Advanced GIS
http://publish.mersin.edu.tr/index.php/agis/index
e-ISSN:2822-7026

Determination of densities of existing intersection by buffer analysis (Samsun- Atakum intersections)

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Keywords
GIS,
Density Analysis,
Intersection,
Buffer Analysis,
Kernel Analysis

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Research Article
Received: 16/05/2023
Revised: 04/06/2023
Accepted: 19/06/2023
Published: 12/09/2023

ABSTRACT

This study was conducted to evaluate the traffic density of nine intersections located between the Highways intersection and the Toplu Konut Boulevard intersection on Atatürk Boulevard in Samsun's Atakum district, and to analyze the traffic flow in detail at these intersections. Analyzes were applied with ArcGIS 10.3 from GIS software. In the study, kernel density analysis was used to determine the densely populated areas, and buffer analysis was used to determine the density levels of intersections. Kernel density analysis was used to determine the density of settlements, then density maps were created depending on the buffer zones created by schools, institutions, hospitals and densely populated areas around the intersections. Buffer analysis was attempted at buffer sizes of 500 and 1000 meters and mapped in GIS software. As a result, it has been determined that the intersection with the least density is Vatan street intersection, and the ones with the highest density are YEDAŞ and Türk-iş intersection. Thus, a local problem was identified and solution suggestions were presented.

1. Introduction

Urban transportation is one of the most important requirements of modern life. However, urban traffic density can occasionally create significant problems. One of the biggest causes of these problems is traffic congestion at urban intersections. Insufficient road capacity, high number of vehicles, inadequate traffic management, and irregular parking are among the reasons for congestion at intersections. With population growth and rapid urban development, traffic density has become inevitable. This situation can occasionally lead to congestion and accidents at intersections. Nowadays, a significant portion of accidents and traffic congestion in urban road transportation occurs at urban intersections. Traffic congestion, which is the most important cause of urban transportation problems, can cause economic and social losses. These losses can affect not only time and money, but also human life. Therefore, handling intersections as a focal point of solutions is among the priority traffic elements (Oğuzhan, 2015). To evaluate traffic density, it is necessary to consider points with continuous traffic flow, such as residential areas, schools, hospitals, and institutions. Determination of traffic density can be performed using geographic information systems (GIS) program.

GIS collects, processes and stores geographic data. GIS is an important tool in city planning. It is also a system that facilitates the arrangement, analysis and modeling of spatial data (Dogan & Yakar, 2018). It is used in various areas such as city management applications, traffic applications, infrastructure applications (Ernst et al, 2019). With GIS, density maps can be created and the busiest intersections can be detected. Traffic density maps help drivers learn about areas with high traffic density in earlier. As a result, it becomes possible to arrange intersections in a way that improves the flow of traffic.

Proximity analysis, also called buffer analysis, is the GIS querying for desired information within a certain geographic distance (Taşkaya & Ulutaş, 2021). Vector data is also performed with this analysis for point, line or polygon features. Buffer analysis is performed around a point with respect to a certain diameter, to the left or right of a line for a certain distance, or both, and inside or outside a polygon with respect to a certain distance. For example,

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Cite this article

Tona, A. U., Maraş, E. E., & Demir, V. (2023). Determination of densities of existing intersection by buffer analysis (Samsun- Atakum intersections). *Advanced GIS*, 3(2), 39-46.

there are some uses that should not be used around a certain distance, such as base stations, schools, bridges, intersections, factories. It can be used for purposes such as detecting the buffer areas of these uses, identifying the misuses in these areas, guiding the decision-making mechanisms in the selection of a new application. It is possible to access the database information as well as the object information of the selected objects in the buffer zone (Belsis, 2023).

In recent years, GIS-based applications of buffer analysis in the scopus search base with a comprehensive perspective; it was searched with the keywords "buffer analysis" and "GIS" and 1519 published studies were identified with the article filter. These studies were examined in detail using the Voswiever program (Figure 1). In recent years, it has been determined by researchers that buffer analysis attracts attention in the fields of ecological network, rural settlements, accessibility, remote sensing land use and land cover and transportation.

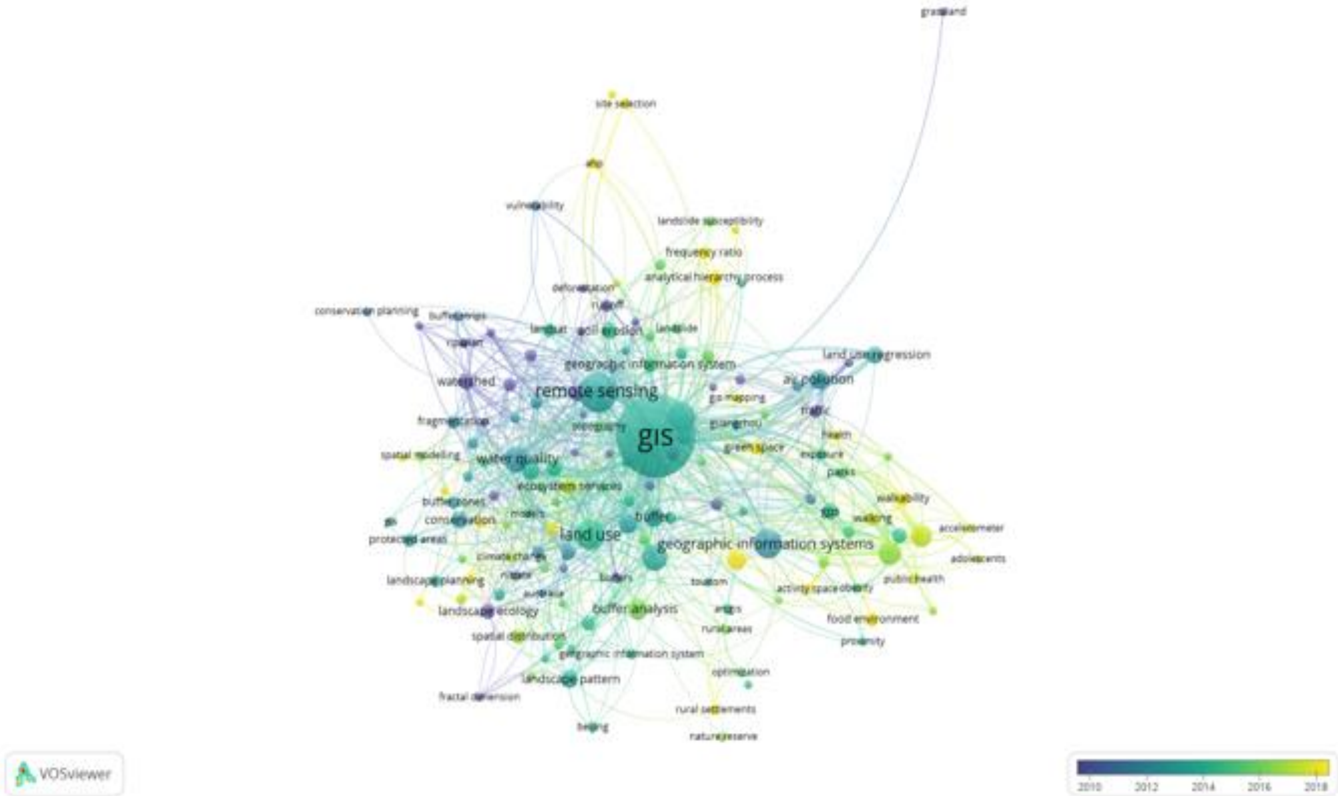

Figure 1. Keyword map of GIS based buffer analysis

In order to benefit from the traffic management and traffic signaling system of Samsun province, it is necessary to develop a new traffic-stimulated intersection model. The reason for this is that continuous stop-go is made at the intersections in the study area and the loss of time spent on the road reaches the highest points. As a result, people's patience in traffic decreases. In addition, fuel consumption increases due to the continuous stop-go operation of the vehicles at the lights, and excessive noise occurs due to reasons such as horn sound, engine noise, traffic accidents due to traffic density. In addition, the increase in fuel consumption causes more toxic gases to be emitted from vehicles and adversely affect the environment (Dönmez Akın, 2020). Zerenoğlu et al. (2022), by using the developed buffer analysis method, the relationship between traffic accidents in the intersection areas of shopping-education, transportation-education and transportation-shopping areas was examined. Using the optimized analysis method, hot spot analyzes of shopping-education, transportation shopping and transportation-education intersection areas were carried out. In the final analysis, traffic accidents occurring within 150 meters of transportation, shopping, education, accommodation and food and beverage areas were examined. As a result of the study, it has been determined that traffic accidents occur mostly in the intersection areas of transportation and shopping areas among the daily activity areas. Sabel et al. (2005), the aim of their study is to determine traffic densities. GIS (Kernel Analysis) and Python programs were used in the study. As a result of the study, the accidents can not be predicted with GIS, but they stated that accident trends can be predicted. Karaman (2013), created a kernel density map according to the number of accident repetitions with a band width of 1000 and 1500 meters in Istanbul. As a result of the analysis, it has been determined that the regions with the highest number of accidents are around Şişli and Fatih districts on the European side. On the Anatolian side, the accidents were concentrated around Ataşehir.

The aim of this study is to analyze the intersections between highways intersection and Toplu Konut Boulevard intersection Junction located in Atakum district of Samsun province. In the density analysis, the images of the intersections in the study area were made with the help of drones. Kernel density analysis was used to identify densely populated areas, and buffer analysis was used to determine the density levels of intersections.

2. Material and method

The data used in the study are in shape file format and were obtained from local governments. The base map used is the developing plan map and it is 1/1000 scaled.

The study focuses on nine intersections located on Atatürk Boulevard in Atakum district of Samsun. The study area is located between the highways intersection and the Toplu Konut Boulevard Intersection. Images taken with Google Earth and a drone for the study area are shown in Figure 2 and Figure 3-4, respectively

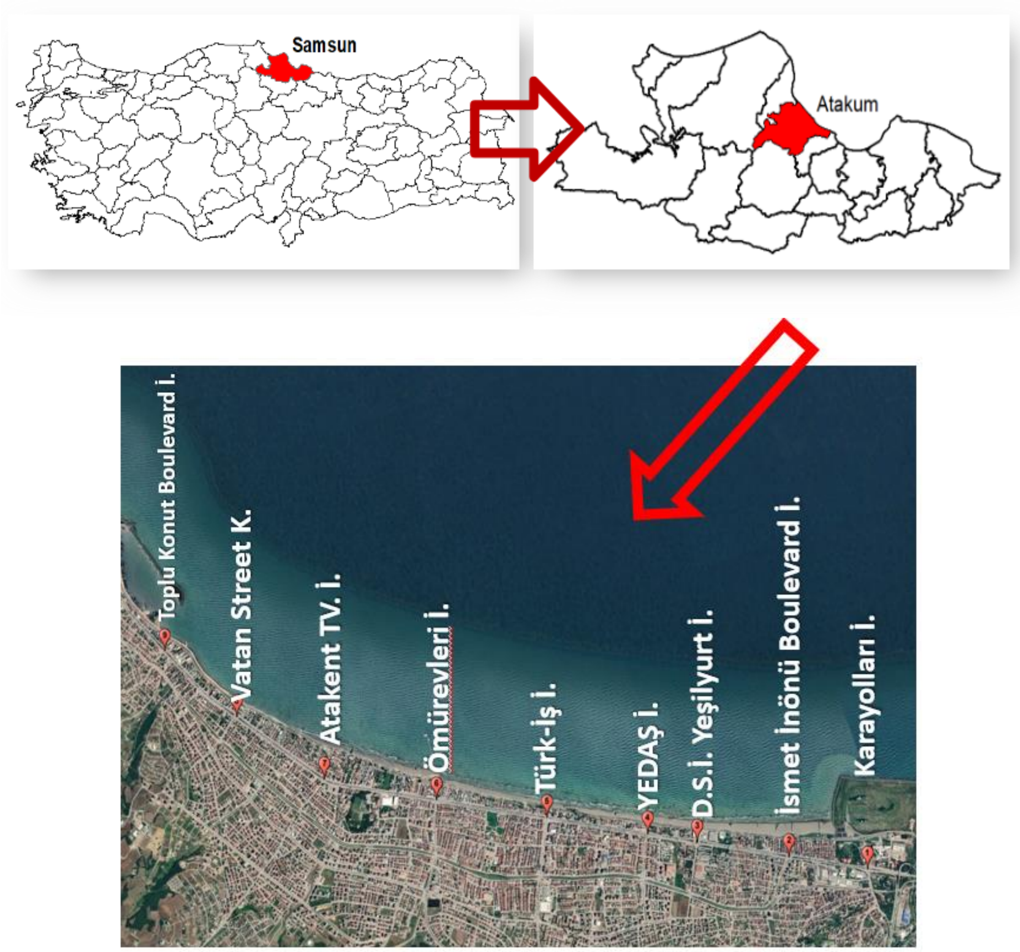

Figure 2. The study area (Google Earth, 2023)

In addition, drone images of 9 intersections in the study area are shown in Figure 4 – Figure 5. These drone images were taken from Samsun Metropolitan Municipality.

(a) (b)

Figure 3. (a) View from the highways intersection to other intersections, (b) highways intersection

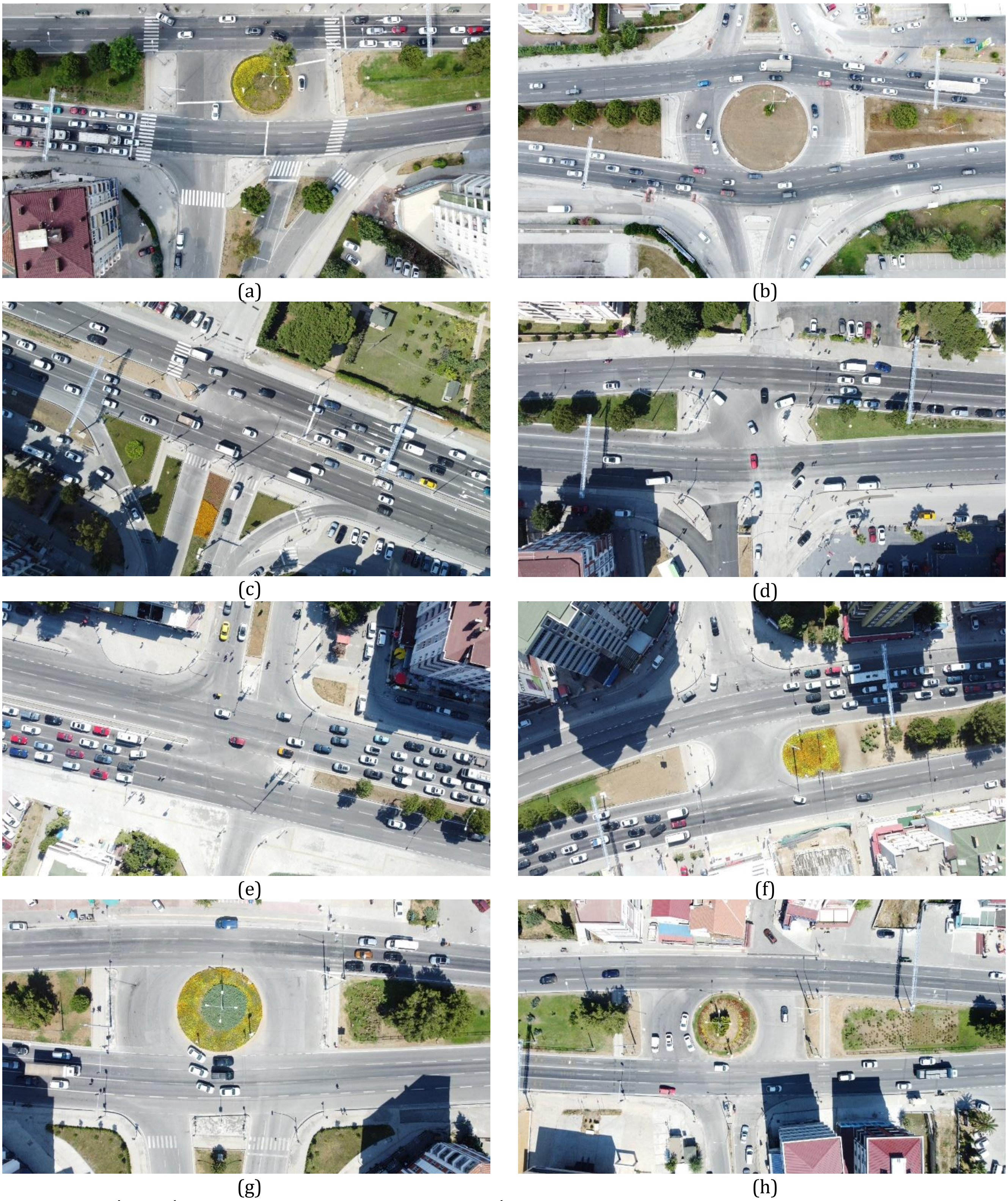

Figure 4. (a) İsmet İnönü boulevard intersection, (b) DSİ Yeşilyurt intersection, (c) YEDAŞ intersection, (d) Türk iş intersection, (e), Ömürevleri intersection, (f) Atakent tv intersection, (g) Vatan street intersection, (h) Toplu Konut boulevard intersection

In order to calculate the densities formed on these 9 intersections, the densely populated areas on the study area were determined by the kernel density analysis method, then the locations of the schools, hospitals and institutions on the study area were determined and transferred to the GIS software. These points have been preferred because they are the most frequently used locations in traffic. Since it is the place where people go most often, this will cause the density at the intersections to increase and the traffic to slow down. In order to determine the density levels of intersections, the parts of these points that intersect with the intersection should be determined. To achieve this, the buffer analysis method was used. Another reason for using buffer analysis is to reveal the most frequent and least preferred intersections in the study area. Schools, hospitals, institutions and settlements in Atakum district layers are shown in Figure 5. The layers from the Google earth base were taken with their coordinates and integrated into the study. Kernel density analysis method and buffer analysis are explained in detail in the following sub-titles.

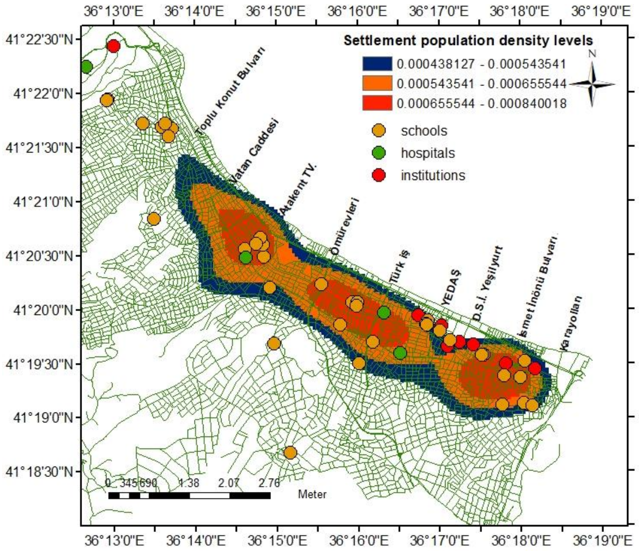

Figure 5. GIS view of schools, hospitals, settlements and institutions in Atakum district

2.1. Kernel density analysis

Kernel density analysis method is a method used to visualize the continuous distribution of data (Silverman, 1986). Linear data are related to the heights and shapes of the curves in the kernel density plot. In this method, the distribution frequency of the points is tested by comparing the observed frequency distribution with the expected value. On the other and point data, corresponds to the density of each point. It creates a grid by dividing the area of points with squares. Each square determines the density with a histogram according to the number of points falling within it (Toprak & Sunkar, 2022). Kernel density analysis refers to the density of points within the circle with a defined radius, instead of cells, and the point density that changes with distance from this source. This analysis method is used to measure the distribution of points in a more detailed and precise way (Bakak, 2016). In the kernel density analysis method, the surface value is highest at the point where the point is located and decreases as it moves away from the point. The search radius distance is the distance at which the kernel density reaches zero. This distance is a parameter used to calculate the density of the data. The kernel density tool calculates the density of the features on the map around these features. The formula used in the calculations of the densities is given in equation 1 (Toprak & Sunkar, 2022). As a result, a smooth, soft and curved surface is defined on each point (Tağil & Alevkayalı, 2013).

$$K(i) = \sum_{d<r} \frac{3}{\tau^2}\left(1-\frac{d^2}{\tau^2}\right)^2 \quad (1)$$

Where K is kernel density value, d is the distance from event, and τ is bandwidth.

In this study, this method was used to calculate the settlement density in Atakum district and coordinates were given to the structures within the boundaries of the study area.

2.2. Buffer analysis

Buffer analysis is one of the most important parts of spatial analysis in GIS. Its main purpose can be defined as a regional area (creating buffer zones), out of a point, line or polygon, at a certain distance around the border. The commonly used name is buffer analysis (Yıldırım, 2016; Zhou et al., 2010; Huang et al., 2004; Dong et al., 2003). Considering the geographical features, a buffer zone is created around it at certain distances by using points and lines. Then, the details within the buffer zones are determined (Taşkaya & Ulutaş, 2021). With this analysis method, many things such as proximity to the road, distance, population density can be found. Buffer analysis can be performed in three different ways, as shown in Figure 6.

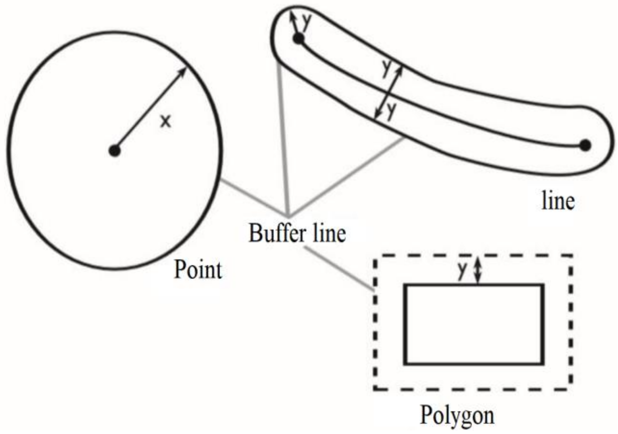

Figure 6. The various approaches in buffer analysis (Yıldırım, 2016)

Buffer analysis is applied in 3 different ways as point, line and polygon based. In this study, point-based buffer analysis method was used.

3. Application

Routes such as areas with frequently used schools, hospitals, institutions, and residential areas were marked on the land-use map, and the density on intersections within the study area was attempted to be identified using kernel density and buffer analysis method. The kernel density analysis method was used to show the density of settlement areas (Figure 7). By throwing points on the structures and giving coordinates, the areas where the pixel values of the analysis are intense were determined, then the regions where the settlements are dense were determined by the kernel density analysis method. To determine the buffer zones created by all of these layers on intersections, buffer analysis was applied with distances of 500 and 1000 meters, and the resulting density maps are shown in Figure 7 and Figure 8.

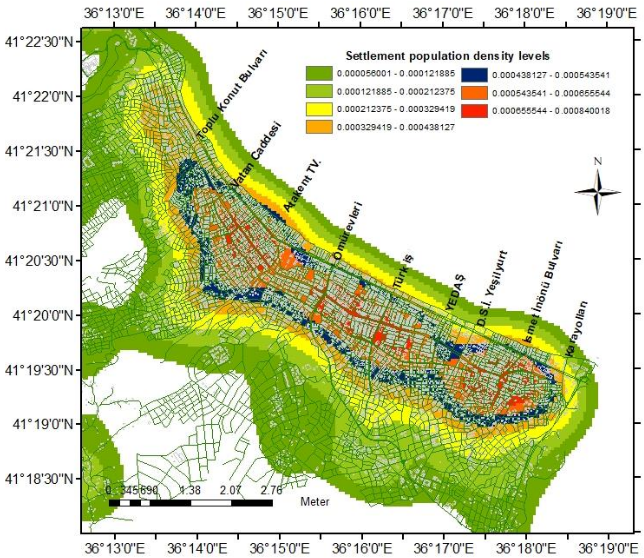

Figure 7. Settlement Kernel Density Analysis Map

In Figure 15, the most intense regions are shown in red, while the least dense regions are shown with green areas. The intensity values shown here are the representation of the pixel values formed according to the structure frequency obtained as a result of the analysis. The building densities increase from the blue colored area and the structuring gradually decreases outside the blue colored border. Therefore, the color blue was chosen as the border color at the density level of the settlement. The density levels of the settlements shown in Figure 8 are shown with the pixel values formed according to the frequency of the buildings. Kernel analysis was performed using spatial analysis tools-density-kernel density tabs in ArcGIS 10.3 software. Buffer analyzes of 500 and 1000 meters were applied to see significant intersections between the intersection dimensions and layers. Buffer analyzes of these dimensions are shown in Figure 9 and Figure 10.

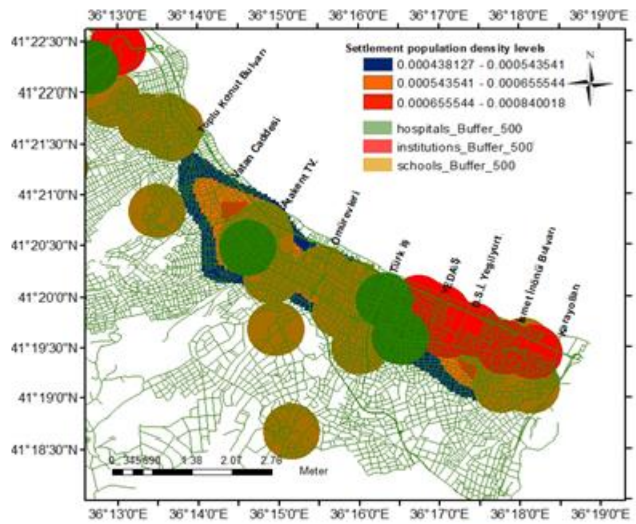

Figure 9. 500 Meter Buffer Analysis Map

In Figure 9, when the 500-meter buffer analysis is performed and the intersections are considered one by one, it is seen that the buffer zone of the institution layer coincides with the intersection at the Highways intersection. At İsmet İnönü boulevard, DSİ Yeşilyurt and YEDAŞ intersections, school, residential and institution layers intersect. At Türk İş intersection, hospital and residential layers intersect. At Ömürevleri and Atakent Tv intersection, residential and school layers intersect. Finally, it was determined that the residential layer at Vatan street intersection and the buffer zones of the school layer at Toplu Konut Boulevard intersection coincide on the intersection.

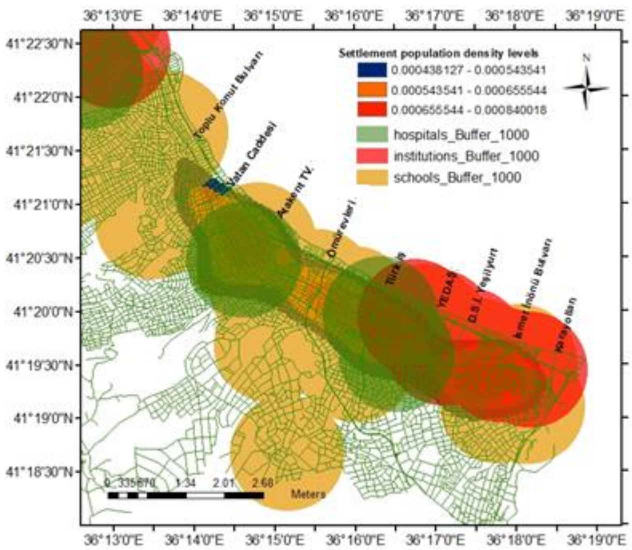

Figure 10. 1000 Meter Buffer Analysis Map

In Figure 10, when the 1000-meter buffer analysis is performed, the buffer zones belonging to the school, residential and institution layers at the highways intersection, the buffer zones belonging to the school, residential and institution layers at İsmet İnönü boulevard and DSİ Yeşilyurt intersections, buffer zones of school, residential and institution layers, buffer zones of hospital, school, residential and institution layers at YEDAŞ and Türk-iş intersections, buffer zones of school and residential layers at Ömürevleri intersection, buffer zones of school and residential layers at Atakent Tv intersection, It was observed that the buffer zones belonging to the residential and hospital layers, the buffer zones belonging to the school and residential layers at Vatan street intersection, and finally the buffer zones belonging to the school layer at the intersection of Toplu Konut Boulevard intersected and coincided on the intersection. Comparing the 500- and 1000-meter buffer analysis, the 500-meter buffer analysis was more in line with the kernel analysis indicators, while the 1000-meter buffer analysis showed intersections in a wider framework.

4. Discussion and conclusions

In this study, the density situations that occurred around the intersections of highways, İsmet İnönü boulevard, DSİ Yeşilyurt, YEDAŞ, Türk-iş, Ömürevleri, Atakent tv, Vatan street, and Toplu Konut boulevard, located on Atatürk boulevard in the Atakum district of Samsun, were examined using kernel density analysis and buffer analysis in a GIS environment. Settlement density was determined using kernel density analysis, and then density maps were created based on the buffer zones around schools, institutions, hospitals, and areas with high population density. As a result of buffer analyses conducted at 500 and 1000 meters, it was observed that the Vatan Boulevard intersection had the least density, while the YEDAŞ and Türk iş intersections had the highest densities. Buffer analyzes of 500 and 1000 meters were made in order to show the intersections of the layers in a meaningful way at the intersections. These analyses enable the development of various models according to the density situations of intersections, and through these models, problems in crowded intersections can be identified and addressed. The densest regions in the obtained density maps are compatible with the literature (Dönmez Akın, 2020; Maraş, 2011). As a result, regulating traffic flow and reducing traffic congestion is an important factor in increasing the livability of cities. Towards this goal, considering many parameters such as the density situation of the intersection, the topography of the area, and the development status, different models can be implemented to make traffic more fluid. For example, an interchange can be built at the highways intersection, and a pedestrian overpass can be constructed at the Vatan Boulevard intersection. Depending on the overall perspective of the surrounding area, models such as interchanges, modern roundabouts, and pedestrian overpasses can be implemented around intersections. Conducting these studies will facilitate people's daily lives and help to make cities more livable. Also, the findings obtained as a result of the study can be generalized in different areas and used to investigate the traffic density problem.

Author Contributions

Aziz Uğur Tona: Literature review, field study, article writing. **Erdem Emin Maraş:** revision and interpretation. **Vahdettin Demir:** Editing, interpretation and revision.

Statement of Conflicts of Interest

There is no conflict of interest.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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