A GIS APPROACH TO EVALUATE INFRASTRUCTURE VARIABLES INFLUENCING THE OCCURRENCE OF TRAFFIC ACCIDENTS IN URBAN ROADS

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ABSTRACT:

Several studies worldwide have been developed that seek to explain the occurrence of traffic accidents from different perspectives. The analyses have addressed legal perspectives, technical attributes of vehicles and infrastructure as well as the psychological, behavioral and socio-economic components of the road system users. Recently, some analysis techniques based on the use of Geographic Information Systems (GIS) have been used, which allow the generation of spatial distribution maps, models and risk estimates from a spatial perspective. Sometimes analyses of traffic accidents are performed using quantitative statistical techniques, which place significant importance on the evolution of accidents. Studies such as those in references have shown that conventional statistical models are sometimes inadequate to model the frequency of traffic accidents, as they may provide erroneous inferences. GIS approach has been used to explore different spatial and temporal visualization technologies to reveal accident patterns and significant factors relating to vehicle crashes, or as a management system for accident analysis and the determination of hot spots. This paper examines the relationship between urban road accidents and variables related to road infrastructure, environment and traffic volumes. Some accident-prone sections in the city of Kocaeli are specifically identified by GIS tools. Urban road accidents in Kocaeli is a serious problem and it is believed that accidents can be related to infrastructure characteristics. The study aimed to establish the relationship between urban road accidents and the road infrastructure variables and revealed some possible accident prone locations for the period of 2013 and 2015 in Kocaeli city.

KEY WORDS: GIS, Accident, Road, Infrastructure, Spatial Analysis

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1. INTRODUCTION

The problem of urban road accidents in Kocaeli city is remarkable and has a significant magnitude. For this reason, a technical study of this important issue that examines the relationship between urban road accidents and variables related to road infrastructure, environment, traffic volumes and traffic control is crucial. Some accident-prone sections in the city of Kocaeli are specifically identified by the spatial analysis methods based on GIS. During 2015 there were a total of 2785 road traffic accidents in Kocaeli.

When the traffic accidents are approached using quantitative statistical techniques, the commonly used indicators conceal the problem's determinant variables. Several studies have been developed that investigate to explain the occurrence of traffic accidents from different perspectives. The analyses have addressed legal perspectives, technical attributes of vehicles and infrastructure as well as the psychological, behavioral and socio-economic components of the traffic users (Flahaut, 2004). There has also been some analysis techniques based on the use of Geographic Information Systems (GIS) which allow the generation of maps, models and risk estimates from a spatial perspective. GIS techniques provide significant tools for maintaining, analyzing, locating and publishing traffic accident-related spatial information. GIS approach has been used to explore different spatial and temporal visualization technologies to reveal accident patterns and significant factors relating to accidents.

Spatial data analysis can be viewed as it is one of the most important tool for traffic accident analysis. GIS aided spatial data provides much information to analysts about risky locations, hot spots and critical patterns. (Liang et al., 2005, Erdogan et al. 2008). Identification of safety deficient locations with GIS will certainly help to decrease the traffic accidents in the region.

This paper examines the relationship between urban road accidents and variables related to road infrastructure, environment and traffic volumes in Kocaeli. Some accident-prone sections in the city of Kocaeli are specifically identified by GIS spatial analysis tools. It is believed that urban road accidents is a serious problem in Kocaeli and accidents can be related to infrastructure characteristics. The study aimed to establish the relationship between urban road accidents and the road infrastructure variables and revealed some possible accident prone locations for the period of 2013 and 2015 in Kocaeli city. Our analyses, hitherto, aim at the identification of high rate accident locations in the city and safety deficient areas on the highways.

Density analysis was applied to identify the accident prone areas in Kocaeli district during the year of 2015. Both simple and Kernel densities were applied in identifying the accident patterns. The road geometry was measured in the accident prone locations to find out the causes for the accident.

2. METHODOLOGY

Traffic safety at a roadway is mainly affected by human factors, environmental factors and vehicle characteristics. However, there are other factors such as highway design and design associated geometry (Mungnimit 2001; Bener 2005). Therefore, improving safety on roadways can be achieved through further improvements in a variety of geometric design improvements in roadway safety features. In developing countries, accident number and type of the accident are mainly registered for the drivers to be the cause of accidents regardless of the real cause of the accident. Hence, neither the roadway geometry nor the environment is considered as a cause for accidents, simply because there is an ambiguity of the accident's cause for the authorities.

Highway geometry should be designed for vehicle traffic safety and efficiency. For example, the minimum radius of horizontal curve is defined with design speed, superelevation and side slip friction factor. The authors suggest that all of the design standard values should have a unique safety factor to keep consistent traffic safety. Studies showed that horizontal curves typically have more crash rates than tangent sections. (AASHTO, 2004; Obaidat and Ramadan, 2012) In fact, the use of composite curves (e.g. spiral curves, simple circular curves) could help to mitigate some of the safety problems associated with horizontal curves by providing a smoother and safer path for drivers from tangent to curve position. It is usually beneficial to design horizontal alignments with combinations of maximum curve radii and minimum deflection angles since crash rates tend to increase with the reduced sight distance associated with either a reduced curve radius or an increased deflection angle or curvature.

It is believed that vertical alignment can also lead to higher crash rates due to the reduced sight distance imposed by the crest of a vertical curve. Thus the severity of vertical curvatures should be minimized. It is avoided for the intersections on or near vertical curves represents one of the practical examples in this respect (Hong and Oguchie 2005; AASHTO, 2004). Roads with poor geometry, with insufficient clear distances, without turn lanes, with poorly laid out intersections or interchanges, pose greater risks to traffic users (TRIP, 2009). Therefore, this paper will focus on hazardous locations in Kocaeli district (Figure 1) and the correlation of accident characteristics with geometrical elements of the roads. The spatial characteristics of road crashes in the city will be analyzed by spatial analysis tools.

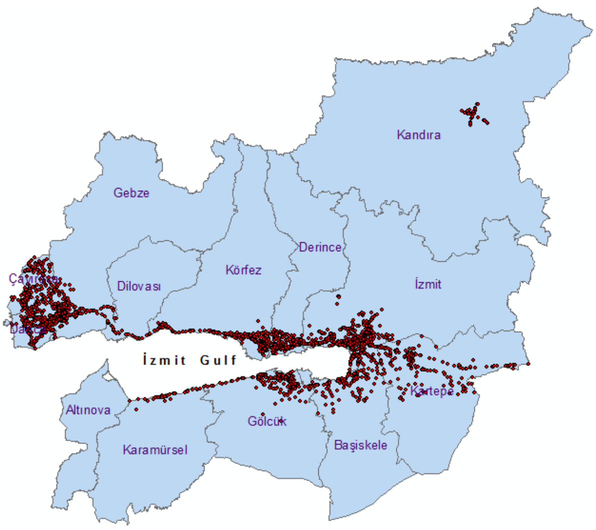

Figure 1: Study area and accident locations for the year of 2015

2.1 Accident density pattern analysis

In order to detect road traffic accident concentration, mainly from the geographic perspective, various methods have been proposed and applied, mainly including spatial autocorrelation methods and kernel density methods. The autocorrelation methods detect whether a given point distribution differs from a random distribution throughout the study area, such as Ripley's *K*-function, Getis's *G*-statistic and Moran's *I* (Boot & Getis 1988; Ripley 1981;Getis & Ord 1992).

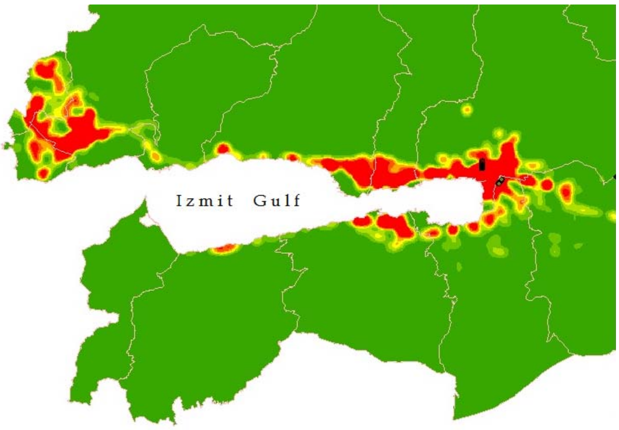

Figure 2: Simple density map for the accidents for the year 2015

Accident data can simply be represented as geospatial points. A cluster of accidents indicates spatial patterns with high density accidents in that area. Therefore, geospatial clustering method may be able to determine the concentrated areas of accidents.
Geospatial cluster analysis, which is also called geospatial clustering, is an approach to applying spatial clustering techniques on georeferenced data. As widely known, spatial clustering is the process of grouping similar objects based on their distance, connectivity or relative density in space (Han et al. 2001). In addition, clustering methods can discern interesting spatial patterns and features, capture intrinsic relationships between spatial and attribute data. Figure 2 shows the result map of simple density map produced for the accidents occurred in 2015.

Kernel density methods aim at calculating and producing a density surface from point features. Usually, the methods divide the whole area into grid cells, and calculate the density of point features around each output raster cell. The raster cells with high values indicate the accident concentration areas (Fig. 3).

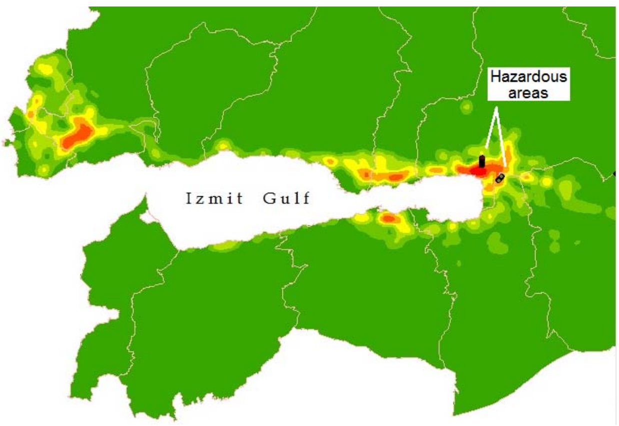

Figure 3: Kernel density map for the accidents for the year 2015

One of our concern is with whether or not the traffic accidents shown in Figure 3 tend to cluster. To answer this question, we may use the *K*-function method. Positive spatial autocorrelation indicates that accident distribution is clustered, which means the concentration may happen in the study area. *K*-function is one of the evaluation methods. It is defined as the expected number of points within a distance *d* of an arbitrarily chosen point, divided by the density of points per unit area. We apply the K-function method to these assigned points in the region. The result is shown in Figure 4. The red line indicates the observed K-function, and the blue line indicates the expected K function obtained under the condition that the points are randomly distributed over the region according to the uniform distribution. Comparing the observed K-function with the expected K-function, we conclude that the traffic accidents tend to cluster in Kocaeli.

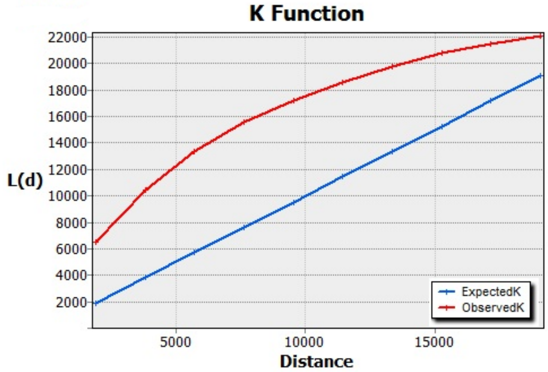

Figure 4: K- function calculated for the accidents (2015)

When the difference between observed and expected K-function versus distance is plotted, the mean distance between clusters is found to be approximately 7950 m (Figure 5).

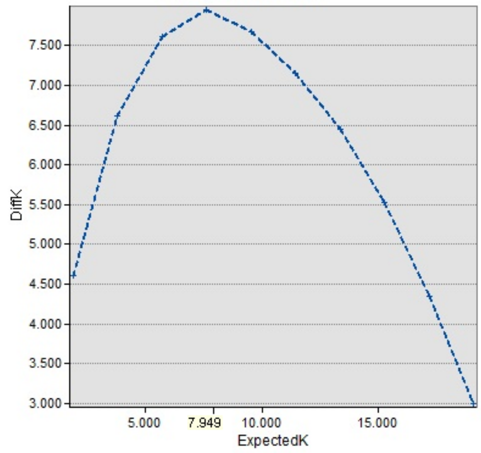

Figure 5: The graph of K- function

Our second concern is with whether or not the traffic accidents tend to gather around some road sections in the region. Naturally if an area on the density map is marked as high risk, that area should be more vulnerable to accidents. Then the road sections located in these risky areas are examined from the geometrical perspectives in the region.

2.2 Results and discussions

Produced density maps show the possible hazardous areas for traffic accidents (Figure 3). Road sections related to the these concentration areas are examined considering the geometric elements of the roads to find relationships. Black dots in the figure 3 denotes these investigated road sections. One of the most critical road section in the region is known as "Gazanfer Bilge Avenue" since the profile slope has quite high (18%) value (Figure 6).

Figure 6: Road section in Gazanfer Bilge Bulvarı

This slope value should not be higher than %10 slope value according to the national highway standards. Accident records at the region are denoted as yellow points in figure 7.

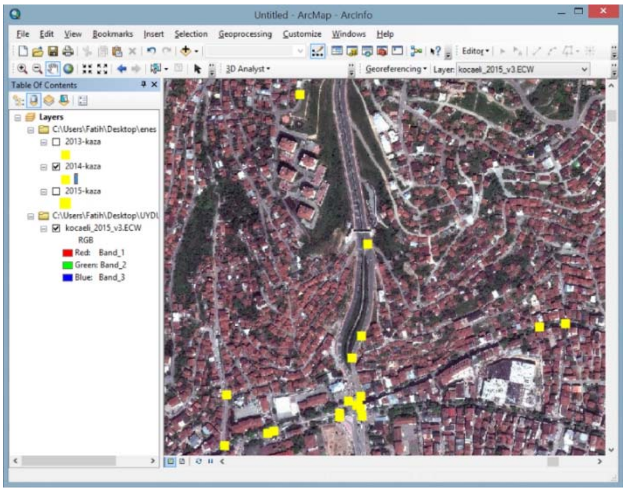

Figure 7: Accidents at the road section in Gazanfer Bilge Avenue

According to a case study (technical report supervised by Çepni, Kocaeli, 2016) which has been conducted to define a new path and to decrease high slope to an acceptable level, topography is not solely factor which should be taken into consideration to a better solution. During the assessments made in surveying along the avenue and evaluating the options, decreasing of slope interpreted as an unfeasible solution for the problem. Despite the extremely high slope, Gazanfer Bilge Avenue is in fact a rational route though to be straight beeline toward northern part from city center. Because of the rough terrain, current alternative routes between downtown and growing settlements (e.g. university campus) are tortuous and time consuming in comparison with the current Gazanfer Bilge Avenue. Therefore, in order to avoid traffic accidents, prescriptive precautions have been recommended instead of the replacement of a new route. The section is also shown in the figure 3 from the geometrical point of view.

The other road section that is marked as high risk on the density map, is known as "DSİ Kavşağı (junction)" region (Fig. 8).

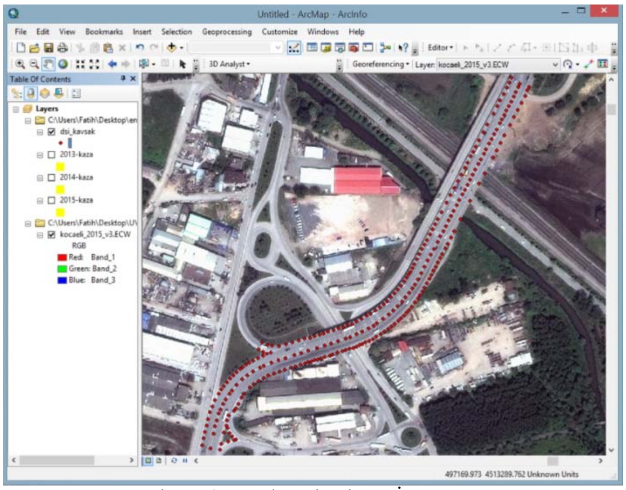

Figure 8: Road section in DSİ Kavşağı

Accident records at the DSİ Kavşağı region are denoted as yellow points in figure 9. It is believed that poor horizontal road geometry tends to increase accidents in the district. Both horizontal and vertical geometry of DSİ Kavşağı was also studied in the case study as previously mentioned above. Marked points in Figure 8 were surveyed due to delineated of the roadway segment. Both components of junction was evaluated as inadequate regarding to the national highway standards. The main handicap of roadway design is redundant unified curb located on north south direction. It has been speculated that at the stage of road construction the curves were planned so as to preserve some current buildings. Distance between two horizontal small radius simple curves can be accepted narrow enough, even though flowing speed on the previous section of curb doesn't support this poor geometric conditions. As it can be seen at Figure 9, accidents are therefore occurred in the passage section of curve because of the unexpected sharp bend. Other deficient of the bend is inaccurate transverse slopes on the curve which is known as superelevation slopes. The effect of centrifugal force on vehicles was not able be reduced to an acceptable level due to incorrect superelevation slopes. Thus, DSİ Kavşağı is found to be the maximum risk point of the road sections at Kocaeli city. Despite the traffic signs and warnings at the region, DSİ Kavşağı has still the most concentrated (high density) accident rates. The exact and radical solution for this intersection is evaluated to remove of the redundant curb in the study. Other suggestions are based on the restoration of geometric features of the roads depending on findings from these analyses of road junction's geometric design.

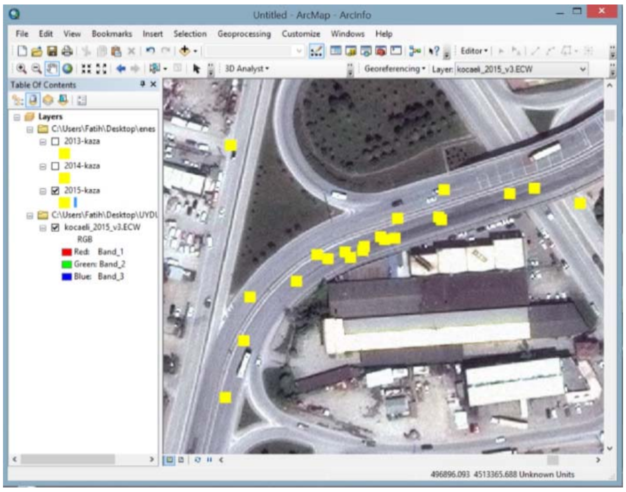

Figure 9: Accidents at the road section in DSİ Kavşağı

The another road section that is marked as high risk on the density map, is known as “Akmeşe- Serdivan bağlantı yolu” region (Figure 10). It is believed that vertical curb geometry and reduced sight distance yielded higher risk for the users.

Figure 10: Road section in Akmeşe- Serdivan access road

This vertical curb is a striking sample for obstructing of vehicle’s (or driver’s) sight in the concavity. As it can be seen from the Fig.10, vehicles on the road are not able to be seen by drivers at this “gap” area. Hence, the journey on this road segment carries significant accident risks depending on lack of visibility. Terrain model analysis which was performed in the case study shows that the dip caused to sightless can be prevented readily. Examination of profiles yielded that the cavity at vertical curve on the road is rectifiable with a small amount filling. It is known that roadways which have many “blind” points as in our example can easily be fixed without high costs and avoided from accidents caused by concavity.

3. CONCLUSION

A GIS-based approach was used to tackle the traffic safety issues in urban roads in Kocaeli city. This study aims at highlighting the influential geometrical factors to accident occurrence at hazardous locations of local urban roads in the region. The paper will focus on identifying hazardous locations using spatial density functions in urban areas and the correlation of accident characteristics with geometrical elements of the roads. When the road sections (or spot locations) containing the studied hazardous locations are determined, these areas are investigated from the geometrical design standards. It is worth mentioning here that further improvements for geometric design of the detected road sections can reduce fatal accident rates in the region.

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