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Analysis of bus accidents by use of geographic information systems

Mehtap Sagir Kayım*[1], Ugur Alganci [2], Dursun Zafer Şeker [2]

[1]Istanbul Technical University, Graduate School, Geographical Information Technologies Program, Türkiye, sagirme@itu.edu.tr
[2] Istanbul Technical University, Department of Geomatics Engineering, Türkiye, alganci@itu.edu.tr, seker@itu.edu.tr

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Abstract

In today's modern world, Geographic Information Systems (GIS) play an important role in effectively processing intricate location data. This multi-purpose technology is successful in collecting, storing, processing and managing location-related data in various fields such as City Information Systems, Traffic Information Systems, Vehicle Tracking Information Systems and Map Information Systems. Its applications contain multiple sectors, greatly improving our lives and providing solutions to numerous challenges. Notably, GIS holds promise in metropolises where high population density and excessive vehicle use cause traffic congestion and accidents. The process begins with the compilation of historical accident data, creating datasets for meaningful analysis. This analysis reveals accident-prone locations, paving the way for targeted improvements and accident reduction. Considering Istanbul, a metropolis where daily public transportation served 8,095,092 passengers in 2023, faced an average of 45 bus accidents per day. In this study, it is examined how GIS can be combined with public transportation analysis and what kind of improvements can be made to prevent these accidents.

Introduction

Road transport systems form the basis of public transport and provide economical and efficient mobility for millions of people. In big cities like Istanbul, public buses are an integral part of daily life. The use of public buses in public transportation is quite common. Unfortunately, accidents are unavoidable. In our country, it is reported that a traffic accident occurs every 45 minutes, resulting in the loss of 10-15 lives each day and an annual economic loss of up to 5 quadrillion. Traffic accidents are a significant cause of death worldwide, with approximately 50% of all accidents resulting in fatalities. In one year, an average of 45,000 people lose their lives in traffic accidents in the United States, 8,000 in Italy, 8,500 in France, 2,000 in Greece, 1,300 in the Netherlands, and 6,000 in our country [1,2]. These statistics highlight the importance of traffic safety and the need for measures to reduce accidents.

Identifying the common causes of accidents is an important step in reducing accidents. Main causes can be listed below:

- Driver Error: One of the most common causes of accidents is driver errors. This includes errors such as distraction (texting, talking on the phone), tiredness, driving under the influence of alcohol or drugs, misjudging road conditions, poor driver training, experience and driving ability.
- Excessive Speed: Driving at speeds higher than recommended or inappropriate for current road conditions can increase stopping distances and cause collisions.
- Mechanical Failures: Mechanical failures of the bus (from brake or steering failure to tire blowout) can lead to accidents.
- Road and Weather Conditions: Poor road conditions such as potholes and bumps or adverse weather conditions such as fog, snow, heavy rain can make driving dangerous.
- Traffic Congestion: The unpredictability of other road users in heavy traffic can be a challenging process for bus drivers to manage.

- Blind Spots: The large design of buses can result in blind spots, increasing the risk of accidents [3].

Traffic accidents are a natural and unavoidable event. However, measures need to be taken by the relevant authorities to reduce deaths and injuries. GIS tools are used to determine what measures should be taken in specific road segments or intersections. With the help of available data, expected accidents can be predicted in the relevant road segment. This is an important tool in making strategic decisions to enhance traffic safety [4]. The resources allocated to efforts to reduce traffic accidents are insufficient. Identifying areas with high accident rates is a critical step for conducting cost-benefit analyses. This information is necessary to ensure the most effective use of resources and thus minimize accidents in the riskiest areas [5].

This study aims to examine the causes of bus accidents that have occurred in the last five years in detail, identify the geographical points where these accidents occur, and provide recommendations for these areas.

Material and Method

Creating and querying the database is one of the most critical stages of the study. In this process, the use of Geographic Information Systems (GIS) technology plays an important role in querying data and processing the results with statistical and geographical analysis. GIS is more advantageous than other information systems because it can store geographical data and process them on the map. These features allow users to more easily query and visually perceive their data, and this has been successfully used for accident analysis of buses used in public transportation in the city of Istanbul [6]. Heat map is a two-dimensional visualization technique created by coloring the map. The clustering of the data can be clearly seen from the tone change in the colors. It provides a great advantage to the user in the analysis of complex data [7].

This study aims to create a heat map showing the geographical distribution of accidents using accident data collected between 2018 and 2023. This map will clearly show areas with high accident rates across the city and will be used to improve traffic safety and identify accident prevention strategies. The accident data for the period 2018-2023 is parameterized as Route Code, Bus Number, Latitude/Longitude Points, and Time (Table 1). The use of these parameters will help in better understanding the causes of accidents and, particularly, in identifying trends in accidents concerning geographical location and time.

Table 1 – An example of data transformation for accident data.

DateTime	Latitude	Longitude	RouteCode	BusNumber
23/09/30 20:19:26	40,991577	28,8447037	146	A-1709
23/09/30 17:31:58	41,014015	29,1896172	131T	C-971
23/09/30 16:55:45	41,041008	29,0858173	11Y	M2281
23/09/30 16:40:11	40,979775	29,0831318	19F	C-1516
23/09/30 16:10:59	41,092545	28,8640785	36V	O2285
23/09/30 15:34:59	41,154152	28,6197681	336H	K1578
23/09/30 14:11:04	41,032085	28,8340900	97GE	A-1836
23/09/30 12:19:13	41,011590	28,7921352	98	M2528
23/09/30 12:07:24	41,066284	28,7306600	78Ş	T1008
23/09/30 09:44:28	41,037990	29,0668583	15ÇK	C-1779
23/09/30 08:06:34	41,028233	29,0744343	15ÇK	C-1779
23/09/30 07:00:56	41,091705	28,9883823	DT1	B-259

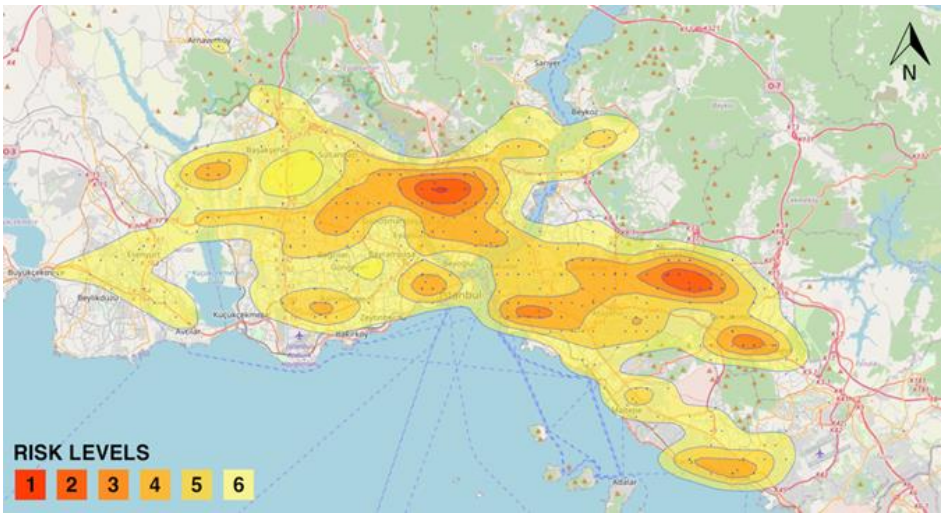

Figure 1. Heat Map of Bus Accidents in Istanbul Province's Public Transportation.

After preparing the accident data table, a heat map representing the geographical distribution of accidents that occurred in Istanbul is created using this data. This heat map is designed to prominently display areas with high accident rates across the city (Figure 1). Such a map is a critical tool, especially for identifying points with high accident frequency and planning measures that can be taken to prevent accidents in relevant areas, and can be used to increase traffic safety and determine accident prevention strategies.

Results

The heat map in Figure 1 provides a color-coded image showing accident densities in Istanbul. Red areas represent highly dense accident points, orange areas represent dense accident points, and light orange areas represent less dense accident points.

According to the analysis results, there are areas where accidents are concentrated on both the Anatolian side and the European side. While the area where accidents are concentrated on the European side includes Şişli, Kağıthane and Alibeyköy districts; On the Anatolian side, the areas where accidents are most common are Dudullu, Sarıgazi and Kirazlıdere districts. There are intercity bus terminals in Alibeyköy district on the European side and Dudullu district on the Anatolian side. There are public transport bus garages in Kağıthane district on the European side and Sarıgazi district on the Anatolian side. Şişli district, also located on the European side, is the busiest stop of the Metrobus system, with a daily passenger count of 1,000,000. As can be understood from here; these centers are very busy main stops. To reduce these accidents that occur in the main centers where public transport buses, intercity buses and transfer points are very dense, the bus terminals and garages in these centers should be moved out of the city or the roads should be widened.

Discussion

One of the most important pieces of information needed in accident analysis is the geographical location where accidents occur. Geographic location provides a lot of information to solve the problem. The cause of the accident that occurred in the same place for similar reasons may also be the same. Therefore, analyzing the geographical locations of accidents with GIS is correct in terms of ensuring traffic safety [8]. Categorizing accident areas in this manner assists in determining what improvements need to be made in relevant locations. This information can be utilized in prioritizing traffic regulations and safety measures. This study provides a road map aimed at preventing bus accidents using geographic information technologies, and such analyzes are an important step to increase traffic safety.

Conclusion

In this study, the causes of bus accidents are summarized and their spatial distribution is analyzed with the use of GIS tools. This analysis helped to understand some of the reasons behind accidents and results provided that main bus accident locations are corresponding to main bus stations where the number of busses and general traffic density is high. This study was designed to guide the process of developing preventive measures using strategic planning and data.

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