety are among these problems.

Accidents that cause a large number of deaths and injuries in our country generally occur more frequently at some critical points. It is of great importance to identify these critical points and to develop systems for them.

Especially in metropolitan cities, with the population and the number of vehicles increasing day by day, the lack of development of solution systems for this cause traffic accidents, which are one of the most serious problems of today (Camkesen and Bayrakdar, 1999; Khokale and Ghate, 2017). It has been seen that the use of visual data methods in solving these problems will benefit the relevant authorities in reducing future traffic accidents (Ersen et al., 2022; Feng et al., 2019).

In order to ensure the safety of people in traffic and to minimize the accidents that will occur, it is of great importance to determine the real causes of accidents in similar locations. During the determination of these procedures, the determination of the accident points where death and injury occurred on the map was made with geographical information systems and it was facilitated to visually perceive the results needed.

In addition to traditional methods and techniques, it is possible to reduce traffic accidents and create safe management strategies by using geographic information systems method in analyzing and interpreting big data based on traffic accidents (Lin et al., 2014).
This study has shown that making discriminatory maps by investigating the causes of the most accidents in the studies on geographic information systems gives more accurate results in helping to prevent accidents. It is thought that the results obtained with the discriminatory maps will guide the teams trying to reduce traffic accidents more accurately. For example, on Halaskargazi Street, where pedestrian collision accidents occur the most, faulty pedestrian lines need to be corrected. On the other hand, although there are signalized intersections on this street, it is thought that vehicles and pedestrians do not comply with the signaling rules. For this reason, regulations that will force pedestrians and vehicles to comply with the rules should be introduced on the streets where accidents are common.
In addition, it was seen that cars had the most accidents between 12:00-16:00 and had more accidents on the weekend. Since the district examined in the study is a region where public transportation transfer centers are concentrated, people should not prefer their own vehicles. Again, a planned transportation policy can be determined according to the peak hours of other vehicle types determined in the study. For example, during the peak hours when the pickup trucks have accidents, alternative transportation routes can be determined and accidents can be prevented.
With this study, it is anticipated that the solution proposals brought to the important accident points determined for the district of Şişli will help the relevant decision-making teams who are trying to reduce traffic accidents.

Researchers' Contribution Rate Statement

The authors' contribution rates in the study are equal.

Acknowledgment and/or disclaimers, if any

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Conflict of Interest Statement, if any

The authors do not declare any conflict of interest.

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