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AN ANALYSIS OF TRAFFIC ACCIDENTS WITH SPATIAL STATISTICAL METHODS IN IZMIR PROVINCE

İZMİR ŞEHRİNDE MEYDANA GELEN TRAFİK KAZALARININ MEKANSAL İSTATİSTİKİ YÖNTEMLERLE İNCELENMESİ

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ABSTRACT

Izmir is one of the significant cities in terms of population in Turkey. Due to increase in the population, car usage in İzmir has increased too. Increased use of the vehicle also causes increase traffic accidents. Therefore, this study was done in order to reduce numbers of traffic accidents. Eleven central districts of Izmir city were chosen as the study area. Eleven districts center in Izmir was chosen as the study areas because they are main focus areas of population density and population mobility in this area. The cities that includes the districts are Çiğli, Karşıyaka, Bayraklı, Bornova, Konak, Buca, Gaziemir, Karabağlar, Balçova, Narlıdere and Güzelbahçe. 2010 and 2014 traffic accidents' data was used in the study. As a method by using Geographic Information System three different spatial statistics analyses were carried out. Spatial statistics methods are consist of point density, line density and Anselin Local Moran I analyses. Aim of the spatial statistics methods is to determine where the accidents intense and where may become intense in the future. According to analyses mapped roads which have high rates of traffic accidents within eleven districts. In conclusion, with this study areas where traffic accidents are dense within eleven districts are revealed in order to reduce the numbers of accidents.

Keywords: Traffic accident, Spatial Statistics, Spatial Analysis, Spatial Clustering, Izmir

ÖZET

Türkiye'nin nüfus bakımından önemli şehirlerinden birisi İzmir'dir. İzmir şehrindeki nüfusun artması nedeniyle araç kullanımı da artmıştır. Araç kullanımının artması trafik kazalarının artmasına neden olmaktadır. Bu nedenle trafik kazalarının azaltılması amacıyla bu çalışma gerçekleştirilmiştir. Çalışma alanı olarak İzmir şehrine ait on bir tane merkezi ilçesi seçilmiştir. Çalışma alanın on bir merkezi ilçesinin seçilmesi nüfusun büyük oranda bu alanda yaşaması ve nüfus hareketliliğin bu alanda gerçekleşmesidir. Şehri içeren ilçeler Çiğli, Karşıyaka, Bayraklı, Bornova, Konak, Buca, Gaziemir, Karabağlar, Balçova, Narlıdere ve Güzelbahçe'dir. Çalışmada 2010 ve 2014 yıllarına ait trafik kaza verileri kullanılmıştır. Yöntem olarak Coğrafi Bilgi Sistemleri kullanılarak üç farklı mekânsal istatistik analizi gerçekleştirilmiştir. Kullanılan mekânsal istatistik yöntemleri nokta yoğunluk analizi, çizgi yoğunluk analizi ve Anselin Yerel Moran I analizidir. Mekansal istatistik yöntemlerinin kullanılmasındaki amaç trafik kazalarının hangi alanlarda yoğunlaştığını ve gelecekte hangi alanlarda yoğunlaşabileceğini tespit etmektir. Yapılan analizlerde trafik kazalarının on bir merkezi ilçesi içerisinde hangi karayollarının trafik kazası bakımından artış gösterebileceği haritalandırılmıştır. Sonuç olarak çalışmanın sonucunda trafik kazalarının azaltılması için on bir merkezi ilçesi içerisindeki trafik kazası bakımından yoğun alanlar ortaya çıkartılmıştır.

Anahtar Kelimeler: Trafik Kazası, Mekansal İstatistik, Mekansal Analiz, Mekansal Kümelenme, İzmir

1. INTRODUCTION

Nowadays, rapid population increase swells up the use of means of transportation. Increased use of means of transport leads to various problems at an extent making it imperative to conduct more studies on this subject.

Transportation, in general, is defined as the movement of people or goods from one place to another (Tümertekin, 1987). One type of transportation is road transport. There has been a rapid growth in

road transport over the last fifty years (Wang, 2010). Particularly in the recent years, the rate of growth can be seen even more clearly with a high impetus. The increased use of road transportation brings about several problems. One of the most important problems is traffic accidents (Çağlıyan et al., 2016).

In the Highway Traffic Law, "Traffic accident is an incident that causes death, injury or property damage, including one or more vehicles that occur while on the move" (Gökçe, 2015; Sungur et al., 2014). Traffic accidents are caused by main four reasons as humans, vehicles, infrastructure, and environmental conditions (Bek, 2007).

Considering the distribution of traffic accidents; death incidents are seen mostly in areas with dense population and social activities (Levine et al., 1995). A total of 1.2 million people have been killed in traffic accidents worldwide and approximately 50 million people have been injured (Korter et al., 2014; Kundakçı, 2014). It is predicted that deaths from traffic accidents will be reduced by 30% in developed countries over the next 15-20 years, while death rate will increase by 80% in low and middle-income countries (Korter et al., 2014). It is observed that in some developed countries, traffic accidents decrease regularly; however, Turkey experiences both decrease and rise in traffic accidents as shown in Table 1. In addition, the number of registered vehicles and the number of people with driver's license are increasing every year as shown in Table 2. Therefore, traffic accidents stand as one of the most important problems waiting for solution in Turkey (Çiçek, 2007; Çağlıyan et al., 2016; Karakaş et al., 2009; Tuncuk, 2004).

Table 1. Traffic accident data in Turkey (TUİK, 2017)

Year	Number of accident	Number of accident involving death or personal injury	Number of material damaged accident	Number of dead at the accident place	Number of Injured
2010	1.104.388	116.804	989.397	4.045	211.496
2011	1.228.928	131.845	1.097.083	3.835	238.074
2012	1.296.634	153.552	1.143.082	3.750	268.079
2013	1.207.354	161.306	1.046.048	3.685	274.829
2014	1.199.010	168.512	1.030.498	3.524	285.059
2015	1.313.359	183.011	1.130.348	7.530	304.421
2016	1.182.491	185.128	997.363	7.300	303.812

Table 2. The number of registered vehicle and people with driver's license in Turkey (TUİK, 2017)

Year	Number of vehicles registered in traffic.	Number of people with driving license
2010	15.095.603	21.548.381
2011	16.089.528	22.798.282
2012	17.033.413	23.760.346
2013	17.939.447	24.778.712
2014	18.828.721	25.972.519
2015	19.994.472	27.489.150
2016	21.090.424	28.223.393

Developed technology has placed Geographical Information Systems (GIS) in a central position for examining of traffic accidents (Saplıoğlu & Karaşahin, 2006; Erdoğan et al., 2008; Karakaş et al., 2009; Çağlıyan et al., 2016). In general terms, GIS is "the resultant of the hardware, software, and methods designed to solve location-based complex planning, organization, and management problems, and which perform storing, processing, management, modelling, analyzing, and displaying of predetermined data and outputs in a geographical location" (Kurt, 2006). GIS enables textual and spatial data to be entered into the database together, questioned, and presented on the map (Gündoğdu, 2010; Anselin, 1995).

GIS is used in many areas predominantly including earth sciences, infrastructure, forest sciences, climatology, archaeology, and biology (Yılmaz et al., 2009). GIS, in relation to distribution and spatial query of cases and objects, helps respond to how, where, and when of the emergence (Karakaş, 2003). This study is carried out with GIS methods that are often used in transportation. GIS is beneficial in studying traffic accidents mostly because they are economical and allow rapid questioning and two and three-dimension projection of space.

The aim of this study is to investigate traffic accidents that occurred in the city of İzmir from 2010 to 2014. For this purpose, the data about traffic accidents between the years 2010 and 2014 were mapped to elicit the variance between the two years.

2. STUDY AREA

The city of İzmir is located in western Turkey. It is bordered by Balıkesir from the north, Manisa from the east, and Aydın from the south. Since the city is spread over a very wide area, it is 180 km between east and west and 200 km from north to south, with a total surface of 12,007 km^2. İzmir has a total of 30 districts. Eleven districts of İzmir were chosen as the study area (Figure 1). This area was chosen for the study because in the particular context of İzmir, the most traffic accidents occur in the central districts. For this reason, the areas with the most traffic accidents were included in the study.

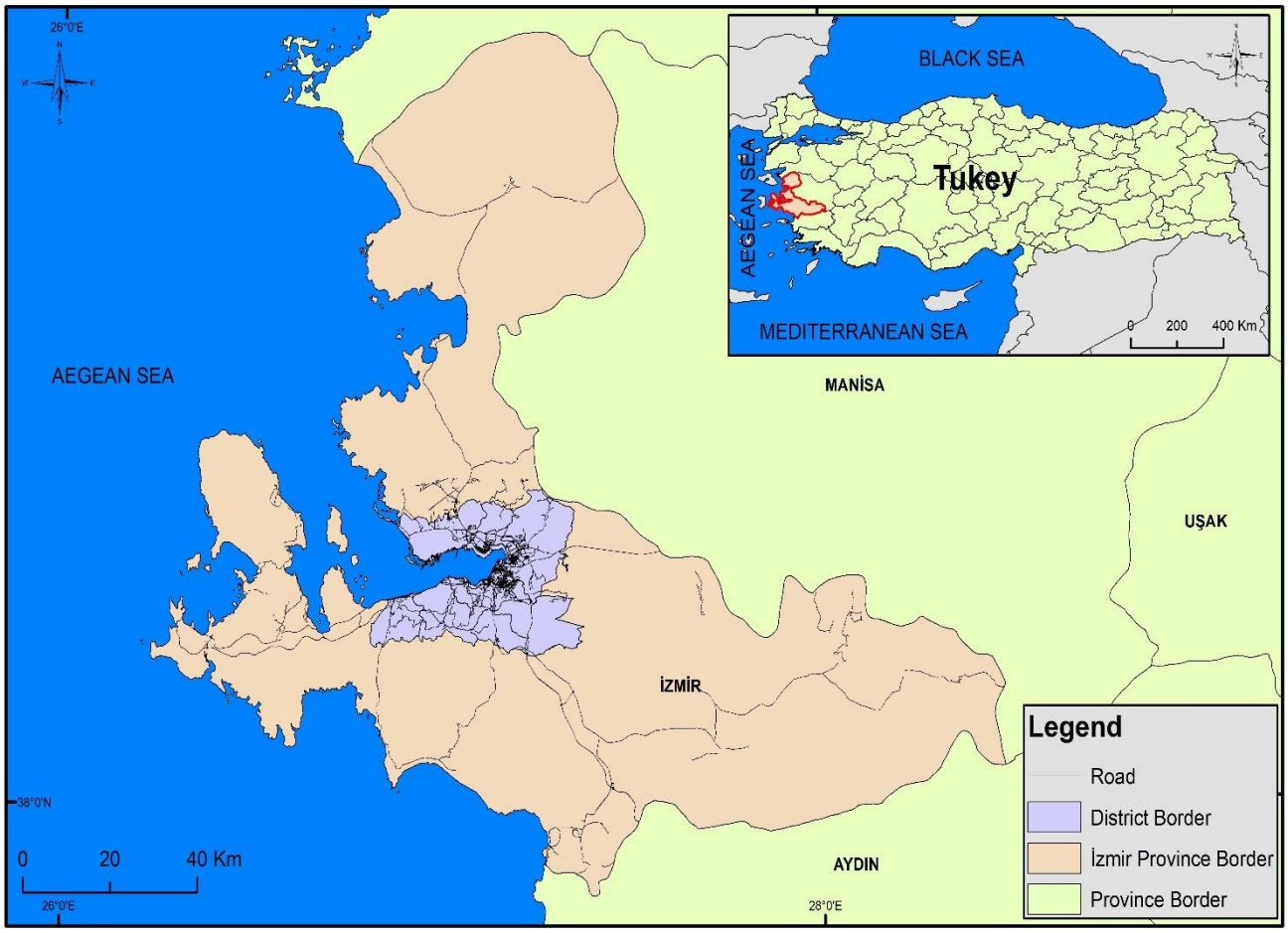

Figure 1. Map of study area

3. DATA AND METHOD

The processing of data is collected in comprised of five main groups. These are collection of data, transferring the data to the computer environment, establishing the database, making it questionable in the GIS, and analyzing by means of applicable tools (Figure 2).

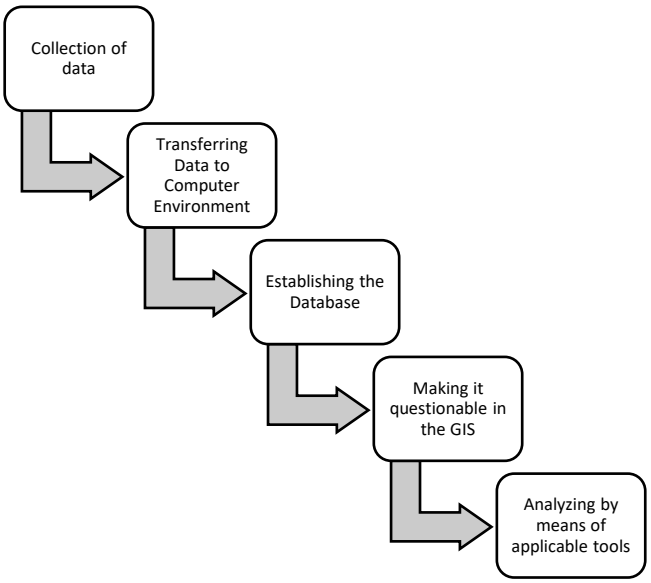

Figure 2. Data processing schema

The basic data used in this study are comprised of the traffic accident data retrieved from the Insurance Information and Monitoring Center (IIMC) and Izmir Regional Branch Directorate of Traffic (IRBDT).

In the first stage, polygonal data from the eleven central districts covering the boundaries of the study area were generated in the GIS environment. The second stage was about the transfer of the coordinated data from the IRBDT to the GIS environment. At the third stage, the data obtained from the IIMC were transferred to the GIS database. However, the data were added to the database after being coordinated according to address data as there were no other coordinates. In the last stage, the data obtained from the IRBDT and the IIMC were combined in the GIS software.

The study was performed using three different GIS-based methods (Figure 3). These methods are point density, line density tool, and hot spot tool, which is under the spatial statistical toolkit. The point density tool gives a raster output by counting the points in the vector form which are within the pixels around it (Costache, 2013). In addition, the points were analyzed without entering weight values. The line density tool was used to calculate the length of the lines within each pixel's diameter (Fontanice, 2013). Additionally, weight values were entered during the line analysis. As the last method, hot spot analysis was performed as a tool of spatial clustering. Hot spot analysis defines hot and cold spots that are statistically important using the Anselin Local Moran's I statistics by giving a weight (Okumuş & Edelman, 2015). Hot spot analysis is performed by weight values, unlike point density analysis (Prasannakumar et al., 2011). The weight values entered in analysis represent the independent variables in traffic accidents.

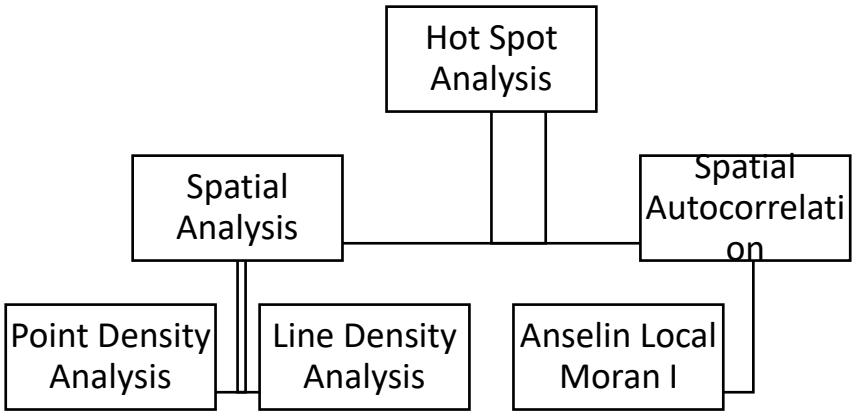

Figure 3. Schema of spatial statistical analysis

3. 1. Point Density Analysis

Point density analysis tool is used for calculating the size for unit from the adjacent point features around each cell. Point density analysis tool consists of five basic elements: point input data, weight value, output raster data, weight size, and calculation of the radius size from the neighboring cells. Density analysis tool is used in various studies. For example, it is used in crime maps, population density maps, and traffic accidents. In the study, the coordinated points where traffic accidents occurred were used to calculate the density in the analysis.

From a general point of view, analysis of the accidents between 2010 and 2014 yielded a number of results. For example, the analysis of the year 2010 demonstrated that the red areas cover a far larger more surface than those in 2014. In the red areas, the number of accidents per square kilometer was 20-52 in 2010. However, it was found to be 26-63 in 2014. It implies that the rate of traffic accidents in 2014 increased, rather than decreasing. Another result of the analysis is that the number of traffic accidents increased in 2014. While the number of traffic accidents was 5794 in 2010, the figure was recorded as 6808 in 2014 as shown in Table 3.

Table 3. Number of crashes per Km^2

Distribution of Classification	Year					
	2010			2014		
	Area (km^2)	Number of Accidents	Number of crashes per Km^2	Area (km^2)	Number of Accidents	Number of crashes per Km^2
Low	768.92	432	1	776.81	672	1
Medium	105.46	2030	19	107.96	2696	25
High	64.72	3332	52	54.33	3440	63
Total	939.1	5793		939.1	6808	

The analysis was performed by using the traffic accident data of 2010. Point density tool was used in the analysis. In the point density tool, coordinated traffic accident point data for 2010 were entered as input. No value was selected in the weight tab in the point density tool because focus was on intensity bound to the location of the accident sites. The other tab in the tool used is the cell size of the output data. It is given as ten in this part. The cell size was chosen as ten because it was intended to obtain well-detailed data. Another operation in this tool is to perform calculation according to the adjacent circumference. In this part, the circle was selected and calculated at a radius of 113 pixels. The default value of the tool was taken as 113 pixels because it is the value that is the most proportional to the cell size of ten.

As a result of the analysis of the year 2010, it was determined in which areas the traffic accidents were concentrated (Figure 4). In the analysis, the intensity levels were examined in three different groups as low, medium, and high. The areas with high number cover six of the districts. These are Karşıyaka, Bayraklı, Konak, Bornova, Karabağlar, and Buca.

The red areas in Karşıyaka district are located within residential areas and central business areas. Due to the fact that everyday population mobility and business areas are in this region, the traffic density is quite high. Anadolu Street, which allows a west-east passage from Karşıyaka, is the intersection point of Girne Avenue, which stretches in the southwest direction. Vehicles arriving from outside of the town and from Bayraklı district use this route to enter the central Karşıyaka. For this reason, the incidence of traffic accidents is very high in this area.

The red areas in Bayraklı district contain the central business areas and Bayraklı Courthouse. The location of these two causes traffic jam and thus increased traffic accidents.

The red areas within Konak district show the region with concentrated central business areas and residential areas in the land use plan. Therefore, daily population mobility and the use of transportation vehicles in this region are quite high. Another reason for the high incidence of traffic accidents in that region is that Kemeraltı Bazaar is located there. The existence of the Kemeraltı Bazaar here causes higher mobility of everyday population. In addition, there are a very high

number of traffic accidents per square kilometer in this area due to the location of the 9 Eylül Crossroads. The crossroads connects two avenues that are important for transportation. These important highways are Gazi Avenue and Mürsel Paşa Avenue.

The red parts in Bornova district are within the business and industrial zones according to the land use plan. The region is also the end point of the Ankara-İzmir highway. Consequently, the concentration of traffic in the region causes a high number of traffic accidents in the vicinity.

In another district, Karabağlar, the red areas refer to the presence of central business area and new residential areas. Within the business areas, there are stores for various products in the area. Another reason for the high number of traffic accidents is the concentrated new residential areas in the region. These areas also contain restaurants, explosive-free factories, and fuel stations, which yields a high mobility of vehicles. From transportation perspective, Yeşillik Road is also there, which connects the south of the central İzmir to the north. It is the road originating from Karabağlar district to the center of Konak. Therefore, a high number of traffic accidents are recorded on Yeşillik Road.

Across the district of Buca, distribution of the red areas is dominated by the presence of public institutions in the region. Şirinyer High School is located in the northwest of the district. Due to these reasons, there occur a lot of traffic accidents in that vicinity. In the red areas to the east of Şirinyer High School, Buca municipality is located. The high rate of traffic accidents in that area can be accounted for by the population and transport mobility here.

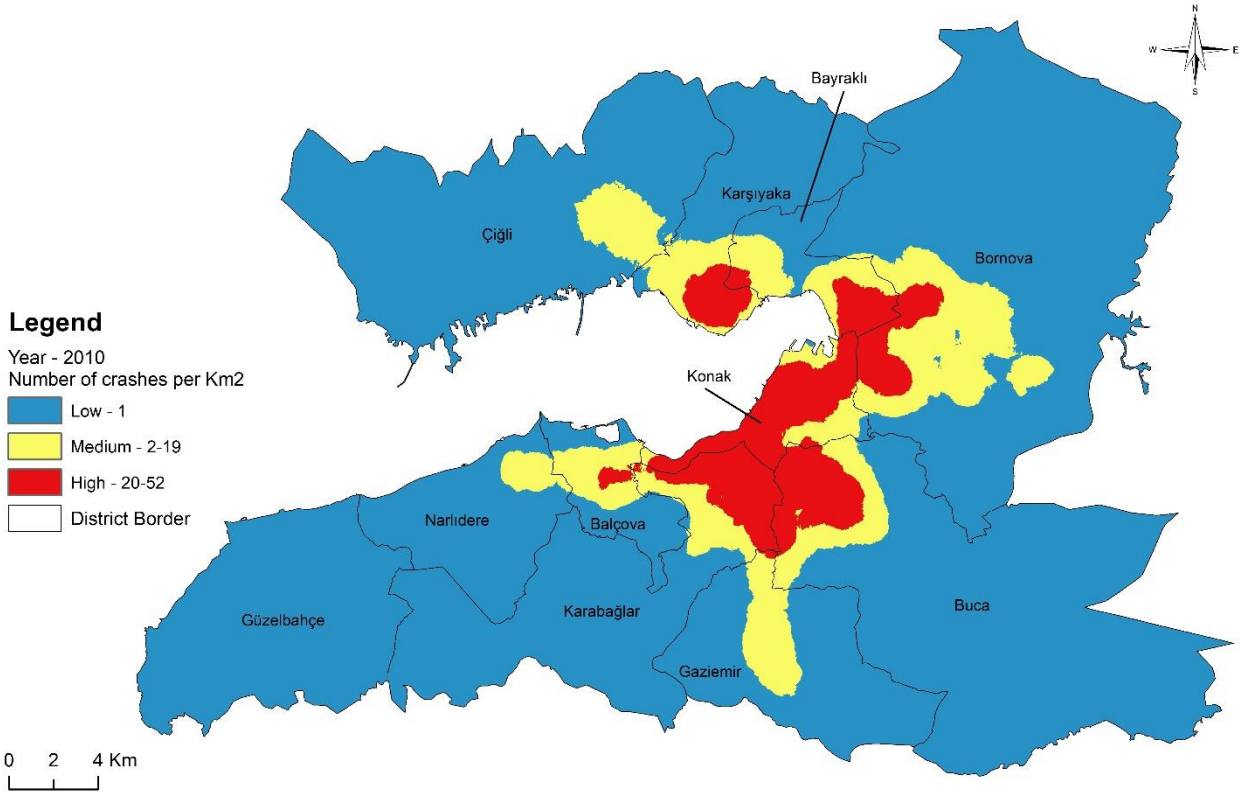

Figure 4. Point density analysis of 2010

In the second analysis, traffic accident data for 2014 were used. The analysis was performed using the point density analysis tool as in the first analysis. In the analysis, the point layer of traffic accident data for 2014 was chosen as input data. No value was selected in the weight value tab in this tool. The cell size of the targeted output data was entered as ten. A circle was selected in the calculation tab according to the adjacent circumference and 113 pixels were entered as unitary value.

As a result of the analysis of the year 2014, it was found out which areas showed a concentrated distribution of traffic accidents (Figure 5). The methods performed in the first analysis were also performed in this analysis. Density degrees were examined in three different groups. In 2014, a high number of traffic accidents occurred in Karşıyaka, Bayraklı, Bornova, Buca, Konak and Karabağlar districts.

The occurrence of high number of traffic accidents in the district of Karşıyaka seems to be due to those for 2010. There is a decrease in the intensity of traffic accidents in Bayraklı compared to 2010. One of the most important reasons is the use of the peripheral road in the north of İzmir because it is used as an alternative route for passage from Bayraklı to the district of Karşıyaka. Likewise, the high number of traffic accidents in Bornova district is due to the same reasons in 2010. These reasons include industrial zones and the end point of the Ankara-İzmir highway. Traffic accidents take place very often around Buca because of the existence of government buildings.

On the basis of the land use plan, the area between Karabağlar and Konak was determined as a settlement area. However, the red area contains important institutions and organizations such as the İzmir Metropolitan Sports Complex, İzmir Sports Complex of Osman Kibar, Mustafa Urcan Primary School, and Bozyaka Training and Research Hospital, which is one of the biggest hospitals in İzmir. In relation with transportation, three different roads are situated within an area which host a high number of traffic accidents. These are İnönü Avenue, Halide Edip Adıvar Avenue, and Ali Rıza Avni Avenue.

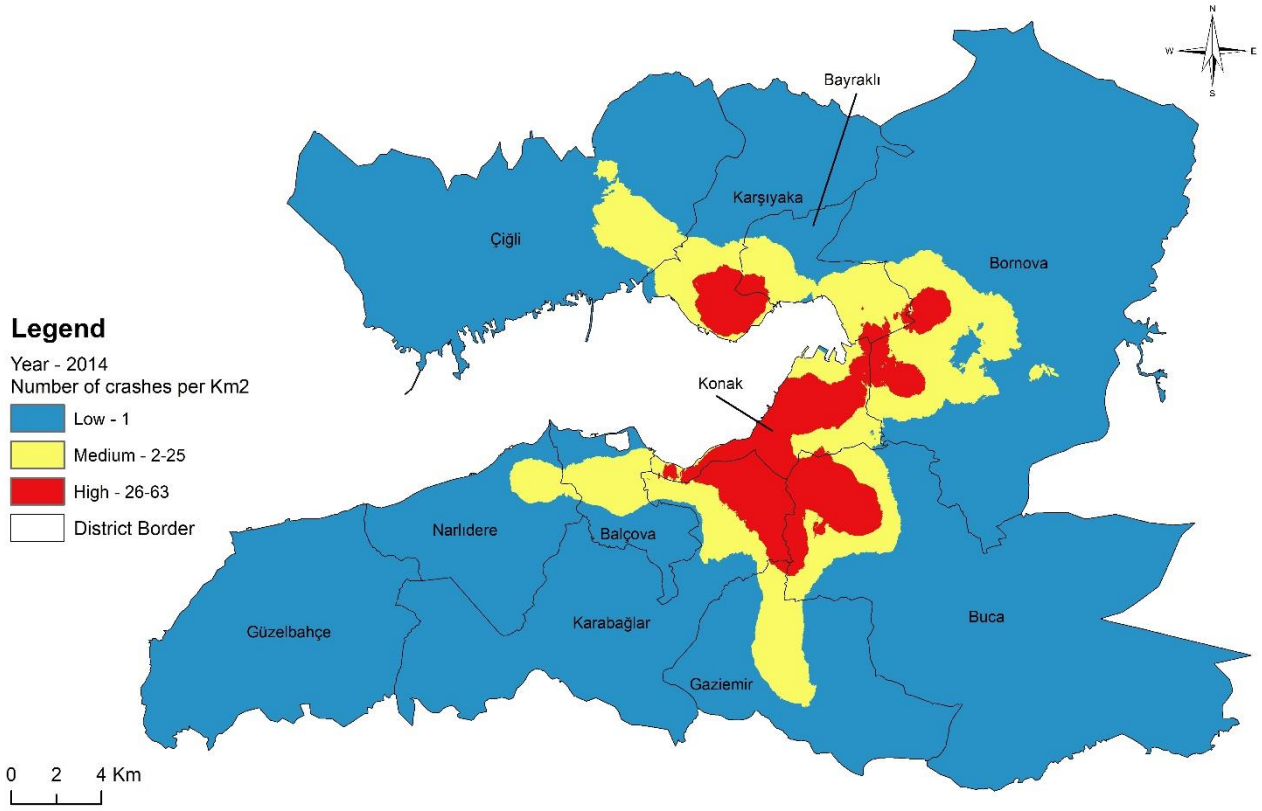

Figure 5. Point density analysis of 2014

3.2. Line Density Analysis

Line density tool calculates the size of the unit area of the line passing through the radius of each cell circumference. In other words, a circle is drawn from the center of each cell and the length of the line passing through the circle is multiplied by the weight value. These numbers are summed up and then divided by the total area of the circle. It is applied as in the following formula. A1 and A2

symbolize the length of the section of each line falling into the circle. B1 and B2 indicate the weight values.

Density = ((A1 * B1) + (A2 * B2)) / (Circle Area)

The line density tool consists of four items. These are input polyline features, weight values, output data, and cell size of the output raster data. In this study, the line density tool was used to calculate the intensity of traffic accidents on the roads. For example, five traffic accidents occurred in one of the streets and ten in the other. Based on the variance of weight values between the two streets, the output data on the tool show that the latter street is exposed to a larger number of traffic accidents.

From a broad perspective, the analyses for 2010 and 2014 yielded different results as shown in Table 4. For example, the analysis of 2014 revealed that red areas cover a smaller area than in 2010. Nevertheless, the red areas for 2014 hold a higher number of accidents than in 2010. This implies an increased density of traffic accidents in 2014 compared to 2010. When density of traffic accidents is examined by districts in 2014, the red areas within borders of Karşıyaka district are seen to have expanded. The increase is in not only in area, expansion of the affected area namely, but also number. Increased numbers suggest that traffic accidents occur in a smaller area but more intensely. This is because everyday population and transportation activities take place in certain areas more frequently.

The land use plan was created in 2012. Some changes have occurred since it was made before 2014. The proliferation of business areas in this region is one of the reasons for the increase of traffic accidents. Another reason is that the highways do not suffice over time in areas where everyday mobility is high.

Table 4. Number of crashes per Km2

Distribution of Classification	Year					
	2010			2014		
	Area (km^2)	Number of Accidents	Number of crashes per Km^2	Area (km^2)	Number of Accidents	Number of crashes per Km^2
Low	707.66	162	1	704.35	161	1
Medium	141.12	1568	11	144.36	1958	14
High	90.32	4064	45	90.39	4689	52
Total	939.1	5794		939.1	6808	

The analysis was carried out by entering the number of traffic accidents for 2010 into the road data. Line density tool was used in the analysis. In the line density tool, the data from roads in the line layer for 2010 were used as input data. The number of traffic accidents for 2010 was selected for the weight tab in the line density tool. The selected number of traffic accidents is the data entered in the feature table of the road data. Another feature used in the analysis is the cell size of the output data and the radius size. The cell size was entered as ten for obtaining the maximum detailed data. The radius size was chosen 113. The radius size was taken as 113 pixels because the line density tool gives the value of 113 pixels proportionately if the value of ten cells is entered.

As a result of the analysis of the year 2010, the spots with concentration of traffic roads by using the road data (Figure 6). In the analysis, density levels were examined in three different groups. Red areas include nine districts: Çiğli, Karşıyaka, Bayraklı, Bornova, Konak, Karabağlar, Buca, Gaziemir, and Balçova.

The prominent reason for the high incidence of traffic accidents in Çiğli district is the Anadolu Street because drivers coming from outside the city take this route. It is the route used by drivers coming from Balıkesir to reach the center of İzmir. Also, Anadolu Street passes through the center of Çiğli district. Therefore, traffic accidents correspond to a very high figure as a result of heavy traffic.

The red areas within the district of Karşıyaka exist as residential areas in the land use plan. However, it is the part with the highest everyday population mobility because the most central portion of Karşıyaka is enclosed in the higher-accident zone. Moreover; Karşıyaka Municipality, banks, pharmacies, and grocery stores are contained in the red zone. Another important reason is the existence of the point where two different highways join, which are Girne Avenue and Ataturk Avenue. Traffic accidents are high in that area due to the fact that the two ways are widely used for transportation.

In Bayraklı district, the areas with traffic accidents per square kilometer are covered within the central business areas and settlement areas in the land use plan. The central business areas are located in the west of the red zone and the east part is depicted as a residential area in the land use plan. The central business areas are situated around İzmir Provincial Courthouse. So it necessarily witnesses quite a busy day in population and transportation. In addition, the red division within the central business areas includes law offices, Bornova Tax Office, and hospitals. The red areas in the residential area include schools, grocery stores, restaurants, estate agencies, and family health centers. In relation with transportation; the red zone encloses Ankara Road, Manas Avenue, Sakarya Street, 252th Street, and 286th Street. The listed roads are the access roads connecting the northeast and east of İzmir to the southwest and the south. For this reason, a high number of traffic accidents occur on these highways.

One of the most important reasons for high rate of traffic accidents in Bornova district is the layout of the Ankara-İzmir highway. The end point of the motorway where traffic flow starts into the town causes density. As a consequence of the density, traffic accidents are recorded high.

The red areas in Konak and Karabağlar districts refer to the busiest parts of İzmir considering daily population and transportation. The intense daily activities in these areas also cause a lot of traffic accidents. There are many schools, places of worship, parks, restaurants, security units, banks, grocery stores, and hotels in this area.

The red areas in Buca district include Buca Municipality and bazaar so it is an area busy with everyday mobility and transportation. Besides, from transportation point of view, the red areas here are contained in the access roads from Buca to Konak and Karabağlar. Therefore, there is a high rate of traffic accidents on the access roads.

In another district, Gaziemir, the high rate of traffic accidents can be explained with the location of Akçay Street within the red zone. Akçay Street is special as a highway that gives connection to the center and outside of İzmir in the South-North direction. This fact makes it one of the most important routes used by those driving into and away from the central town. The fact that it is one of the most important routes causes the street to be used quite a lot and causes a high rate of traffic accidents.

Moving to the district of Balçova, we found out the most important reason for the high traffic accidents as the flow from the western neighborhoods Güzelbahçe and Narlıdere into the center of İzmir. Moreover, Mithatpaşa Street is the only highway linking to the city center of İzmir.

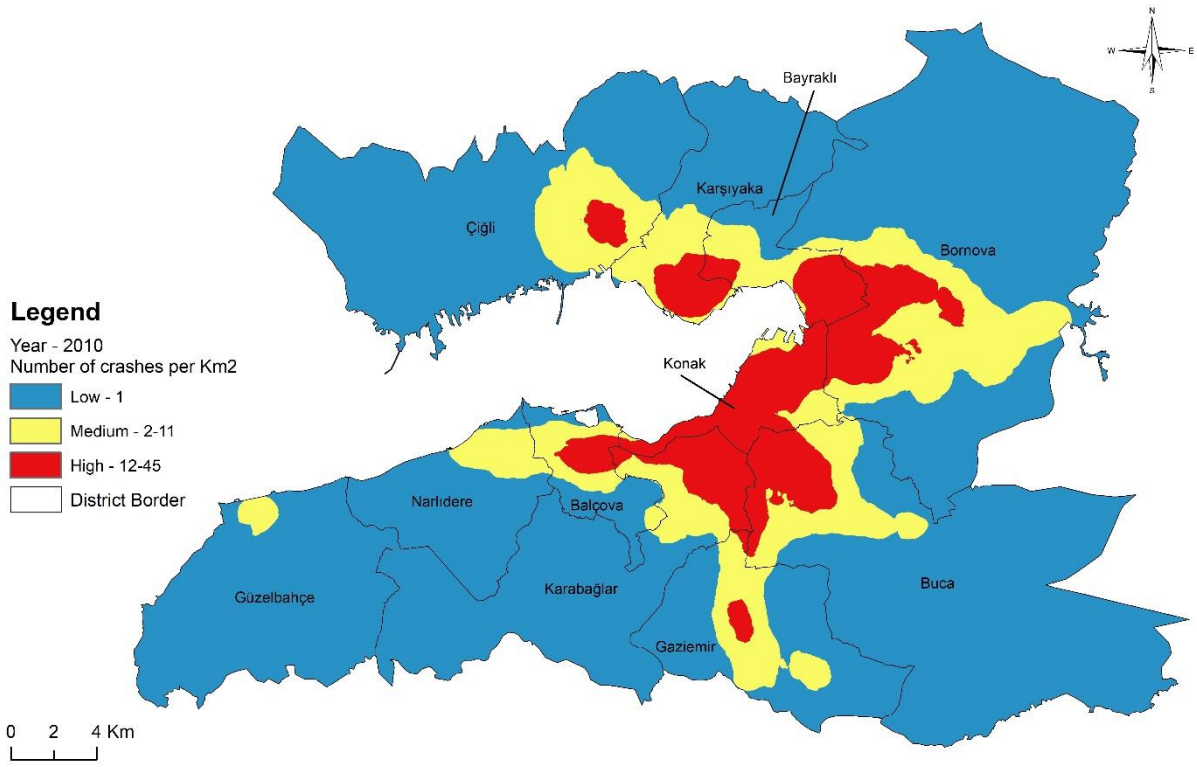

Figure 6. Line density analysis of 2010

The second analysis of the line density analysis was prepared with the traffic accident data for year 2014. The same analysis tool from the first analysis was also used in that analysis. As the input data in the analysis, road layer of 2014 was entered. The number of traffic accidents for 2014 was selected in the weight tab in the tool. The number of accidents represents the accident information in the attribute table of the road layer of 2014. The cell or pixel size in the output data was entered as ten. The radius was taken 113 pixels as default value.

As a result of the analysis for 2014, the intensity of road traffic accidents was determined by road layer (Figure 7). The same method in the analysis for 2010 was applied to the data of 2014. Again, the density levels were examined in three groups. As a result, red areas were seen to cover nine districts: Çiğli, Karşıyaka, Bayraklı, Bornova, Konak, Karabağlar, Buca, Gaziemir, and Balçova.

The occurrence of red areas across Çiğli is due to similar reasons for 2010. It refers to the existence of Anadolu Street and vehicles coming from outside the city connecting to the center of İzmir.

The red areas in the district of Karşıyaka refer to the areas where intense everyday population mobility takes place. It is located within the intersection of two important roads: Girne Avenue and Atatürk Avenue. While Girne Avenue connects the central district from south to north, Atatürk Avenue carries transportation from east to west.

The red areas between Bornova and Bayraklı district boundaries represent the connection point of the two districts. Therefore, there is a busy flow of everyday daily population from the northeast to the southwest, which in turn brings frequent traffic accidents.

Between the districts of Konak and Karabağlar, the areas with very high rates of accidents are situated on the transportation passage from east to west or west to east. It is also a densely populated area because there are many governmental offices and organizations in this region such as schools, supermarkets, restaurants, parks, and public institutions.

The red areas in Buca district cover a smaller area than such red areas in the other districts. This region is located in the central part of the district of Buca. The red section is an area exposed to busy transportation. Therefore, traffic accidents are seen at a very high rate.

The high rate of traffic accidents across Gaziemir and Balçova districts seems to be accounted for by the same reasons set forth in the analysis of the year 2010, which is the Mithatpaşa Street in the district of Balçova allowing east-to-west access. In the case of Gaziemir, the high incidence of traffic accidents is because of Akçay Street that links the north-south direction.

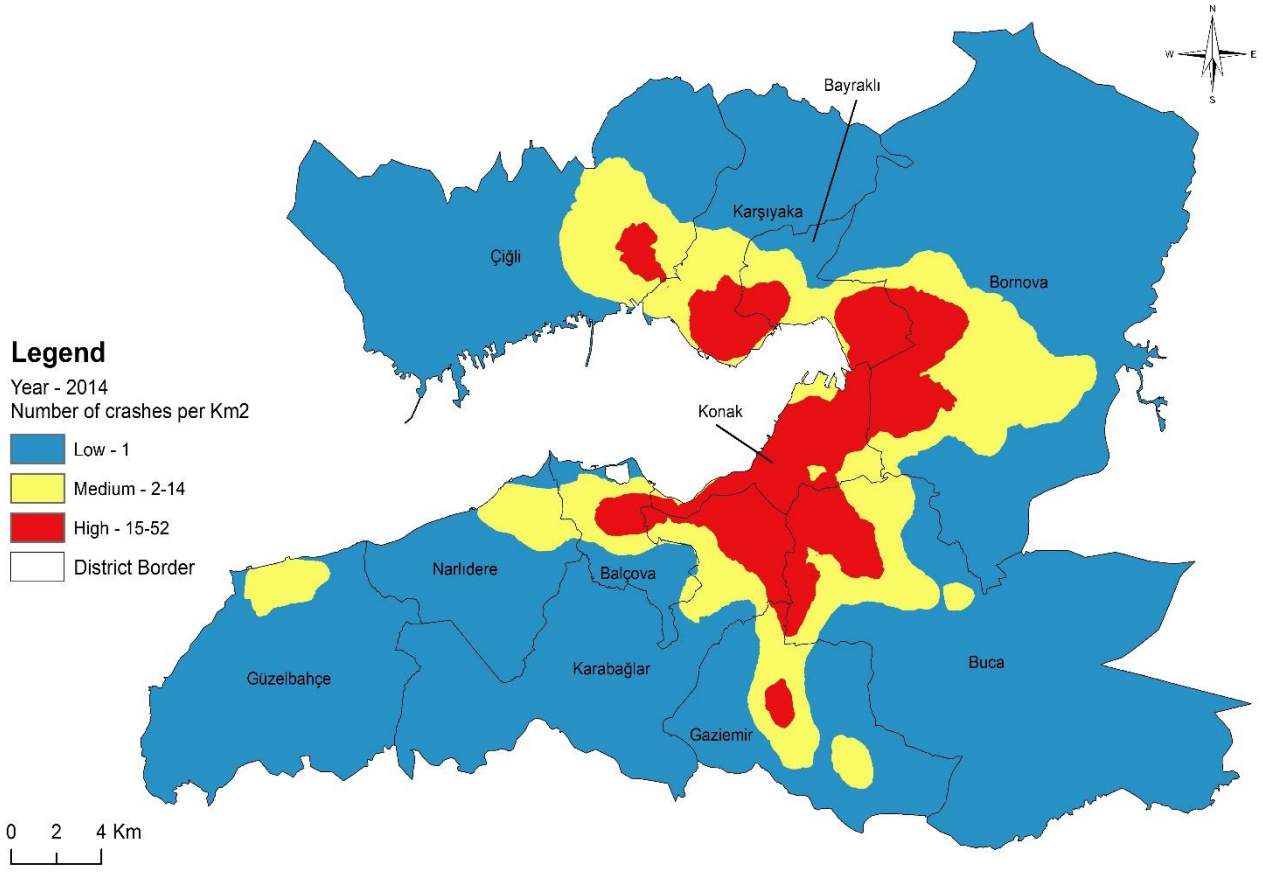

Figure 7. Line density analysis of 2014

3.3. Anselin Local Moran's I Analysis

In this method of analysis, traffic accidents are analyzed with clustering method as the statistical method. The analysis was performed using the spatial statistics tool in ArcGIS. The values in the textual table data of the input data were used when performing the analysis with this tool. The textual data used are considered as weight values in this tool. As a result of the analysis, output data are obtained in different groups as high clustering, low clustering, low-high outlier, and high-low outlier. The table for the result data contains the column CO type, which displays the groups of clustering by type of input data. As a result, it depicts high-clustered data as high-high and low-clustered data as low-low. If the numerical data around the high-clustered has a lower level of clustering, it indicates high-low in the column for result. Another type of result is displayed as low-high in the column for result if the surrounding data show high clustering while specific data have lower clustering.

The road layer of 2010 was used in the analysis. In the attribute table of the road layer, information such as the number of traffic accidents for 2010 is available. In the Anselin Local Moran's I used in this study, the road data for 2010 were selected as input data. The number of traffic accidents for the year 2010 was selected in the weight tab of the tool. In relation with conceptualization of spatial relations, zone of indifference was chosen. Euclidean distance method was used as distance method.

When the analyses of 2010 and 2014 are examined from a general point of view, clustering forms of highways are discussed as shown in Table 5. Two different types of clusters were observed between two different years as low and high clustering groups. Two groups point out that the clustering

patterns did not change between the two years. The other group shows the highways with low clustering in 2010 but high clustering in 2014. Another group represents the occurrence of clustering pattern only in one of the years while there is no clustering of the highway in the other year. Another remarkable result is the fact that whereas there was high clustering of highways in 2010, no highway shows low clustering in 2014. The analysis shows that road traffic accidents on the highways have increased and clustered from 2010 to 2014.

One of the four groups refers to the highways with low clustering of traffic accidents in both 2010 and 2014. It implies that the low-clustered highways in 2010 have not gone through a distinct manner of clustering in 2014. Thus, low-clustered highways indicate the probability of high clustering in the coming years. The common feature of the low-clustered highways is the fact that they are highways that connect the neighboring districts to the central business districts in Konak.

As a result of the analysis, 7/8 of the highways with low clusters in 2010 and 2014 appear in the table revealing increased traffic accidents. Exceptionally, a decrease is observed in the side road of Ankara Street. The most important reason for this is the road works carried out on the İzmir-Ankara highway which was under construction in 2014. In addition, it led to the use of Kemalpaşa Street as an alternative route indirectly, which caused increased traffic accidents on this road.

One of the clustering groups is the high-clustered on highways in both of the sample years. The common feature of the high-clustered highways is that they are located in the central business areas in Karşıyaka and Konak. Concerning traffic accidents, the most important highway with high clustering in both of the sample years is Gaziler Street accounted for an increase from 34 accidents in 2010 to 59 in 2014. The main reason is the fact that Gaziler Street is the highway in continuation of Kemalpaşa Street coming from Bornova district. The construction works on the İzmir-Ankara highway forced drivers for destination of the central Konak to take Kemalpaşa and Gaziler Street as alternative routes. Resulting intensive use of the two highways seems to lead to a high number of traffic accidents there.

Another high-rise road with high clusters is Girne Avenue. This avenue witnessed 33 traffic accidents in 2010; the figure was recorded as 56 in 2014. The most important explanatory factor is the connection of Girne Avenue to the peripheral road as a result of the road works started in 2011. The linkage via bridge has increased the number of vehicles coming from the peripheral road and thus pushed traffic accidents upwards.

The third group of clustering refers to low clustering in 2010 but high clustering in 2014. There are 6 highways with these features. It was also demonstrated by the analysis that the increase in clustering is accompanied by increased traffic accidents. Between 2010 and 2014, these roads recorded a 72% increase in traffic accidents because passengers reach the business centers and social activity areas in the center of Konak district via these highways causing intensity. Considering the high-clustered highways distributed across old settlement areas, the number of vehicles and drivers above the capacity of the roads seems to be one of the most important reasons for the occurrence of traffic accidents. It can also be inferred that those roads cannot be improved sufficiently. The reason for the increase in 2014 in Karşıyaka district is the short capacity of highways against the population due to the spread and development of the central business areas across the district center.

As for the increased traffic on İnönü Road from 2010 to 2014, it was caused by the closure of Üçyol Crossroads for traffic in 2010. The crossroads had been closed in 2010 due to the underground construction works in the neighborhood but it was reopened in 2013, which stands out as the prominent concrete reason for the increase of traffic accidents. As for the variance of traffic accidents between the two years on Anadolu Avenue; the connection of Girne Avenue to Anadolu Street is regarded as the most remarkable cause because drivers in Karşıyaka district can access Anadolu Street via Girne Avenue only. The reason for the increase on Menderes Street seems to be the bridge works in 2012 when a connection was built from Yeşildere Street to Menderes and Onat

Street. Therefore, passengers to the district of Buca via Yeşildere Street from Konak center travel on this highway, which results in accumulation of transport on Menderes Street. It can be observed that traffic accidents have increased since 2012. Particularly, the increase along Mustafa Kemal Beach Avenue seems at an average level compared to the average of five years. On Old İzmir Street, the increase of traffic accidents started in 2012, which corresponds to the most important change around Old İzmir Street as transformation of the urban areas. It can be suggested that the urban transformation works had a growing effect on traffic accidents in the neighborhood. It was found out that traffic accidents on Yeşillik Street were not too many compared to the average of five years.

Number four pattern of clustering concerns the highways which show clustering in the last applicable year. To put in another way, while clustering was seen on that highway in 2010, it was not the case in 2014.

Table 5. Clustering information of 2010 and 2014

Road Name	Road Length (km)	Year - 2010		Year - 2014	
		Co - Type	Number of Accidents	Co - Type	Number of Accidents
Kemalpaşa St.	20,76	Low	49	Low	69
Akçay St.	15,96	Low	55	Low	67
Ankara St.	23,43	Low	38	Low	46
Mithatpaşa St.	12,96	Low	36	Low	42
Mithatpaşa St.	7,92	Low	27	Low	38
Kamil Tunca Blet al.	5,69	Low	18	Low	27
Mustafa Kemal St.	3,44	Low	12	Low	18
Ankara St. Side Road	5,93	Low	23	Low	15
Gaziler St.	6,11	High	34	High	59
Cemal Gürsel St.	9,24	High	53	High	57
Girne Blet al.	8,07	High	33	High	56
Eşrefpaşa St.	4,85	High	40	High	38
Fevzipaşa Blet al.	2,08	High	29	High	37
Halide Edip Adıvar Blet al.	4,56	High	15	High	22
Şair Eşref Blet al.	3,28	High	18	High	21
Birleşmiş Milletler St.	3,05	High	21	High	19
Hasan Ali Yücel Blet al.	2,77	High	13	High	18
Talatpaşa Blet al.	1,77	High	7	High	17
1735 St.	1,75	High	18	High	8
İnönü St.	12,23	Low	53	High	104
Anadolu St.	15,07	Low	56	High	100
Menderes St.	4,04	Low	40	High	80
Mustafa Kemal Sahil Blet al.	12,05	Low	69	High	79
Eski İzmir St.	6,54	Low	27	High	65
Yeşillik St.	7,18	Low	32	High	48
İsmail Sivri Blet al.	7,41	High	47		
Mithatpaşa St.	7,11	High	34		
Yeşildere St.	7,3	High	34		
Hasan Tahsin St.	3,09	High	27		
Özmen St.	1,04	High	22		
Uğur Mumcu St.	2,12	High	22		
Altınyol	6,81	High	22		
Şehitler St.	4,25	High	18		
Gazi Osman Paşa Blet al.	1,81	High	17		
Doç. Dr. Bahriye Üçok Blet al.	1,79	High	15		
İnciraltı St.	3,93	High	14		
Saim Çıkrıkçı St.	1,63	High	14		
Yeşillik St. Side Road	1,24	High	13		
Forbes St.	1,42	High	13		
306/2 St.	0,81	High	13		

Liman St.	6,65	High	12		
1671 St.	4,58	High	12		
Ali Rıza Avni Blet al.	2,32	High	11		
Birleşmiş Milletler St.	0,31	High	10		
Bestekar Yusuf Nalkesen St.	1,49	High	10		
Şehit Cengiz Topel St.	1,91	High	7		
Latife Hanım St.	0,88	High	7		
Üniversite St.	7,32	Low	26		
373 St.	4,17	Low	19		
372 St.	0,78	Low	13		
8790/5 St.	3,39	Low	12		
Cengiz Han St.	4	Low	12		
Yavuz St.	3,44	Low	10		
Cumhuriyet Blet al.	3,69			High	14
Gürçeşme St.	2,55			High	11
6371 St.	1,3			High	10
Gazi Blet al.	1,77			High	9
Atatürk St.	2,57			High	9
Yeşillik St.	2,22			High	8
Yeşildere St.	0,61			High	8
Talatpaşa Blet al.	1,77			High	7
Mithatpaşa St.	7,06			Low	25
3820 St.	2,11			Low	14
Anadolu St.	9,93			Low	14
4165 St.	1,81			Low	13
252 St.	2,05			Low	11
8850 St.	5,04			Low	10
4174 St.	1.00			Low	7

As a result of the analysis for the year 2010, it was found out which of the highways were exposed to clustering of traffic accidents (Figure 8). The analysis tool used produces results in four different patterns of formats. In our study, the analysis yielded results in two different patterns as high-clustered and low-clustered. High-clustered means that traffic accidents are clustered more on these highways compared to other highways. On the other hand, low-clustered highways indicate lower levels of clustering on the highways concerned in comparison to those surrounding the clustering.

When we look at the areas with high-clustered highways in 2010, they show distribution across the districts of Karşıyaka and Konak. The highways in red in Konak district refer to enclosing of central business sites and settlements according to the land use plan. This part of the town is the place where a high number of traffic accidents take place because of the population and transport mobility. The area hosts numerous public institutions, hospitals, supermarkets, shopping centers, banks, the Kemeraltı bazaar, parks, hotels, museums, and historic sites. The prevalent spread of institutions and organizations across the area implies intensive use of highways. Therefore, traffic accidents are recorded at quite a high level.

Considering the low-clustered highways in 2010, it is likely that traffic accidents will increase in the following years. When the distribution is analyzed, it is observed that low-clustered highways are continuation of high-clustered ones.

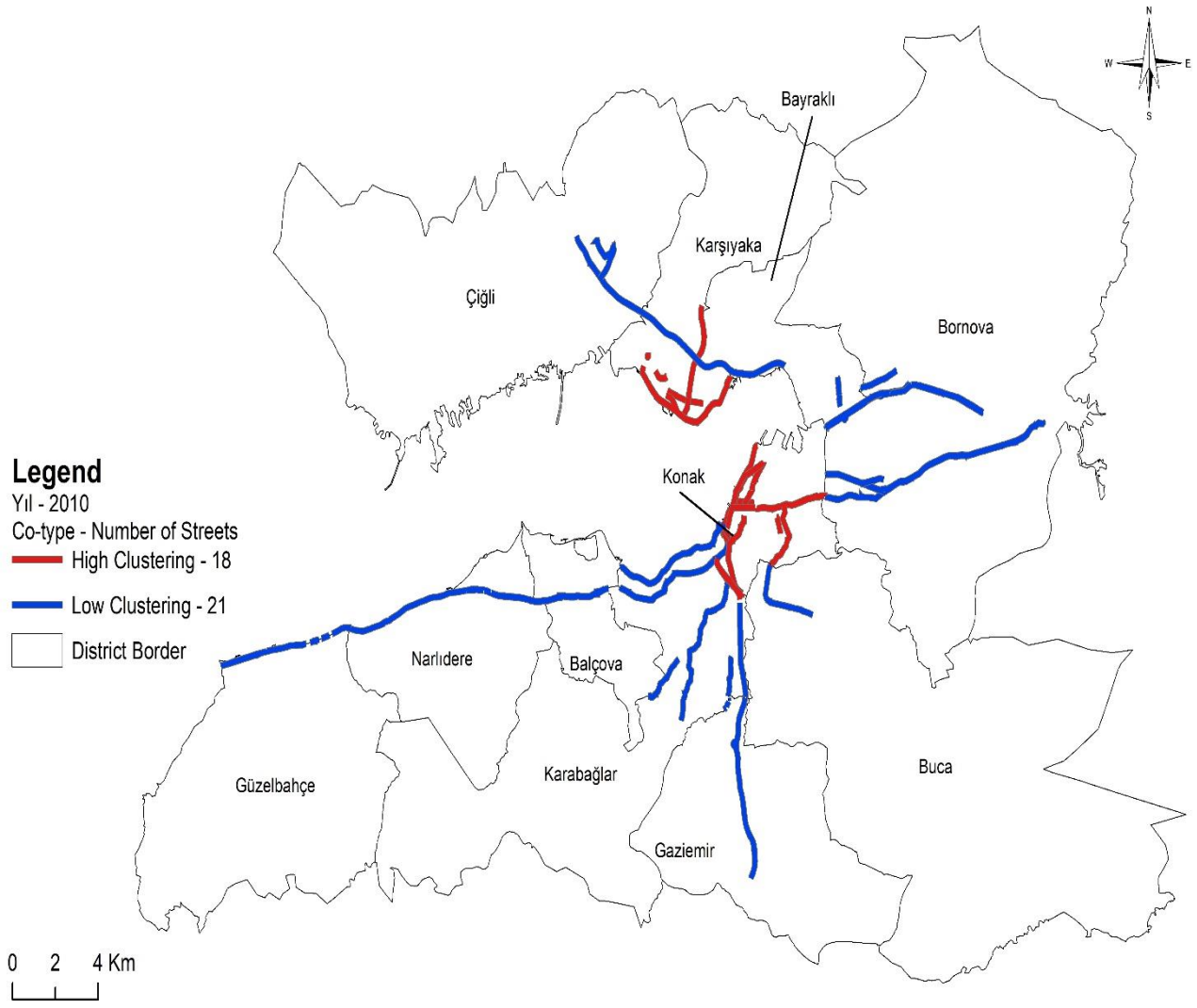

Figure 8. Anselin Local Moran I analysis of 2010

The analysis of the year 2014 marked the highways which witness traffic accidents (Figure 9). As a result of the analysis, two of the four different forms of clustering were calculated. These are high-clustering and low-clustering patterns. High-clustered highways show a distribution in Karşıyaka, Bayraklı, Konak, Buca, Karabağlar, and Balçova. Conversely, lower clustering is observed on highways in Bornova, Gaziemir, Narlıdere, and Güzelbahçe districts.

It was found out that the sites with high clusters for 2014 are scattered across areas inhabiting central business areas, new housing areas, port area, sports areas, parks, and residential areas in the land use plan. These areas include supermarkets, workshops, sports complexes, markets, shopping centers, hotels, government agencies, historical sites, banks, and museums. As a result of the increase in social and daily activities in the city center, it is seen that clustering of traffic accidents increased in 2014. Considering the low-clustered roads, they seem to be continuation of high-clustered roads. Therefore, roads with low clusters have been identified as risky highways with potential traffic accidents in the coming years.

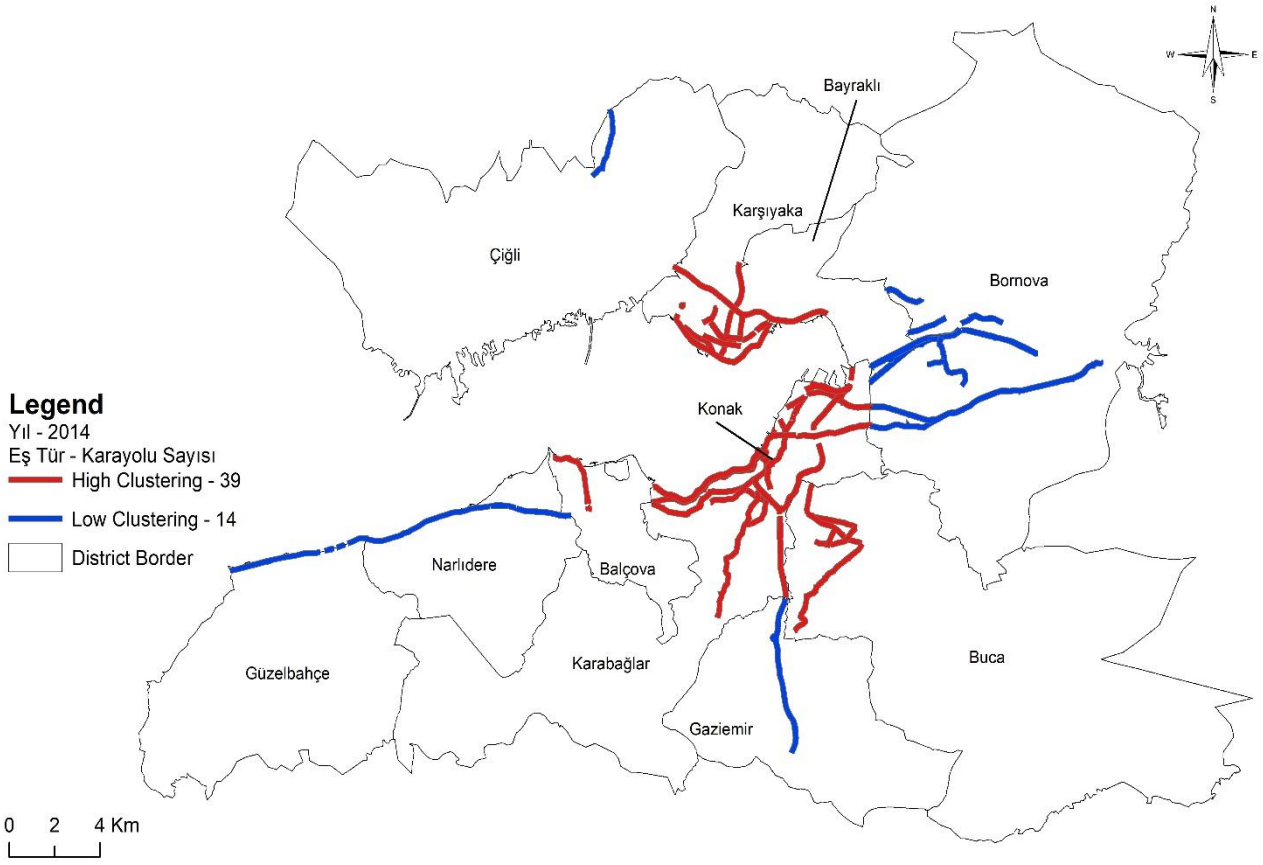

Figure 9. Anselin Local Moran I analysis of 2014

4. RESULT

In parallel with the increase of population in our country, there has been an increase in the use of different modes of transport. Among others, road transport is frequently used as a means of transport in Turkey. The highest use of highways among other means of transport leads to an increase in overall traffic accidents. For example, Turkey experienced 1.104.388 traffic accidents in 2010 but the figure increased to 1.199.010 in 2014. The number of traffic accidents increased by 8.57% from 2010 to 2014. Similarly, the number of registered vehicles in traffic in Turkey was 15.095.603 in 2010 going up to 18.828.721 by the year 2014, which indicates an increase by 24.73% from 2010 to 2014. Again, the number of traffic accidents within the study area was increased from 5,794 in 2010 to 6,808 in 2014, which shows a variance of 17%. While the number of registered vehicles in the study area was 679.822 in 2010, it increased to 791.361 in 2014. It refers to an increase of registered vehicles by 16.41% between 2010 and 2014.

The study revealed that traffic accidents are clustered at certain spots. These spots are accumulated in the south of Karşıyaka district, all over the district of Konak, northeast of Karabağlar district, and northwest of Buca. The connections of these spots regarding traffic accidents were evaluated separately.

First of all, the area to the south of Karşıyaka district was evaluated. The reason for traffic accidents in this area is the high level of everyday population mobility. Among the reasons for the high daily population mobility include governmental offices, supermarkets, and banks along with many businesses in this vicinity.

The mobility of transport in this area is accounted for by meeting of two important highways there. These highways are Girne Avenue and Atatürk Avenue. The former allows transportation in North-South direction, while Atatürk Avenue hosts transportation in West-East direction. Moreover, Street

1671 and Bahriye Üçok Avenue bring more traffic flow in this region. During the time between 2010 and 2014, increased use of vehicles on these streets seems to have increased traffic accidents.

As the second region, the results of the area to the northwest of Konak were discussed. The distinguishing feature of this specific area is the highest everyday population mobility. Another fact is the concentration of vehicles coming from other districts due to daily population mobility. The reasons for such concentration include the existence of governmental offices, shopping centers, Kemeraltı Bazaar, hotels, cultural park fairgrounds, big banks, historic sites, libraries, and museums in that neighborhood.

From the perspective of transportation, traffic flow coming from such surrounding districts as Bayraklı, Bornova, Buca, Gaziemir, Karabağlar, and Balçova towards Konak. In other words, the highways originating from the surrounding districts converge in this part of the district of Konak. Roads where traffic accidents occur most often happen on roads leading to the region. The reason for the increase of traffic accidents on these roads is the increase in the number of vehicles coming from the surrounding districts in the course of time. People from the surrounding districts visit Konak as a mandatory destination for commercial spots, governmental institutions, and social attraction areas as daily activities of İzmir residents.

By looking at the region in the northeast of Karabağlar district, the causes of traffic accidents were deduced from the analysis. Among others, one reason for the relatively smaller number of traffic accidents in this region is the fact that vehicles arriving from the southwest of Konak district use this route. As a result of the study, it was found out that Old İzmir Street is one of the most used highways as a connection to Konak district from Karabağlar district. Strikingly, the rate of traffic accidents on Old İzmir Street increased by 140% between 2010 and 2014. Among reasons for that increase, it must be mentioned that gradual population increase and resulting increase in vehicles around Karabağlar district do not suffice to bear connection to Konak. Besides, commuters who live in Karabağlar go to and from work in Konak, which hosts a heavy number of business places, via this route.

As a result of the study, also, the reasons for intense traffic accidents in the northwest of Buca district were highlighted. Among reasons for the increase in traffic accidents, everyday commuters travel via Menderes Street. It is the highway that connects the northwest of Buca district to the southeast of Konak. By the year 2014, traffic accidents on roads increased by 100%. Drivers take Menderes Street as one of the most important routes connecting to central business areas on their way to center of Konak district.

In the light of the overall results obtained from the study, it was revealed that traffic accidents are related to the specific spot they take place. The study also demonstrated that the increase in traffic accidents is accounted for by commercial areas, residential areas, sports areas, urban development areas, parks, and recreation areas at a certain extent. As a conclusion, the need becomes even clearer for planning highways by considering particular land uses.

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