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RESEARCH ARTICLE

A GIS-SUPPORTED ANALYSIS ON ACCESSIBILITY IN WOMEN-FRIENDLY SOCIETIES: EVALUATION OF WALKING ROUTES AT NIGHT HOURS

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ABSTRACT

Developing safe cities is one of the Sustainable Development Goals (SDGs) and a vital factor in creating sustainable communities and cities. From this point, ensuring that women use urban spaces accessibly and safely is crucial. This study aims to determine the walking routes between the most used venues in Kadıköy district, Türkiye, open at night hours, and the transportation points using GIS methods. Density analysis was made using Foursquare check-in data collected from 4 different categories in July 2021, and the closest walking routes between the locations and the bus stops were developed using closest facility analysis. The results were classified in a 5-scale suitability range, in which 5 refers to the highest density and more accessible (closest) bus stops. Zone 2 has 266 shortest routes, while zone 5 has 90 shortest routes and there are many eating and drinking places on the shortest routes. Lastly, some sample routes from the densest and least dense routes were observed using Google Street views in terms of safety criteria. The results and the approach used in this study are expected to encourage the local authorities and the decision-makers to improve safe access between the venues and transportation points.

Keywords: Women-friendly societies, Walking routes, Closest facility, Geographic Information Systems (GIS), Night hours

1. INTRODUCTION

Within its 2030 Sustainable Development Agenda, the United Nations outlined a list of sustainable development goals (SDGs). These objectives were introduced on January 1st, 2016, and will be in effect through 2030. There are 169 targets and 17 SDGs on the agenda, and 232 indicators will be used to gauge progress [1]. Sustainable cities and communities are one of the SDGs and besides various issues associated with creating urban and public sustainability, it also focuses on providing fair access to safe and inclusive public spaces for women [1]. However, when considering women's issues, making public places is extremely difficult and requires comprehensive and holistic implementations. Therefore, various dimensions should be considered to provide women-friendly public spaces. For example, urban plans must embrace gender equality principles for developing spatial solutions regarding social life, transportation, housing, and infrastructure services [2,3]. Gender-sensitive applications provide prevention of gender discrimination and work on changing women's status in society because women have a disadvantage in decision-making about urban life [4-6]. Urban buildings and public spaces should be redesigned to become gender-sensitive [7]. Mixed land use and clear street views in the city are essential to support women feel safer in urban places [8].

Many people congregate in public places in cities, especially on walking paths, squares, and public transportation areas [9, 10]. The street is one of the public places in a sustainable environment, and improving walkability is the main issue for people to feel more secure when walking [11-13]. Meetiyagoda [14] investigated pedestrian safety principles in Kandy Heritage City, Sri Lanka in terms

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of parking vehicles on the street [15, 16]. Street lighting, one of the essential types of city lighting, is also critical in terms of security provided at night [17, 18]. Therefore, cities should be safer for women regarding pedestrian paths, transportation, and street lighting [8].

There are many studies about women in urban life. The research conducted by Umaña-Barrios and Gil [19] shows that women's walking distances are longer than that of men's and the primary public transportation users are women in Latin America. According to different studies, gender equity in transportation should consider design, cost, and safety [20, 21]. Women's issues are also examined from different perspectives and in different urban places such as residential, working, and public spaces. Ceylan [22], for example, implemented a questionnaire for men and women to detect the impacts of women's issues in different urban spaces. The results revealed that the workspaces should be designed considering the needs of the women, and safety and accessibility should be primary issues in the design of urban parks and streets. Lawton and Kallai [23] showed that women felt less safe and had more wayfinding anxiety than men in Hungary and the United States.

Urban spaces and women's safety have also been studied with crime-based viewpoints in the literature. Erkan and Sevin [24] investigated crime fear in Kadıköy, İstanbul, and revealed that people felt more fear at night hours. Another study surveyed in Santiago, Chile, found that women felt unsafe in the darkness in garages, public parks, and underpasses [25, 26]. Women avoid frightening routes, and this situation plays an important role in their travel behavior. Women also notified crime circumstances more than men [27, 28]. The significance and role of street lighting in decreasing crime in the urban environment is another essential emphasis in the literature [29, 30].

In Türkiye, similar studies and research have also been conducted. The Women-Friendly Cities Program is the first project in the country with a sustainable, gender-sensitive, and human rights-based approach. The Women-Friendly Cities United Nations Common Program was introduced in 2006 with the goal of integrating the principle of gender equality into local governments' planning and programming procedures while concurrently fortifying local governments and women's organizations and expanding opportunities [31]. The Women-Friendly Cities United Nations Common Program's second phase began in April 2011, upon the completion of the first phase [31]. Women-Friendly Cities Program suggests well-lighted public places and emergency call point emplacement for public places [32]. Streets can also be equipped with proper lighting and security camera solutions to provide safe walking access to the urban environment [33].

As it is clear from the past studies reviewed, creating safer cities is one of the SDGs of the United Nation's 2030 Agenda [1]. Studies show that urban safety planning is insufficient for women [34]. Public place safety is crucial for creating sustainable communities, and especially providing secure access for women in public spaces both day and night is a significant issue. In crowded cities, creating safe public spaces for women at night hours emerges as a problem that poses crucial risks for creating sustainable communities. Within this scope, it is necessary to support women's participation in social interactions in the city and ensure safe access between the urban spaces and public transportation areas at night hours.

Past studies mainly dealt with the social aspects of women's safety in the city or how safe cities can be created. The number of spatial analysis-based studies within this context is relatively scarce. This study determines the access routes between the popular/densely used urban spaces/uses in the study area open at night hours, as nighttime safety is particularly a critical issue for women. The study focuses on geospatial data-driven analyses to put forward spatial outputs rather than discussing the social aspects of women's participation in nighttime entertainment and views on safety issues. The results are expected to encourage the local authorities and the related parties to improve a wide range of implementations from the planning process to physical measurements in streets to achieve women-friendly and sustainable urban communities.

This study aims to evaluate the walking routes between particular urban spaces and public transportation stops at night hours in Kadıköy district, İstanbul,Türkiye, to provide easy access, especially for women, and an opportunity to evaluate and improve the determined walking routes. The district was chosen as the study area due to the high number of visitors, the existence of diverse socio-cultural facilities, and popular entertainment opportunities. First, the most popular urban destinations (restaurants, pubs, museums, etc.) open at night hours in the district were detected. Then shortest walking routes between the selected places and public transportation stops were determined using geographic information system (GIS) methods. Lastly, the routes were evaluated regarding some basic safety criteria for women. The safety criteria of the routes were based on studies from the literature [32, 33]. Accordingly, the sidewalk, lighting elements, security cameras, and emergency call points were examined to evaluate safe walking routes for women in the city.

2. STUDY AREA

İstanbul is an important historical city, the capital of the Eastern Roman and Ottoman Empires. With this historical background, İstanbul is the most populous city in Türkiye and the twenty-second in the world [35]. Besides, the city is a cosmopolitan urban area, including different communities and cultures [36, 37]. İstanbul connects the Asian and European continents and serves as a vital trade center, resulting in approximately 16 million inhabitants [1].

There are 39 districts in İstanbul. 25 are located on the European and 14 on the Asian side (Figure 1a). The Kadıköy district, located between 41°07′ 00″ N and 29°54′00″ E coordinates, has been selected as the study area (Figure 1b). Kadıköy comprises an area of 25.20 km^2 for its 21 neighborhoods [38]. According to the address-based population registration system, the male population is 218.661, whereas the female population is 266.572. With this rate, the female population corresponds to 54.94% of the overall population of Kadıköy [35]. Kadıköy has critical activity/movement density and hosts various activity opportunities such as shopping, entertainment, art, and culture [39]. The number of people arriving at Kadıköy by public transportation reaches 900.000 people per day [24]. Consequently, the motivation for selecting the Kadıköy district as the study area is the presence of diverse mixed uses (residential, commercial, entertainment, etc.), availability of public services (transport and parks), diversity of transport modes, and the high number of visitors.

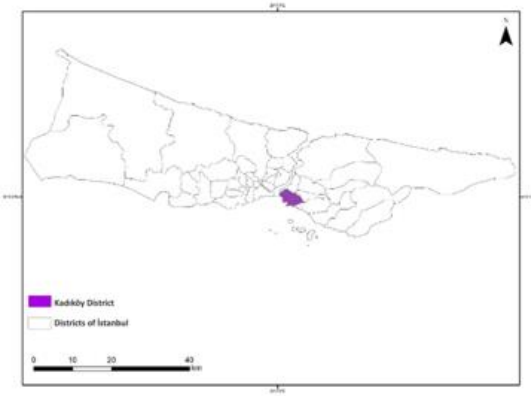

Figure 1a. Districts of Istanbul

Figure 1b. Kadıköy District

3. MATERIALS AND METHODOLOGY

Foursquare users' check-in data and bus stop locations are the primary data sources of the study. Density analysis was applied to the Foursquare check-in places based on night hours, and buffer zones were created around bus stops. The resulting layers obtained from these two analyses were then overlayed.

The closest facility analysis was carried out from the night venues to the bus stops. Lastly, the sample routes were selected from the most accessible and least accessible zones, and these routes were evaluated from Google Street Views regarding the existence of some basic safety criteria.

Detailed information about the materials and methods of the study is explained in the following sections.

3.1. Materials

The primary material of the study is Foursquare check-in data, road networks, and bus stop locations. Daily Foursquare check-in data was collected using the Python API between June 30 and July 30, 2021, and then saved to the PostgreSQL database. In ArcGIS, Foursquare check-in data was filtered according to user visiting times, and only user check-in data between 10:00 p.m. and 3:00 a.m. were included in this study. The total number of all check-in data is 654, and the number of filtered check-in places is 390. The Foursquare data ignores the gender of the users since gender information for the Foursquare check-in data was unavailable. Table 1 shows the sample content of Foursquare check-in data.

Table 1. Data content of a sample night-time place

ID	5a9a9c0d9de23b77757f0695
Name	Kuba Pasta Cafe & Restaurant
Category	Cafés
Latitude	40.985099
Longitude	29.047953
Address	Feneryolu Sokağı, Feneryolu Mahallesi, Kadıköy, İstanbul (Fahrettin Kerim Gökay Caddesi)
Date	7/9/2021
Check-in Days/Hours	Monday 13:00:00-23:00:00 Wednesday 12:00:00-23:00:00 Friday 10:00:00-0:00:00

The places were divided into four categories (drinking and eating, entertainment, recreation, and shopping) according to their functions/use types. Table 2 shows the four categories of selected places. Drinking and eating places constitute approximately 70% of the overall data, shopping places constitute 8%, and recreation and entertainment comprise 11%.

Table 2. Details of places used in the study

Category of places	**Details of place type**
Entertainment	Art gallery, museum, theatre, gym, etc.
Drinking and eating	Restaurants, cafes, pubs, etc.
Recreation	Park, stadium, pool, etc.
Shopping	Shop, market, mall, store, etc.

Road networks, bus routes, and bus stop datasets were obtained from Open Street Map (OSM) sources using QGIS. Since the buses also operate at night, bus stop data were used as this study's primary public transportation data. The data of this study is illustrated in Figure 2.

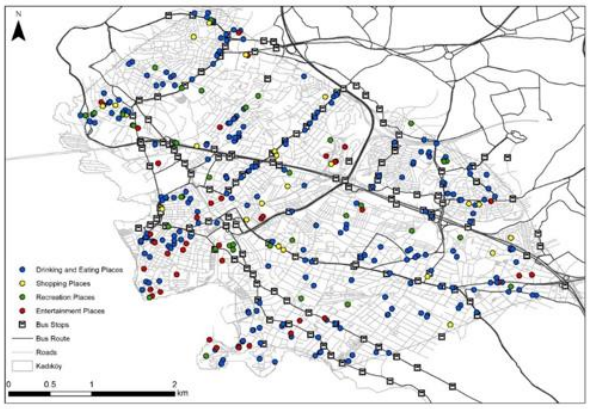

Figure 2. Dataset of the study

3.2. Methods

This study was conducted to determine the closest walking routes between the selected places open between 10:00 p.m. and 03:00 a.m. and the bus stop locations in the Kadıköy district. First, check-in data was obtained from Foursquare places API using Python code, and then data information was automatically saved in the database created in PostgreSQL. The data in the Postgresql database was recorded in the grid values of Kadıköy district coordinates created in QGIS and the check-in data was converted into point (vector) data.

The methods of the study include the implementation of some major GIS analyses used to develop density maps, buffer zones, overlaid layers, and the closest paths between the locations. The spatial layers of the study were developed with the application of the below-given methods:

- **Kernel Density Estimation (KDE):** The density estimations of the selected places were determined with the KDE method. KDE is based on a heat map distribution between core areas (kernels) and surrounding neighborhoods to create a cleaner display of break values for quantitative groups [40]. The various density levels in GIS-based KDE are determined using a radius input, and this radius of the circle can be adjusted manually or automatically [41]. The search radius is determined as 50 meters to include the night places located every 50 meters.

- **Buffer Analysis:** Buffer analysis was used to assess the distance to bus stops. A buffer is an area surrounding a geometric geographic feature measured in distance or time and is categorized into vector-based and raster-based techniques [42]. In this study, buffer analysis was applied to identify walking distances to public transportation stops. Past studies suggested walking distances between 300 and 800 meters for public transport [43, 44]. Therefore, 300-meter buffer zones were created around 141 bus stops in the study.

- **Closest Facility Analysis:** Routes were sought by calculating the shortest path between the locations and bus stops in the study area. Within the scope of this study, the shortest routes from the selected places to bus stops were calculated to examine the closest routes. The closest facility analysis finds the closest path for pedestrians or vehicles between incidents and facilities [45]. The closest facility is one of the network analysis techniques in GIS and networks consisting of edges (lines) and junctions (points) [46].

- **Overlay Analysis**: Overlay analysis is one of the multicriteria decision-making methods performed with GIS capabilities. It is widely used in various research fields, such as susceptibility mapping for land use, site selection, and potential zone detection [47-50]. The

densest and least dense zones in the study area were determined according to proximity to the bus stops and the density of places. In other words, the overlay method was used to detect the KDE areas falling into the 300-meter buffer zones around the bus stations. The shortest paths layer produced via closest facility analysis was also overlaid to evaluate all the analysis results in one major map. Analysis of the study was performed in ArcMap 10.3.

After determining the shortest routes, two sample routes were also specified from the study area's densest and least dense zones, and these routes were evaluated depending on the observations made on the Google Street views. The evaluation was simply performed visually focusing on the existence of safety criteria examples along the routes. Therefore no detailed measurements and detections were available. The safety criteria are the sidewalk, lighting elements, security cameras, and emergency call points [32, 33]. Fig 3 shows the methodology of this study.

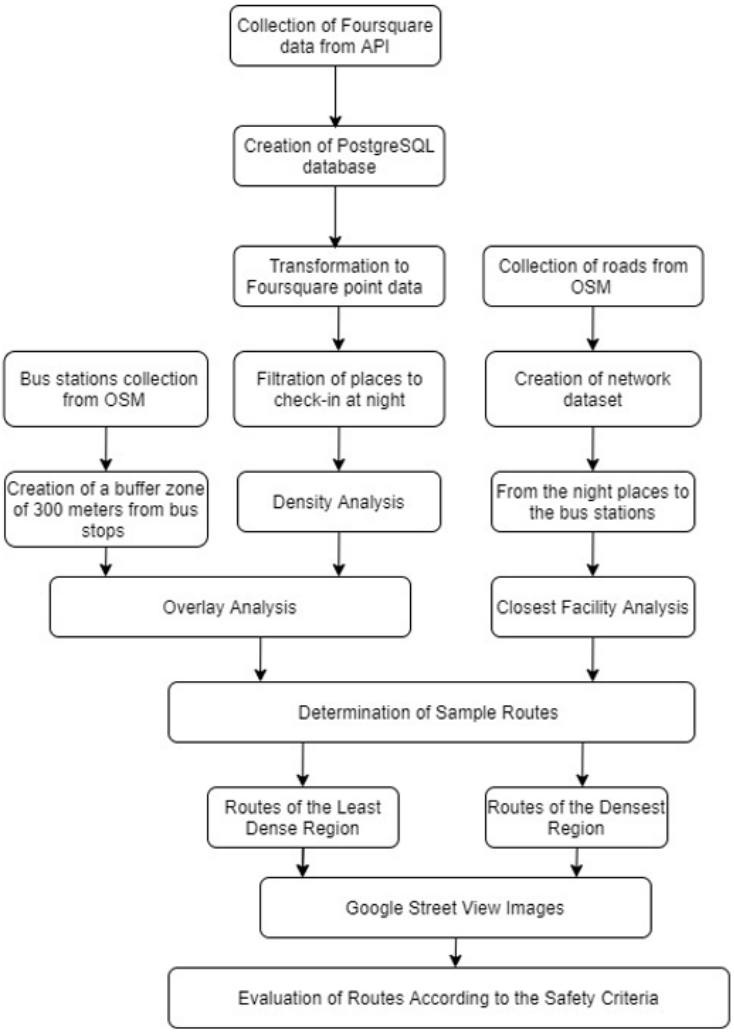

Figure 3. Methodology of the study

4. RESULTS AND DISCUSSION

The results include the spatial layers/outputs obtained concerning the study methodology explained in the relevant sections. As explained, KDE analysis was used to investigate the spatial distribution of places used at night using sample Foursquare check-in data ignoring the gender of the users (Figure 4). The density map was created according to the number of places at night. The analysis revealed that the densest locations are in the southwest Kadıköy district. According to the results, an average of 5 places exist in the least dense area, while the number of venues in the densest zone is around 25. The densest areas are mostly located in the southwest parts of the study area.

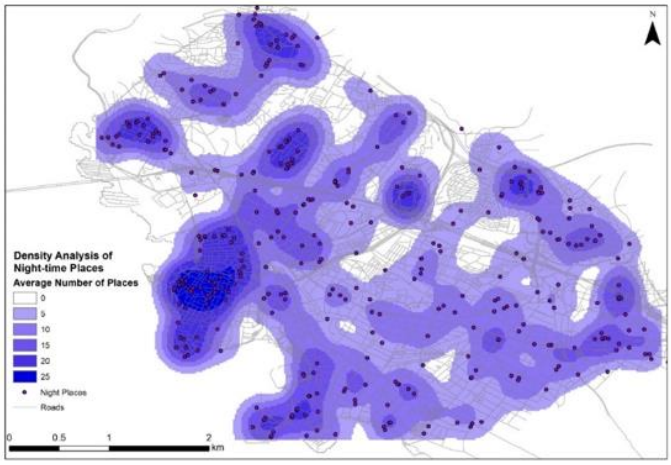

Figure 4. Density analysis of the urban places used at night

Buffer analysis results were made to determine the accessible zones to bus stops, and the dissolving process was applied to combine the buffer areas (Figure 5). According to the overlaid map developed with KDE and buffer analysis layers, the densest and least dense zones in the study area were determined according to proximity to the bus stops and the density of places (Figure 6). The density analysis results and buffer zones were overlaid in a 5-scale suitability range. 1 indicates zones with the least dense places with the furthest access to bus stops, while 5 refers to the highest density and more accessible (closest) bus stops. The closest routes between the locations and the bus stops are given in Figure 6.

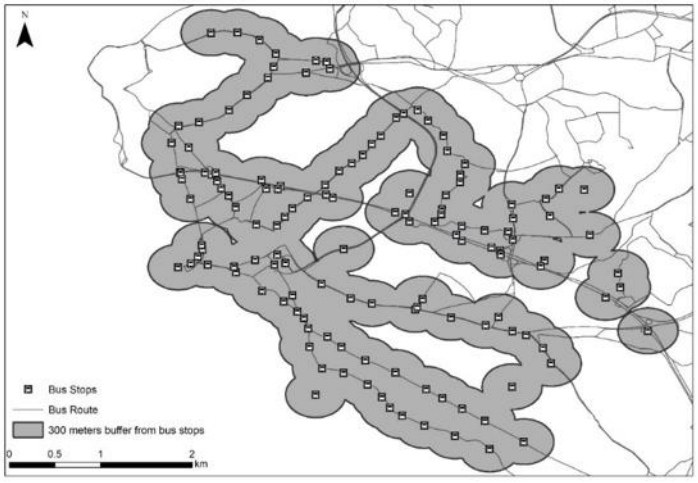

Figure 5. Buffer analysis of bus stops

According to the overlay results, in class 5 eating and drinking venues are the most common. Besides, the number of spaces listed under the recreation and sport category is more than the others in class 1. On the other hand, the closest facility results show there are a total of 780 shortest routes from nighttime venues to bus stops. The overlay result shows that the shortest routes in zone 2 are more than in other zones. Zone 2 has 266 routes, while zone 1 has 83 routes. Moreover, zone 3 has 303 shortest routes while zone 4 has 216 shortest routes. Besides these, zone 5 has the least number of routes and there are 90 shortest routes.

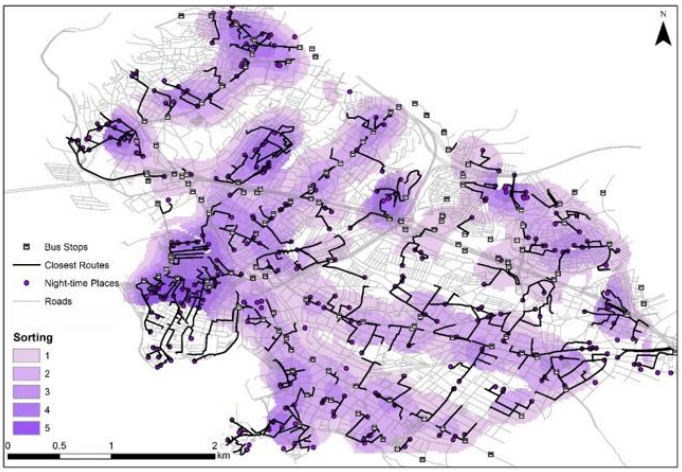

Figure 6. Overlay and closest facility analyses

The final phase of the study includes the observatory evaluations of sample routes. Sample routes were determined from the densest (Figure 7a) and the least dense (Figure 7b) zones according to overlay results. The densest and the least dense zones have more drinking and eating (bars, pubs, restaurants, etc.) places. Google Street views of the selected streets were visually evaluated according to the specified criteria given in Table 3.

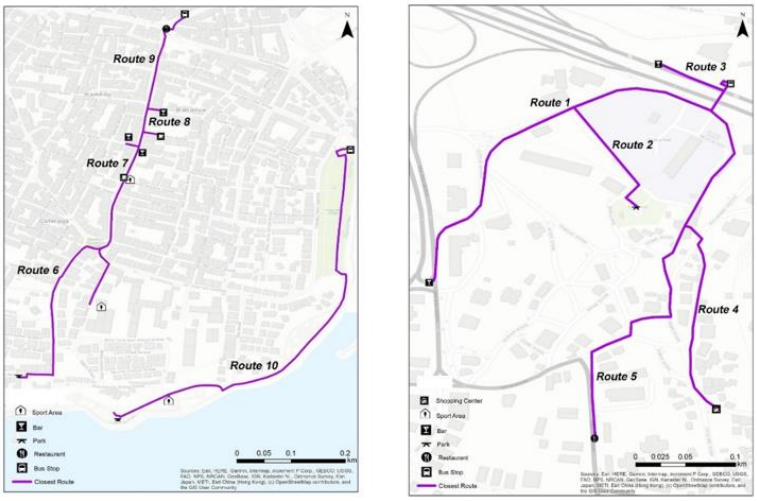

Figure 7. (a) Sample routes of the densest zone; (b) Sample routes of the least dense zone

Routes were evaluated to clarify whether particular safety criteria exist in the selected Google Street photos (Table 3). This is a subjective evaluation based on limited observations of the photos and may fail to reflect necessary details that should be detected comprehensively and quantitively determined via field surveys or other scientific methods. In other words, the safety evaluation explained here is limited, based on personal observation, and aims to present a sample approach and fast evaluation of the routes.

Table 3. Evaluation of sample routes according to the specified criteria

	Sidewalk	**Lighting elements**	**Security cameras**	**Emergency call points**
Route 1	√	√	×	×
Route 2	√	√	×	×
Route 3	√	√	×	×
Route 4	√	√	×	×
Route 5	√	√	×	×
Route 6	√	√	×	×
Route 7	√	√	√	×
Route 8	√	√	×	×
Route 9	√	√	×	×
Route 10	√	√	×	×

Routes 1,2,3,4, and 5 are in the least dense zone, and 6,7,8,9, and 10 are in the densest zone. There are sidewalks and lighting elements on the routes in both areas, while the security camera (route 7) is available on the routes in the densest area.

Figure 8. Google Street Views of least dense zones' routes

Figure 9. Google Street Views of densest zones' routes

There are more night venues in the densest sample zone, and bus stops are more accessible. The abundance of lighting elements, the sidewalk, and a security camera on a route indicates a safer zone (Figure 8). On the contrary, in the least dense sample zone, safe walking routes meet fewer requirements that may pose risks for women or make them feel unsafe. Access to the bus stop from the overpass on Route 3 can be considered less secure than others. On Route 7, women may feel safer at night because there are security cameras on the street (Figure 9).

In the study, since gender information for the Foursquare check-in data was unavailable, it was impossible to detect the number of female or male users in the study area. However, the safety of walking routes from the venues to bus stops was assessed. The evaluations were made only based on the existence of particular elements along the walking routes. Comprehensive research and field surveys are necessary to determine the safety level of the selected routes exactly.

5. CONCLUSIONS

The main purpose of this study is to determine the walking routes at night between the highly preferred (dense) venues and the bus stops within the Kadıköy region, İstanbul, using GIS techniques. For this aim, various data were obtained from different sources, and spatial GIS analyses were performed. Foursquare, one of the social media datasets, was used in this study to detect the places primarily used at night. Bus stops were selected as public transportation data. In addition, the closest routes from the venues to the bus stops were determined in the case study. Sample routes from two zones were then evaluated according to the selected safety criteria. While determining the security criteria, studies for the safety of women in public spaces were used [32, 33].

Safe cities are among the 16 SDG goals and must be created and organized equally for all residents. This study assessed routes providing access between the locations used at night hours and the transportation points (bus stops), particularly to develop output for the relevant parties and the decision-makers so that women-friendly precautions can be taken to create sustainable urban spaces and communities.

However, the study has some limitations, especially in the data scope/characteristics, safety assessment, and generalizability. The study uses 1-month data from Foursquare, which, as mentioned in the material section, does not differentiate the users' gender. As a result, a gender-neutral approach was adopted, and gender-based specific concerns were ignored in the study. Further detailed analysis based on a more comprehensive and extensive check-in data set is strongly recommended for future research to allow for the possible seasonal changes, the beneficiaries of the target night places, the number of women users, the popularity of the places, and the target period. Utilizing women users' data and a higher number of check-ins within a broader time scope would provide more precious insights and results.

Furthermore, the sample safety assessment practice using Google Street View images is limited in terms of the scope of safety criteria and qualitative assessment methods. Here, the main focus was on the simple and fast detection of particular safety items on the street photos and lead the way for the relevant parties to conduct further and detailed examinations. Therefore, field surveys or other scientific methods to more comprehensively evaluate the safety concerns on the streets are suggested. A similar approach is also essential for future research when considering the data used to determine the routes. This study uses only one mode of public transport, the bus stops. It should be enriched with other modes, such as metro stations, taxis, tram, etc., to provide a comprehensive perspective on accessibility.

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CONFLICT OF INTEREST

The author(s) stated that there are no conflicts of interest regarding the publication of this article.

AUTHORSHIP CONTRIBUTIONS

Ezgi Tukel: Writing - original draft, Formal analysis, Visualization, Investigation, Conceptualization. K. Mert Cubukcu: Formal analysis, Supervision, Conceptualization. Saye Nihan Cabuk: Writing - original draft, Supervision, Visualization, Conceptualization. Gurkan Ozturk: Supervision, Conceptualization.

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