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IDENTIFICATION OF BLACK-SITES USING GEOGRAPHICAL INFORMATION SYSTEM

Muhammed Yasin Çodur[1], Kadir Diler Alemdar[2], Ömer Kaya[3], Emre Kuşkapan[4]
[1,2,3,4] *Erzurum Technical University, Civil Engineering, Transportation Department, 25050, Erzurum, Turkey*

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Abstract: As the number of vehicles increased in the world, more traffic accidents happen and traffic accidents have become one of the important problems in the World. According to the researches and statistical information made, traffic accidents cause material and spiritual loss as much as natural disasters. Because of this, traffic accidents have an important role in the policies of the countries. Therefore, many studies are being conducted in this area. Some of these studies have focused on traffic accident analysis. By analyzing the traffic accident, it is very important to determine the points where traffic accidents are concentrated. These points; can be detected with the help of Geographical Information System. In this study, points of density traffic accidents were identified and black-sites were determined using the 2017 traffic accident data of Erzurum province, in Turkey. Various suggestions were made to reduce traffic accidents, at the black-sites and in the whole city.

Keywords: Geographical Information System, black-sites, traffic accidents, traffic safety, Erzurum.

1. Introduction

Rapidly growing population in the World and in the Turkey brings the need for transportation. Due to this need, the number of vehicles on the road increases every day. In addition to these factors, due to rapid and crooked urbanization and the reasons of various transportation policies, traffic problems and traffic accidents have become a crucial problem. According to data from the end of February 2018, there are a total of 22,377,559 road motor vehicles in Turkey (TSI, 2018a). Road traffic accidents cause an average 1.25 million deaths per year, or 3,424 deaths per day. Road traffic accidents alone account for 2.1% of all deaths worldwide and rank 11th among causes of death. 90% of the deaths on the road are in low and middle income countries (WHO, 2013). Between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury. The results of traffic accidents in our country are of both material and spiritual dimensions of worry. 1,182,491 accidents in 2016 occurred in Turkey. A total of 7,300 people lost their lives and 303,812 people were injured (GDS, 2018). Due to these very bad results of traffic accidents, many studies have been carried and are being continued on this area. Some of these studies have focused on the points where traffic accidents happen. The aim is to make research and implementation in order to reduce the number of accidents. It is considered that the source of the studies to reduce traffic accidents is insufficient (Erdoğan *et al.,* 2008). For this reason, studies done to prevent more accidents

[1] Corresponding author: mycodur@erzurum.edu.tr

at low cost should be given importance. In other words, it is necessary to determine the points where traffic accidents are experienced intensively. If the accidents at these points are three or more in a year period, these points are called black-sites. It is imperative to identify black-sites in order to reduce the number of fatal or injured accidents or reduce them below a certain number.

Various methods are used to determine black-sites and one of these methods is Geographical Information System (GIS). The purpose of this study is to determine the black-sites where traffic accidents happened in Erzurum province roads using GIS. Mapping of traffic accident data for 2017 with ArcGIS help was done. Later, black-sites were identified by determining the areas where the accidents were clustered. Erzurum province to do study, where is one of the most developed provinces in Turkey's Eastern Anatolia Region. Some traffic accidents may occur due to heavy winter conditions in the region, snow and ice. For this reason, the accidents may have been clustered at some point. These points must be examined experts on transportation area. Suggestions were made about measures that could be taken in these black-sites, in the end of the paper. Some of the studies done on this subject have been given in the continuing of the paper.

Various studies have been carried out using GIS or spatial-temporal methods. A study was conducted about traffic accidents using both of these methods in 1996 in Norfolk, UK. In this study, K-function analysis method was used for determining the presence or absence of hotspot clustered. The researchers were able to determine the locations of the clustered central accidents and to reduce the number of accidents that occurred at these points (Jones *et al.,* 1996). Thieman (1998) has done a study on black-sites detection in Cheyenne. In this study, Thieman was able to compare and query data without causing confusion with the GIS. In other study, GIS is a publication that will form an infrastructure for the need for road safety. The main objective in this publication is to ensure that GIS experts and security staff work together (Smith *et al*., 2001). Terzi and Karasahin (2002) explained the importance of GIS in transportation engineering. They gave information about the use of GIS in traffic accident analysis, inventory studies, and transportation planning and junction control. Many studies have been conducted to determine the black-sites where vehicle accidents happen (Flahaut *et al.,* 2003).

Again in 2004, a study was carried out in the Mechelen section of Belgium to find black-sites. After using the linear and planar cluster analysis methods and comparing them, the researchers detected hotspots (Steenberghen *et al.,* 2004). Saplıoglu and Karasahin (2006) using GIS analyzed the traffic accidents in the city center of Isparta between 1998-2002. It was seen that most of the accidents took place at junctions. For this reason, junctions and streets have been examined separately and priority has been given to the examination of junctions. According to the results obtained, the black-sites numbers are as follows; 12 for 1998, 16 for 1999, 14 for 2000, 13 for 2001, 21 for 2002. Increase in black-sites numbers is observed year by year. Erdogan et al. (2008) worked on a highway at the entrance of Afyonkarahisar, in Turkey, to determine the accident distribution. They identified three significant hotspots in their research and proposed to relevant traffic departments to solve these problems. In 2009 in London, a study using GIS and kernel density was made on the models injured accidents. This study

tends to present a methodology for finding in terms of accidents hotspots, using GIS, kernel density, accident data of relevant regions and average K algorithms of the similar regions. This methodology and clustering technique were obtained by examining the 5-year accident data in the study area in London. Despite previous investigations, it was assumed in this survey that the accidents occurred in the same region. Also, this research tends to investigate hotspots, to cluster these points, and to perform semiotics based on spatial indices (Anderson, 2009). Kabakus et al. (2012) evaluated with GIS the traffic accidents that took place in the district of Erzurum. They showed that GIS helped in traffic accident analysis and showed that there were more traffic accidents in the district center of Erzurum. Dereli et al. (2014) used spatial statistical methods supported by GIS to determine the black-sites. For the application, a case study of highways for 30 Control Cut Numbers (CCN) belonging to Afyonkarahisar-Konya provinces was selected. During the period of 2005-2011, a total of 9,280 traffic accidents occurred in the pilot region. Due to these accidents, 965 people lost their lives and 22,011 people were injured. In the scope of this study aiming to reduce traffic accidents, 20 points were determined as black-sites. (Codur and Tortum, 2015) conducted a study for the analysis of traffic accident in the Erzurum province. Traffic accidents were investigated by help from GIS in 2016 in Kahramanmaras, Turkey. As a result of this study, it is suggested to use GIS in terms of effective accident analysis (Geymen and Dedeoğlu, 2016).

2. Materials and Methods

The material of the work is the city of Erzurum and its immediate surrounding (Figure 1). The center of the city has an area of approximately 825 km^2 and is located in the south in the southeastern part of the Erzurum Plain, one of the largest plains of the Eastern Anatolia Region, and on the north slopes of the Palandöken Mountains. With an average elevation of 2,000 m, Erzurum city is the largest city with the highest altitude among the cold-belt cities in the northern temperate zone (Kocaman *et al.,* 2013). Turkey's most severe climate reigns in this region where summers are hot and dry, winters are cold and snowy. The average annual temperature is 6°C, the coldest month average –8.3°C. The hottest month average is 20.2°C. The average temperature is about 8°C below about 220 days of the year.

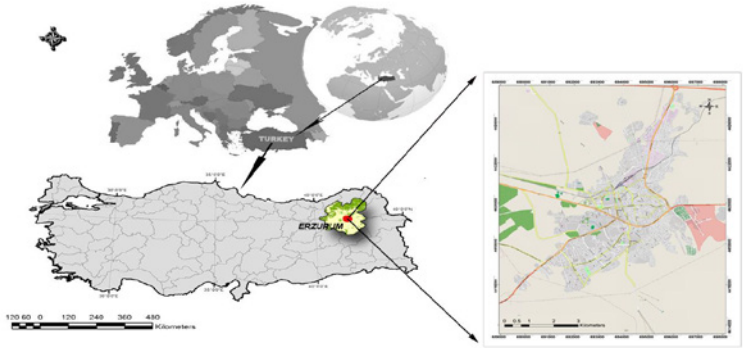

Fig. 1.
Erzurum City Location Map

Population statistics of Erzurum province are given in Table 1. However, the population of the city may vary in the year because of the region is most important winter tourism in Turkey. There is also a student population due to the two universities in the city. As of January 2018 has a total of 22,325,033 vehicles, In Turkey. Vehicle types and numbers in Erzurum are given in Table 2. However, only the number of vehicles registered in Erzurum province. Apart from these, it belongs to another city and there are vehicles used in Erzurum. The lengths of state and province roads in Erzurum are given in Table 3.

Table 1

Population Statistics of Erzurum

Year	2010	2011	2012	2013	2014	2015	2016	2017
Population Statistics	769,085	780,847	778,195	766,729	763,320	762,321	762,021	760,476

Source: Turkish Statistical Institute, 2018b

Table 2

Vehicles types and numbers in Erzurum

Car	Minibus	Bus	Small truck	Truck	Motorcycle	Special purpose	Tractor	Total
57,943	3,013	1,167	26,600	5,981	2,657	704	19,584	117,539

Source: Turkish Statistical Institute, 2018c

Table 3

State and Province Roads in Erzurum

State and Province Roads (Km)							
Asphalt Roads							
Asphaltic Concrete	Surface Treatment	Total	Stone Block	Stabilized	Earth	Primitive	Total Length
482	1,038	1,520	2	32	15	132	1,701

Source: General Directorate of Highways, 2018

Accident analysis studies are usually based on statistical data. Because traffic accidents, when and where will come, are unpredictable events that cannot be tracked objectively (Bayrakdar, 1996). Accident area analysis is a research that reveals what the necessary corrections can be made by using traffic safety or solving problems related to it. The analysis of the accident area begins with the identification of the accident parts called black-sites. In order to be defined as a black-sites, it is necessary to have 3 or more accidents that have occurred in the same type within 1 year. However, this value may vary from country to country. There are many methods used to detect black-sites and some of them:

- Number of Accidents (Accident Frequency, Map) Method;
- Accident Repeat Rate Method;
- Table (Number- Ratio) Method;
- Equivalent Weight (Accident Severity) Method;
- Ratio Quality Control Method.

GIS based on number of accidents were used to determine black-sites in the paper. A brief on GIS is given below.

GIS is a computer-based system developed for entering, archiving, analyzing and outputting geo-referenced data linked to the country and land reference system. In other words, it can be defined as providing efficiency when spatial data is related to the database on the graph (Mandloi and Gupta, 2003). A GIS consist of the following sections:

- For data entry; maps, aerial photos, satellite imagery and other sources;
- Data storage, retrieval and query;
- Data transformation, analysis and modelling;
- Preparing a data report (Prathibha, 2014).

The most important stage in GIS technology is the creation and inquiry of the databases. Statistics and geographical analysis studies are conducted according to the results of the inquiry. Their study with visualizations facilitates the visual perception of the results as it allows the user to interrogate for different purposes. In the field of transportation; it is thought that this system which supports the decisions that engineers, traffic planners and administrators will make at every stage of the planning, design, implementation, maintenance, repair and supervision process will help prevent material and moral loss that may occur due to accidents during today's information and communication age.

3. Results and Discussion

Due to location of Erzurum province, the city is an intersection point where the highways of neighboring provinces. Due to the ease of access to other eastern provinces and the fact that it is a city of the region, the trade in Erzurum province is advanced according to the surrounding. This situation is still going on and it is an important center for road transportation. Due to the fact that there are two universities in the city and it is haunt point for winter tourism, there are high levels of mobility in the city. In urban transportation system of Erzurum, there are three main axes extending in the east-west direction in terms of traffic density (Figure 2). These are:

- North Circle Road and 50th Street;
- Cemal Gürsel – Cumhuriyet Street passing thorough the city center;
- South Circle Road, which is located between the Ataturk University and Karskapı.

The main axis of the center of the province is Cumhuriyet Street, extending in the east-west direction. The main roads connecting this road to the peripheral road running south; Paşalar and Ali Ravi streets. The main streets extending in the north direction are; Hastaneler, Çaykara, Mumcu, Adnan Menderes, Taş Mağazalar and İstasyon streets. The majority trade and business centers of the province are concentrated on these streets. For this reason, heavy traffic is seen in these regions (Gökdağ and Yarbaşı, 2004).

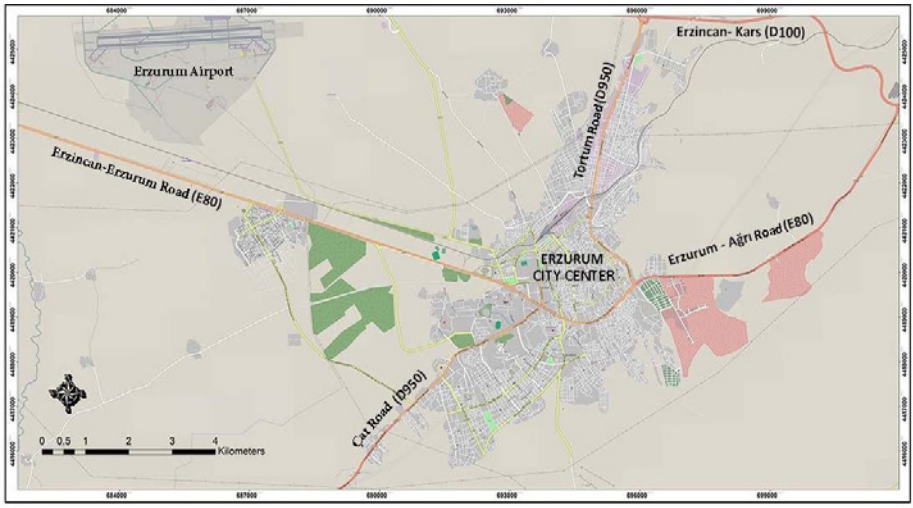

Fig. 2.
Erzurum City Highway Network on Google Earth

The above figure shows the general highway network map of Erzurum. The E80 road is 5,600 km length and is an international road that starts in Portugal and ends at the Gürbulak border gate upon entry to Iranian. Because an international road passes through the city center, the traffic density is occurring and traffic accidents happen in the city. In Erzurum and Turkey, statistics of traffic accidents is given *Table 4*. Material damage accidents that the parties have made in agreement between themselves are not included. It contains the dead numbers from the crash point as a result of traffic accidents.

Table 4
Accident Statistics (in 2017)

	Death and Injured Accident	Material Damaged Accident	Number of Dead	Number of Injured
Turkey	182,424	227,943	3,530	303,663
Erzurum	1,598	2,056	47	3,233

Source: General Directorate of Security, 2018

In Erzurum, the traffic accidents that occurred during the year 2017 were questioned via GIS and the maps obtained helped to observe the regions where traffic accidents density. By transferring the spatial data of the accidents to the GIS, it is possible to establish relations with their distributions and spatial components. From this point, the ArcGIS program was used to determine the places where all the accidents that occurred during the year 2017 were concentrated. As a result of the analysis, the traffic accidents are shown in as point via Google Earth in Figure 3. In Figure 4, these accidents are shown on the roads around Erzurum province and its vicinity. Figure 5 shows a cluster of traffic accidents and black-sites.

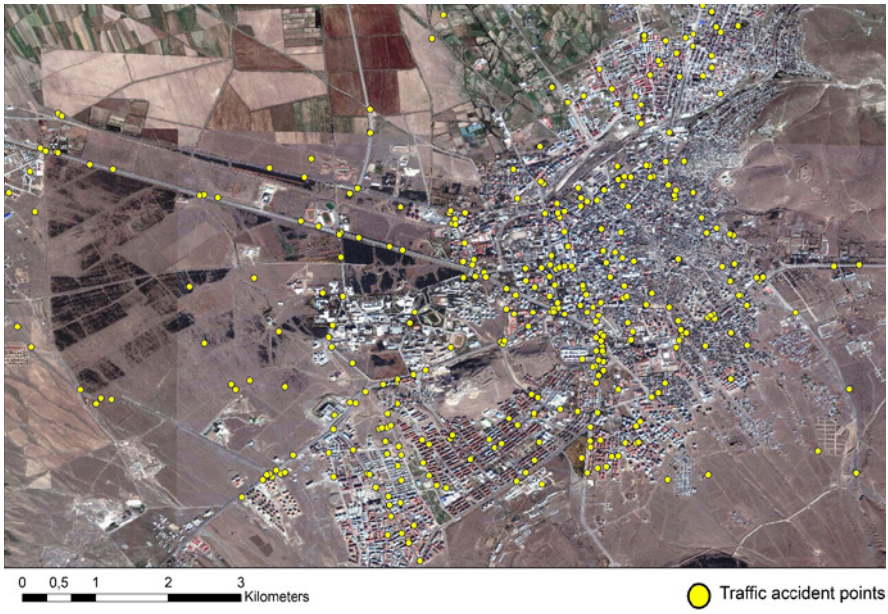

Fig. 3.
Traffic Accidents Locations on Google Earth

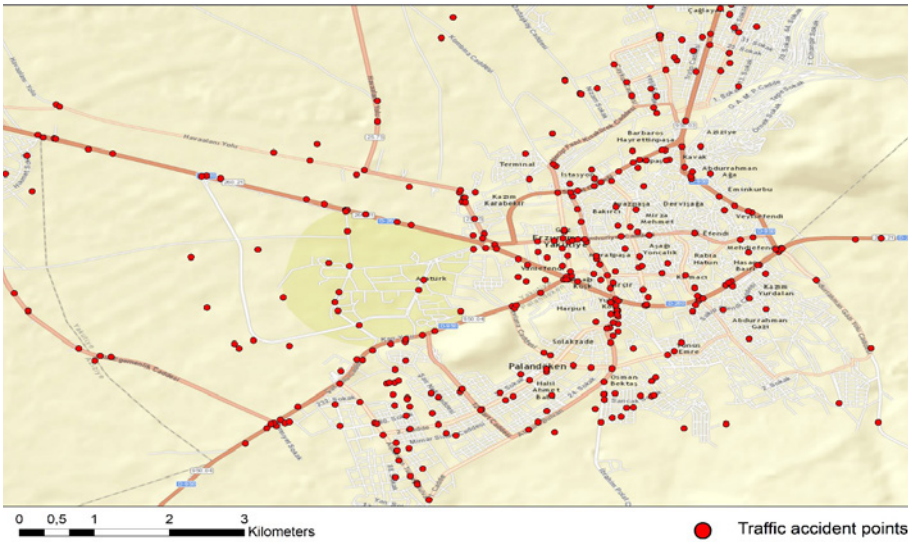

Fig. 4.
Traffic Accidents Locations on Roads

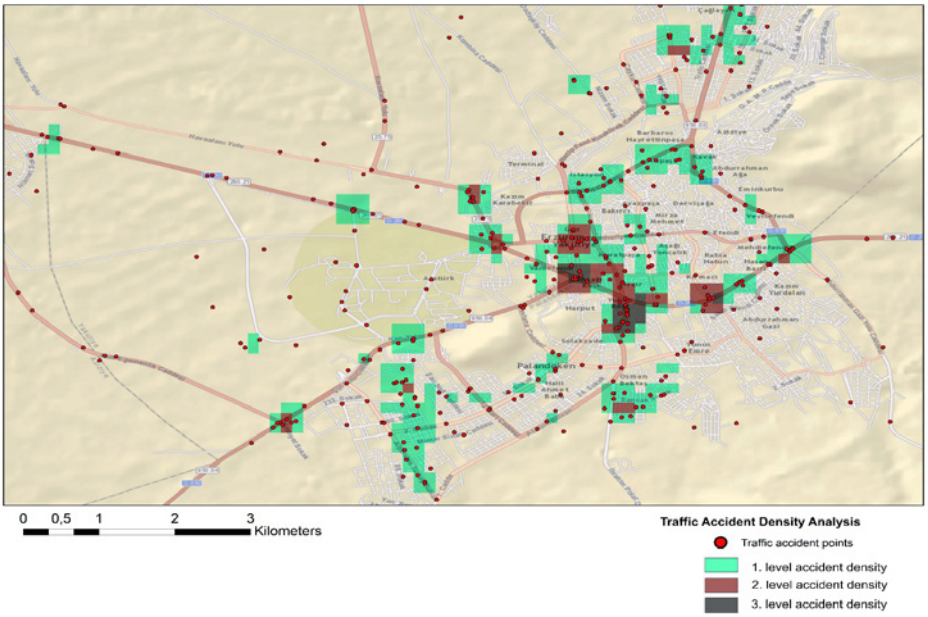

Fig. 5.
Locations where Traffic Accidents are Intensified

As a result of the analysis, the accidents that occurred in 2017 were examined on three criteria and these; 1st, 2nd and 3rd level. If there are 3 or more traffic accidents at the point in a year period, these points have 3rd level accident density. If there are 2 traffic accidents at the point in a year period, these points have 2nd level accident density. If there are 1 or less traffic accidents at the point in a year period, these points have 1st level accident density. Regions with 3rd level are places where accidents density is highest. These points are called black-sites. Accident density is highest at Buhara Hospital junction where on Fatih Sultan Mehmet Boulevard and Ataturk Boulevard (Figure 6). This road section is located at the intersection of Ataturk Boulevard and Fatih Sultan Mehmet Boulevard. This road is also one of the roads connecting the southern parts of the city to the northern parts of the city. The only private hospital in Erzurum is at this point. In addition, this point is on the transit route of the E80 highway. Because of all these reasons, both the urban traffic and the transit traffic occur at this junction and its surrounding. Because of this traffic, many accidents happen at this point.

Fig. 6.
Fatih Sultan Mehmet Boulevard on Google Earth

Another point where the high density of the accident is again the junction of Governorship located on Fatih Sultan Mehmet Boulevard. This road section is one of the roads connecting the western and southern parts of the city to the north section. There is a state hospital, many public buildings in this region and it is on the transition route of the biggest hospital of Erzurum. This road section is the intersection of the E80 and D950 highways. Traffic density is high at this point due to both the urban traffic and the intersection. The image of this junction is shown in Figure 7.

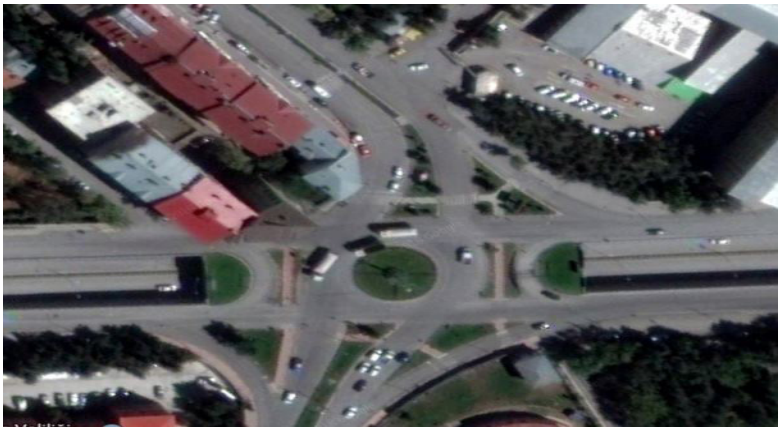

Fig. 7.
Junction of Governorship on Google Earth

4. Conclusion

The consequences of traffic accidents can be deaths, injuries and material damage. These negativities caused by traffic accidents are great importance for the country. In order to reduce these negativities, most of the local governments have planned the transportation systems. The purpose of the planning of transportation systems is to optimize the location of the activities required to be created and developed in specific locations and the location of the interchanges between them. A good transportation planning is realized by finding the problems, collecting the necessary data, analyzing collected data, producing solution options, finding the most suitable solution considering the resources and constraints. Today, one of the biggest problems facing cities is traffic congestion. Particularly in urban centers, traffic is completely blocked at certain times of the day. Traffic congestion causes vehicles to travel at very low speed, thus reducing both fuel efficiency, increasing the amount of the emissions and the time people spend on transportation (Elbeyli, 2012). Traffic accidents caused by vehicles have become one of the most important issues threatening human life today. The use of motor vehicles has increased rapidly, but transportation systems and road conditions are not ready for this increase. Therefore, accident rates on the World have increased. This situation is valid also in Erzurum. In recent years, accidents have been increasing year by year in parallel with ongoing vehicle traffic, especially in highway transportation.

As can be understood from the analysis of the maps obtained with the help of GIS, the accidents seem to concentrate mostly in the city center and junctions. In order to reduce this density, studies should be carried out to direct the people of Erzurum to public transportation. For this, the number of voyages of public transportation or reduce public transportation fees. But it takes a long time get it. Because of this, traffic lights may need to be improved in areas where accident are density. In addition, warning plates and Intelligent Transportation System applications can be used in these areas. Because Erzurum is a city where winter conditions are severe, it is important to fight against snow and ice in the whole city and especially the black-sites.

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