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Utilizing Nighttime Photos to Locate Attraction Zones at the Metropolitan Scale: An Analysis of Istanbul

Asli Ozdarici-Ok*
Kivanc Ertugay**

Abstract

Up-to-date information about different forms of land-use (residential areas, industrial areas, central business districts, recreational areas, etc.) is essential for city planning processes to obtain better urban and regional planning decisions. Traditional methods (e.g., field surveying or WEB/GPS based data collection) used to gather up-to-date information can often contain some errors and can also be time-consuming and expensive, especially for large metropolitan urban areas. With the integration of Remote Sensing (RS) and Geographic Information Systems (GIS) related technologies, the difficulty of providing up-to-date information about different types of land-use can be greatly reduced. On the other hand, in terms of urban and regional planning, the level of utilization of these technologies is still considered to be insufficient. In this respect, authors wanted to draw attention to another possible usage of night-time data in urban and regional planning discipline for the purpose of determination of the location, size, and hierarchy of the attraction zones in urban scale which are mostly composed of central business districts (CBD), commercial zones, touristic corridors and/or concentration areas etc., as these regions are more illuminated areas compared to other zones of a city. Thus, a methodology based on GIS and RS integration and spatial and statistical analysis capabilities of GIS is presented in this study to determine the boundary and size of the attraction zones and their hierarchical levels by using the night-time imageries. To show how effective the suggested model is, the proposed methodology has been used in the city of Istanbul. The assessment of the location, size, and hierarchy of the attraction zones could give an essential decision support for the decision makers, especially those working in the urban planning discipline, as the attraction zones of cities need to be developed in a more specific and detailed manner. Thus, the model's outputs' reliability and potential applications in the field of urban planning are also examined.

Keywords:
Night-time photo, GIS (geographic information systems) and RS (remote sensing) integration, city attraction zones, urban scale, Istanbul

*Ankara Hacı Bayram Veli University, the Academy of Land Registry, Ankara, Türkiye. (Corresponding author)
E-mail: asli.ok@hbv.edu.tr

**Akdeniz University, Faculty of Architecture, Urban and regional planning department, Antalya, Türkiye. (Corresponding author)
E-mail: kivancertugay@akdeniz.edu.tr

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INTRODUCTION

Obtaining up-to-date information about different forms of land-use (e.g., residential areas, industrial areas, central business district areas, recreational areas etc.) is significantly important for many disciplines but especially for urban and regional planners. Therefore, new technologies and strategies are used to obtain repeatable and reliable up-to-date information.

Remote Sensing (RS) technology is a powerful tool for gathering information about an object, area, or fact without requiring physical intervention (Lillesand et.al. 2004). Geographic Information Systems (GIS) are powerful tools for supporting RS technology because they can collect, store, retrieve, transform, and display spatial data acquired by RS products (Burrough, 1986). In this study, a method is tested to identify attraction zones and their hierarchical levels with RS and GIS supported techniques and spatial and statistical data analysis related capabilities of GIS using night-time images. Section below summarizes the fundamental research that uses nighttime imagery to obtain various types of information.

Based on the literature, a number of research demonstrate that night-time lights and socioeconomic indicators such as population, gross domestic product, wealth, poverty, migration, etc. have high correlation. Thus, utilizing night-time lights is an inventive way to figure out socioeconomic markers. Multi-date night-time data series is also particularly vital for tracing human activities at the desired time interval (Li, et.al., 2016). Despite these facts, there are a limited number of valuable research papers in this respect in the literature. For this reason, it is necessary to perform systematic studies to widespread the usage of night-time images in terms of monitoring urbanization activities. Night-time lights can be categorized into three main categories in terms of spatial resolution: (i) low, (ii) moderate, and (iii) high. Defense Meteorological Satellite Program/Operational Linescane System (DMSP/OLS) (launched by U.S. Airforce) forms the low-resolution category of night-time images with 2.7km (smooth mode) and 0.55km (fine mode) ground sampling distance. It is the first satellite to provide night view and more specifically designed for cloud detection enlightened by moon light thus it has brought certain deficiencies (e.g., coarse spatial resolution, on-board calibration deficiencies, six-bit quantization, etc.) (Web1). These deficiencies could be improved to a certain extent by the usage of Visible Infrared Imaging Radiometer Suite (VIIRS) instrument. The VIIRS was designed by NASA and NOAA and launched from Suomi National Polar Partnership (SNPP) satellite in 2011. Although the VIIRS also provides low-light data by panchromatic images (0.5 μm – 0.9μm) similar to the DMSP/OLS, it has several advantages over the DMSP/OLS data with improved spatial resolution (0.742km), higher quantization level (14-bit), on-board calibration, and availability of spectral bands to identification of thermal sources. Therefore, the VIIRS images can be utilized to view urban areas more

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effectively than DMSP/OLS images. Other sources of night-time images, space photographs, produced from International Space Station (ISS) taken by astronauts from spacecrafts are categorized as moderate resolution (≈ 60m) images in terms of viewing night lights. The color astronaut photos make city lights more visible especially in nadir viewing and can be access freely since 2003. However, velocity of the spacecraft can affect optimal exposure times and spatial resolution of the images besides the lack of calibration parameters (Elvidge et, al., 2013). The only commercial satellite platform providing high resolution night-time images is EROS-B launched in 2013 by ImageSat International. It provides color images to obtain city lights with less than 1 m spatial resolution at nights (Levin et.al., 2014). In addition to satellite-based high-resolution EROS-B images, some aerial platforms (e.g., Cirrus (1.5m spatial resolution at 16-bit quantization level) integrated to NASA's ER-2 aircraft) also provide high resolution night-time photographs (Elvidge et, al., 2013).

An extensive review paper describing the nightsat mission concept was written in 2007 by Elvidge et.al. In this paper, products of satellite and airborne sensors were examined with their advantages and limitations based on their spatial, spectral, and temporal resolutions. It was concluded in the paper that night-time images provide valuable capability to observe human activities both in global and regional scale as opposed to conventional earth observing systems (Elvidge et.al., 2007). Other recent review paper examining DMSP/OLS night-time images was conducted in 2017 (Li and Zhou, 2017). In this paper, blooming effect due to the deficiency of spatial resolution, lack of intercalibration parameters is shown main restrictions of the use of DMSP/OLS data. Authors offer a major suggestion about the integration of DMSP/OLS and nighttime data of VIIRS and developing new methods to reduce uncertainty and provide more reliable data for the future.

One of the earliest attempts of offering night-time data (DMSP/OLS) was published to produce a global population database for estimating populations at risk in the scope of Landscan' project (Dobson et.al, 2000). It was concluded that remote sensing sources of images and night-time lights are requisite to produce more effective population models. Other valuable study conducted at the beginning of the year 2000 (Henderson et.al, 2003) was about delineation of urban boundaries of three different cities (San Francisco, Beijing, and Lhasa) with DMSP/OLS and Landsat Thematic Mapper (TM) data. After co-registering the images, three different classification thresholds were applied to the DMSP data to recognize urban boundaries. Analysis demonstrates that each city requires different thresholds to delimit urban extents.

The first detailed study of night-time light characteristics (DMSP/OLS) regarding to local economic activity was performed by Doll et.,al., 2006. Relations were searched between the night-time radiance and gross regional products of cities and potentials of using night-time

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data were revealed in the paper. A method that provided the first detailed analysis to estimate global economic activity from night-time DMSP/OLS data was presented (Doll et. al., 2006). Maps showing relationships between nigh-time lights and local economic activities were produced to 11 European Union countries and United states in the study. Results showed the importance of night-time images to provide flexibility of producing spatial maps of countries. Urbanization dynamics of India, China, Japan, and the United States were investigated using multi-date DMSP/OLS night-time data for two-year intervals between 1992 and 2000 (Zhang and Seto, 2011). Unsupervised Isodata classification algorithm was applied iteratively to the night-time images and final urbanization maps were produced as steady growth and urban growth zones. This study showed the potential use of night-time images for monitoring the local and global scale urbanization activities. Same year a different study was published that examines the relationship between night-time lights and population density of Hong Kong with pixel-based and polygon-based approaches (Liu, et. al., 2011). Two data types (DMSP/OLS and ISS space photographs) were used as night-time images in the study to evaluate the performance of ISS space photographs over the performance of DMSP/OLS. Results displayed that better correlations were observed between the DMSP/OLS and population data although the ISS night-time photographs have higher spatial resolution.

An extensive multitemporal night-time research of 271 China's cities during 1992-2012 were performed to categorize urban forms of the cities as 5 classes (low, low-medium, medium, medium-high, and high) (Ma, et.al., 2014). The method used was based on constructing gradients and spatio-temporal analyses of nighttime images. Successful results were obtained with the methods. It was anticipated that the use of high-resolution images (e.g., VIIRS) minimized the over glow effect and produced closer results to the real lightening areas.

A new multitemporal (2000-2009) method was presented by integrating DMSP_OLS and MODIS data to monitor large-scale settlement areas of Yangtze River Delta-China (Shao and Liu, 2014). A spatially adaptive regression model was developed instead of using a linear regression model to estimate urban dilatation. Promising results were acquired compared with the linear regression model estimation. An evaluation study was conducted to reveal the application areas (estimation of socioeconomic parameters, spatialization of population, regional development, light pollution etc.) of nighttime images (Li et.al., 2016). A different multitemporal study was performed based on DMSP/OLS data series from 1992-2013 to evaluate changes of urbanization intensity of China (Yu et.al., 2017). Urbanization dynamics were categorized by an unsupervised image classification method.

Spatial pattern of urbanization change was examined by Moran's I in local and global scale. Capacity of spectral night viewing capability of Landsat 8 OLI image was evaluated for multiple large urban areas

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(Berlin -Germany, Las Vegas -USA, Nagoya - Japan and Tel Aviv – Israel) and gas flare locations (Basra – Iraq and Kuwait) (Levin and Phinn, 2016). Results were compared with VIIRS products and astronaut photos of the test sites. Analyses demonstrated that visible channels of the Landsat 8 OLI data have capability of detecting nighttime lights of urban areas and gas flare locations although it was not designed for this purpose. Authors stated that Landsat 10 should be designed in advance to detect nighttime lights more effectively. Poverty estimation was done for the counties of China by average light index (ALI) of VIIRS data (Yu et.al., 2015). Results were validated using integrated poverty index (IPI) including 10 different socioeconomic variables. Linear regression and comparison of class ranks were utilized in the evaluations. High correlations (R2 of 0.8554) were computed between night-time lights and poverty of China's counties. It was stated that night-time images of VIIRS could be reliably used in poverty estimation. A recent extensive research paper that analyzes the factors affecting the VIIRS nighttime data at global scale were published by Levin and Zhang (Levin and Zhang, 2017). Correlations of multiple variables (Landscan data, NDVI, snow cover etc.) and VIIRS nighttime data of 4153 urban areas were examined in the study. Results showed that phenological cycles of vegetation and snow cover is as important as other variables like GDP and road network and it should be taken into consideration.

In the light of the above mentioned literature, it could be observed that although there are several different types of research efforts on night time imagery such as; determination of location and size of settlements, urban macro forms, producing spatial maps of countries, comparison of the gross domestic/national products (GDP/GNP), estimation of socioeconomic parameters, specialization of population, regional development, spatial pattern of urbanization change, light pollution etc.), the proposed research is considered to have a value in terms of its aim and the proposed methodology. In this research, authors wanted to draw attention to another possible usage of night-time data in urban and regional planning discipline for the purpose of determining location, size, and hierarchy of the attraction zones in urban scale which are mostly composed of central business districts (CBD), commercial zones, touristic corridors and/or concentration areas etc., as these regions are more illuminated areas compared to other zones of a city. Therefore, a methodology (Figure 1) based on GIS and RS integration is presented in this study to determine the location and size of the attraction zones and their hierarchical levels by using the night-time photos. The research is expected to provide up-to-date, precise, and more detailed information about the distribution of attraction zones in urban area with their location, boundary, size, and hierarchical levels in a fast and reliable manner. The outputs of the model could create an important decision support for the decision makers working on urban and regional planning discipline for better understanding of the attritional dynamics of a city and its important zones and locations. The proposed methodology has been applied in the city of Istanbul to able to demonstrate the efficiency of the proposed model. The presence of many city centers of Istanbul metropolitan city with different hierarchical levels, played an important role in this selection.

The rest of the paper is organized as follows: The methodology part of the paper (Section 2) describes the details about the proposed model, Section 3 describes basic results and conclusions about the research, provides general evaluation of the obtained results, gives possible usage areas of the model in the field of urban planning, and explains possible future works.

METHODOLOGY

The proposed methodology consists of five main steps: (i) data collection and preparation, (ii) unsupervised stepwise classification, (iii) spatial analysis of the classified data based on GIS and RS integration, (iv) validation and (v) evaluation of the results (Figure 1).

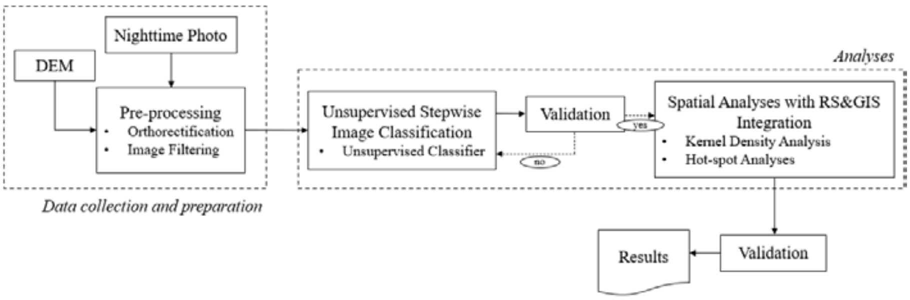

Figure 1. Methodology of the proposed study

In RS part of the research, the PCI Geomatica software of PCI Geomatics company and in GIS part of the research, the ArcMap software of ESRI company was used. However, many other software and freeware are also available in the technology market to perform GIS and RS based analysis.

DATA COLLECTION AND PREPARATION

Istanbul is a metropolis with over 15 million populations, and it has a very fast changing scene. These characteristics makes easy to access night-time astronaut photographs and therefore Istanbul were chosen as study area by the authors. The astronaut photographs are freely available in the web site called “Gateway to Astronaut Photography of Earth” (Web2). An astronaut photograph of Istanbul dated 2012 were acquired from that site (Figure 2). For the acquisition of the photo (15.08.2012) Nikon D3S Electronic Still Camera with 155mm (camera tilt: 37 degrees) has been used. The spacecraft altitude of the photograph has been recorded as 396 km with 41.8 oN and 31.6 o E spacecraft nadir point. Cloud cover percentage of the image is 10% (Web 3). Unfortunately, the photo has not a certain radiometric process to correct radiometric errors, thus authors have used original pixel values in the analysis.

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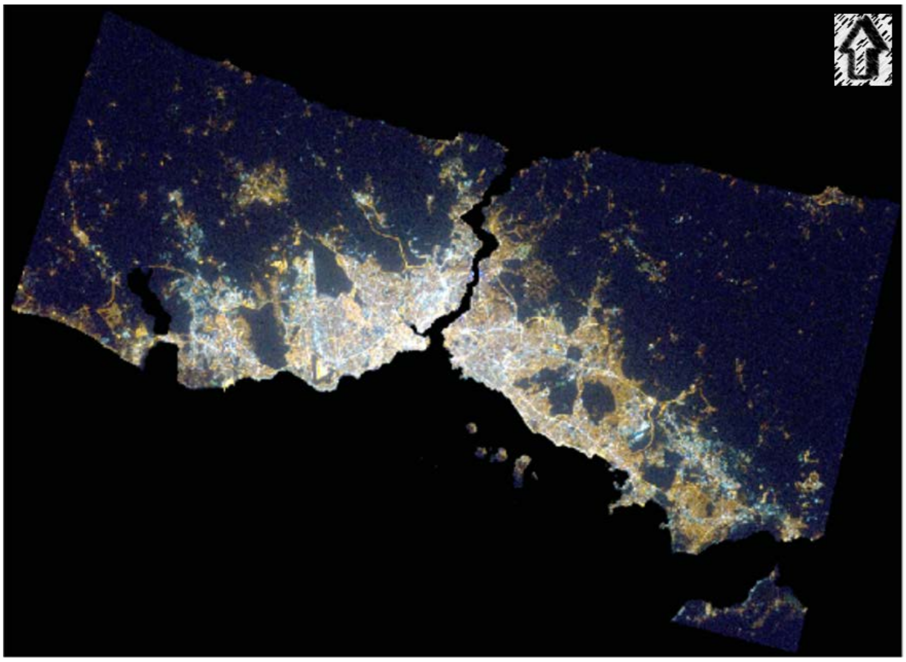

Figure 2. Astronaut photo of Istanbul city taken in 2012

Available images with the highest resolution were downloaded from the web site and orthorectified first using approximately 10 ground control points (GCPs). In the orthorectification process GCPs were selected from distinctive light sources of the astronaut photos and selectable points from the corrected Landsat ETM image (acquisition date: 23.07.1999) of the test site. ASTER GDEM was utilized for the orthorectification process (Web 4). At the end of the orthorectification process, root mean square error was computed to be less than 1 pixel, which is a sufficient error rate to continue the analysis phase.

The orthorectified night-time astronaut photographs were then filtered using Savitzky Golay (SG) filter to eliminate noise from the data. The SG filter is a low-pass filter that smooths noisy data by linear least squares fit via a moving average window by a desired polynomial degree. The characteristic that distinguishes it from the other moving average filter is its efficiency of preserving higher moments of the peaks (Press et.al, 2002).

Unsupervised stepwise image classification

A stepwise image classification strategy was adopted to the orthorectified astronaut photograph to group night-time lights. Isodata unsupervised image classification method was utilized for that purpose. First, the image was grouped into 100 classes based on the Isodata classifier. Next, illuminated, and non-illuminated classes were aggregated to two classes based on an expert knowledge and a mask area was produced for the illuminated regions. Next, pixels inside the mask were reclassified again to obtain 10 new classes. After the aggregation process, four main classes (low-level light, moderate level light, high level light, and others) were obtained. A new mask was produced again for the areas classified as strong light and those areas were reclassified to access the central business regions. It was observed

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that this strategy was sufficient to characterize urbanization dynamics. First step results were evaluated using Google Earth images of the study area with 100 random points and image classification accuracy over 85% was observed.

Spatial analysis of the classified data based on GIS and RS integration

Three sequential processes; visual evaluation of the classified data, kernel density analysis, hot spot analysis, were performed for the determination of attraction zones within the metropolitan area of Istanbul by using the classified image.

VISUAL EVALUATION OF THE CLASSIFIED DATA

As the attraction zones of a city which are mostly composed of "central business districts (CBD), commercial zones, touristic corridors and/or people's concentration areas etc." are more illuminated compared to other zones of a city, visual exploration of the classified night-time images could give some significant clues to the decision maker about the distribution of the locations of important attraction zones. For example, darker regions and corridors in the figure demonstrated below represent highly illuminated areas and could be visually noticed as some of the representatives of attraction locations (Figure 3).

On the other hand, there are hundreds of different levels of illuminated areas with fragmented scattered structures, it is not possible to differentiate the location, size, and hierarchy of these illuminated areas by just visual evaluation process. Thus, determination of the location, size and hierarchy of the attraction zones must be supported by further spatial and statistical data analysis processes.

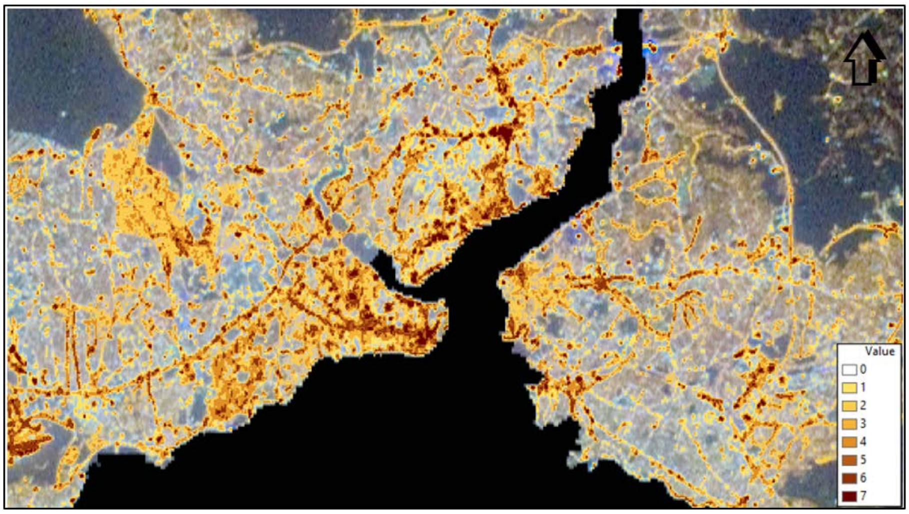

Figure 3. Visual exploration phase of the classified images (darker cell means more illumination score)

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KERNEL DENSITY ANALYSIS

Kernel Density determines the concentration of points in the area surrounding each raster cell in the final output. In this conceptual model, a smoothly rounded surface is superimposed over every single point. The surface value is greatest at the point itself and decreases outwards, eventually becoming zero at the search radius distance (Web 5).

Kernel density analysis was performed in the research to understand the distribution density of the illumination zones within the city and to better clarify especially the attraction zone's concentration location (at where) and the hierarchy (in which degree/importance) which is difficult to perceive visually in the previous phase. However, an important problem in this phase is that; the kernel density analysis in GIS environment requires point-based illumination distribution datasets in vector format. To solve this problem; 2 different types of comparative approaches were tried; one of which is "polygon centroids approach" (a) and the other is the "pixel centroids approach" (b)

Polygon centroids approach

In this approach, the night-time illumination data in raster format, in which the light reflection values were classified in 0-7 range classes, were firstly converted into vector data in polygon format by using the "raster to vector conversion function" of GIS. The approximate position and size of the light reflection values for each of the 0-7 class range were transformed into an attribute table which enabled the illumination values to be spatially and statistically analyzed by decision-makers and provide more effective decision support.

In the next step, the centroids of the vector data in polygon format (the point location that represent the center of gravity in a polygon object) was converted into point format by using the "centroid function" of GIS to able to benefit from kernel density function of GIS which helps better understanding the location and hierarchy of the illumination concentration zones. During the conversion process, both pixel value and the total area information were transferred (Figure 4).

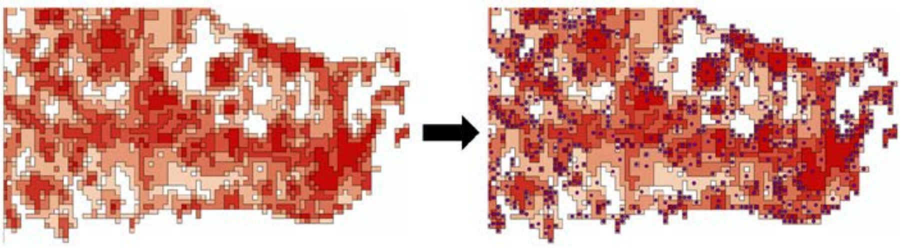

Figure 4. Conversion of the vector data in polygon format into point format as polygon centroids

To ensure a healthy comparison between the illumination scores (pixel values) and their size (total area), all values in the attribute table were normalized/standardized in the range of 0-100 (for pixel values), and in the range of 0-1 (for total area values).

Kernel density analysis function in GIS environment was performed by considering “multiplication of the standardized pixel values with their standardized total area values”. It means that both the illumination scores and their size were represented in the results.

As the attraction zones which were mostly composed of central business districts (CBD), commercial zones and touristic corridors and/or people’s concentration areas etc. were expected to be more illuminated areas compared to other zones of a city, kernel density analysis was performed by considering the illumination scores in the range of 5 to 7 (the top 3� the most illuminated ranges).

The obtained kernel density scores for the study area by “polygon centroids approach” was presented below in 5 classes according to Jenk’s natural breaks classification (which seeks to reduce the variance within the classes and maximize the variance between classes) with the illumination scores and their size (see figure 5).

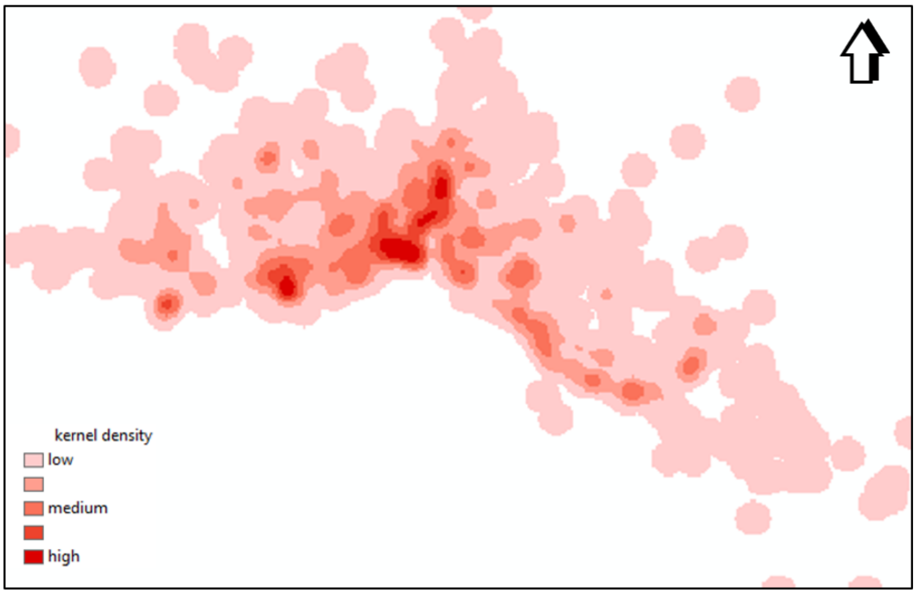

Figure 5. The results of the kernel density analysis by using the polygon centroids approach with illumination scores and their size

Although “polygon centroids approach” was considered to be faster and less processed approach compared to “pixel centroids approach” to convert illumination scores into point format, it’s disadvantage is that; representation of illumination scores as polygon centroids could be misleading for decision makers in terms of positional accuracy of illumination zones especially in the case of where there are large and non-uniform shaped polygons after raster to vector conversion process (Figure 6). The mentioned disadvantage could be overcome by the pixel centroids approach.

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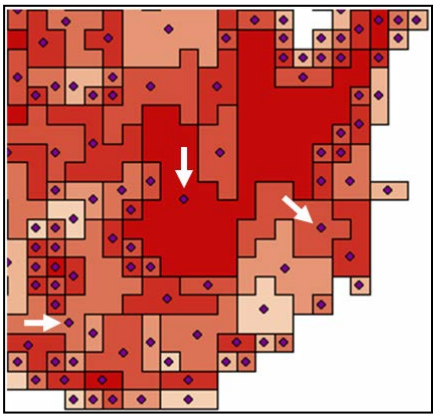
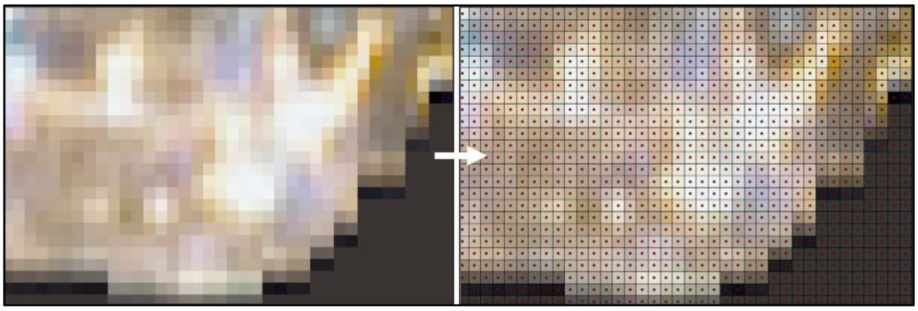


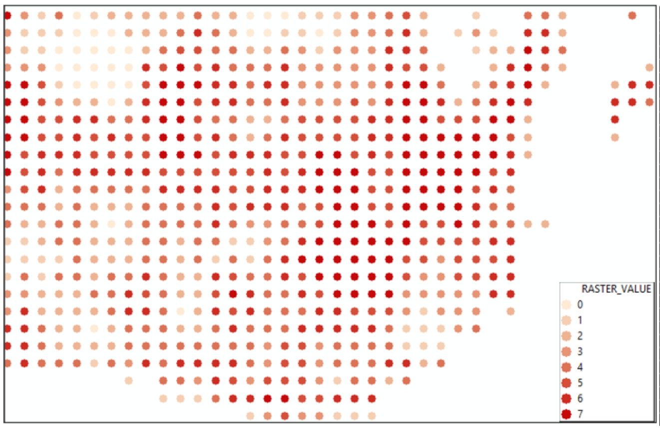
Figure 6. The centroids of large and non-uniform shaped illumination polygons

Pixel centroids approach:

In pixel centroids approach, using the same extent and pixel resolution of the night-time data in raster format, the study area was converted into vector-based grids in polygon format by using the "fishnet function" of GIS, which could basically divide a defined region into grids according to a defined extent and resolution/grid size.



(a)



FID	OBJECTID	Pixel Value	Normalized Pixel Value
0	247693	1	14
1	264159	2	29
2	266500	2	29
3	292243	2	29
4	292247	4	57
5	292248	2	29
6	292424	1	14
7	294582	2	29
8	294583	2	29
9	294584	2	29
10	294585	2	29
11	294586	2	29
12	294587	2	29
13	294588	4	57
14	294589	6	86
15	294590	4	57
16	294765	3	43
17	294766	5	71
18	294767	3	43
19	296923	2	29
20	296924	2	29
21	296925	4	57
22	296926	2	29
23	296929	2	29
24	296930	4	57
25	296931	4	57
26	296932	4	57
27	297107	3	43
28	297108	3	43
29	297109	1	14
30	297181	2	29

(b)

Figure 7. Vector-based grids in polygon format by using the "fishnet function" of GIS (a) and transferring process of raster-based light reflection values into point-based fishnet/grid centroids (b)

In the next step, the light reflection scores stored in raster format were transferred into vector-based grid centroids in point format. Thus, as an advantage of the pixel-based approach, it was ensured that all information about illumination scores in the raster data were transferred into the attribute table of fishnet centroids in point format without any loss of information and spatial accuracy. To ensure a reliable comparison between the illumination scores (pixel values),

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again all pixel values in the attribute table were standardized in the range of 0-100. That time there was not any "size" column in the database as every illumination pixel in the raster data was represented by a point feature in the database (Figure 7).

Although "pixel centroids approach" is process intensive approach compared to "polygon centroids approach", its main advantage is that; all information about illumination scores in the raster dataset could directly be transferred into the attribute table of fishnet centroids without any loss of information and spatial accuracy.

In the next step, all obtained points by pixel centroids approach were again analysed by kernel density function of GIS by considering the standardized illumination scores in the attribute table. As the attraction zones were expected to be more illuminated areas compared to other zones of a city, kernel density analysis was performed for the illumination scores in the range of 5 to 7 (the top 3 the most illuminated ranges). The obtained kernel density scores for the study area by "pixel centroids approach" was presented below in 5 classes according to Jenk's natural breaks classification with and without considering the illumination scores (Figure 8). According to the figure, the obtained kernel density scores with considering the illumination scores was more informative (more clear/sharp/plain boundaries for the illuminated areas) in terms of determination of concentration zones of illumination zones and their hierarchical levels as expected.

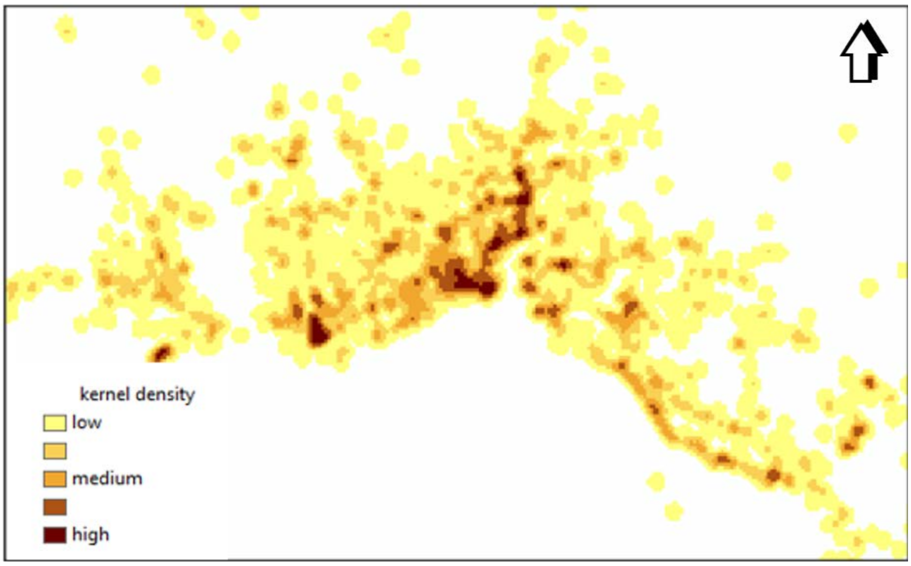

Figure 8. Kernel density analysis scores by using the fishnet/grid centroids (pixel centroids approach) considering the illumination scores

As the kernel density scores could be more clearly understood by the decision makers in vector environment, the classified kernel density scores in raster format (considering the illumination scores) were converted into vector format. By using the database query opportunities in vector environment, decision makers could obtain significant clues about the location (at where), the hierarchy (in which degree/importance) and the size (at what size) of the attraction zones

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which was difficult to perceive visually in the previous phase of visual exploration.

HOT SPOT ANALYSIS

Kernel density analysis tells the decision maker where clusters in the area exist, but do not tell if clusters are statistically significant. Therefore, after analyzing the distribution of vector-based illumination points by kernel density analysis, another point-based spatial data analysis was performed by the help of the hot spot analysis which created a map of statistically significant hot and cold spots using the Getis-Ord Gi statistic.

The Hot Spot Analysis could calculate the Getis-Ord Gi statistic for each of the feature in a point dataset by looking at each feature within the context of neighboring features. A feature with a high illumination value could be interesting but may not be a statistically significant attraction zone (hot spot). To be a statistically significant hot spot, a point feature must have a high illumination value and must be surrounded by other features with high illumination values as well. The Gi statistic returned for each feature in the dataset is a z-score. For statistically significant positive z-scores, the larger z-score is, the more intense clustering of high values (hot spot). The smaller z-score is the more intense the clustering of low values (cold spot) for statistically significant negative z-scores (Web 6) (see Equations 1-3).

The Getis-Ord local statistics is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (1)$$

Where x_j is the attribute value for feature j, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2} \quad (3)$$

The Gi* statistic is a z-score, so no further calculations are required.

The illumination locations obtained by "polygon centroids" approach and "pixel centroids" approach were both analyzed in a comparable manner by the help of the hot spot analyzes and the results were given below (Figure 9).

The results obtained by pixel centroids approach could be considered as more accurate and realistic compared to polygon centroids approach as all information about illumination scores in the raster dataset could directly be transferred into the attribute table of fishnet centroids without any loss of information and spatial accuracy.

(a)

(b)

Figure 9. Hot spot analysis of the illumination locations obtained by polygon centroids approach (a) and pixel centroids approach (b)

In the next step, the results of the hot spot analysis of the illumination locations obtained by pixel centroids approach were transferred into the polygons of fishnet grids and a dissolve operation was performed based on Gi_bin scores to provide better understanding of the size of the hot spot zones (Figure 10).

The performed dissolve operation of the fishnet grids could help decision makers to have more information about the size and location of the hot spots. For example, analysis of the illumination hot spots with higher confidence level (e.g., higher than 95%) and larger than a defined threshold in size (e.g., larger than 5 hectare) could be analyzed by the decision makers in a comparable manner (red polygons in Figure 10). Detailed explanation about the interpretation of the results is given in Section 2.4.

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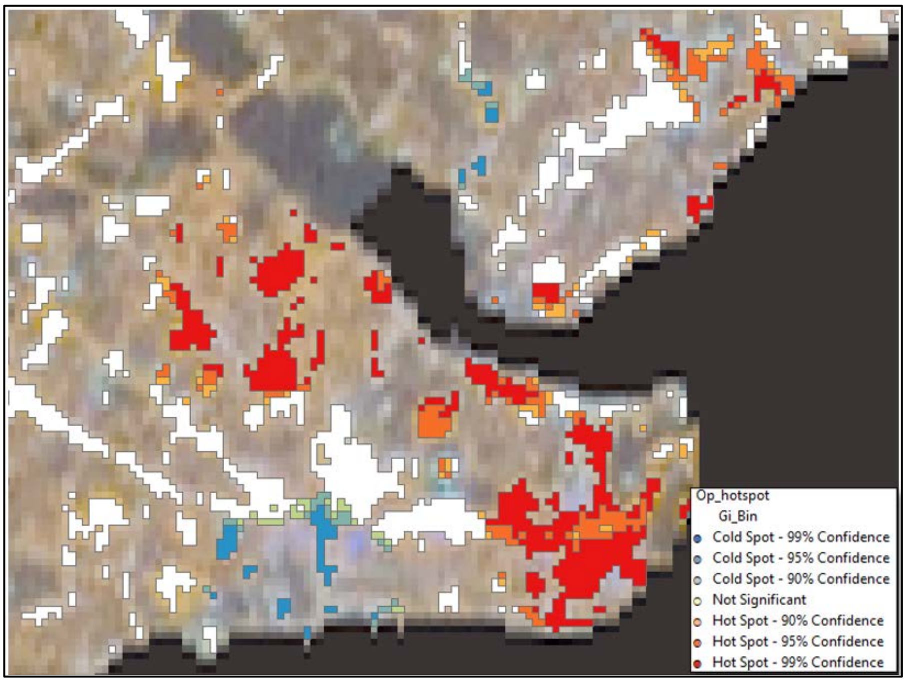

Figure 10. Hot spot locations on fishnet grids

VALIDATION OF THE RESULTS

The validation process consists of two stages; in the first stage, the widely known attraction zones in urban scale both in Anatolian and European parts of Istanbul was marked on the map and the extent of the overlap with the attraction zones obtained by the proposed methodology was investigated.

The well-known attraction zones in the European side of the city are; 1- The historical semi-island zone (Istanbul's major historic central attraction zone: The Grand Bazaar and its surrounding Tahtakale, Sultanhamam, Sirkeci region, 2- Galata, Taksim, Beyoğlu and İstiklal street zone 3-Nişantaşı and Ortaköy zone 4-Şişli and Mecidiyeköy zone and 5- Levent and Maslak zone and its surroundings (the new central attraction zone of the city attracting modern business centers, shopping malls and foreign companies). The widely known attraction zones in the Anatolian side of the city are 6-Altunizade zone 7-Kadıköy zone 8-Bağdat Street zone and its surroundings including Küçükyalı, Maltepe and Kartal districts and 9) Ataşehir zone (Figure 11) (see IMP 2009, Web 7).

The historical semi-island zone (Istanbul's major historic central attraction zone; the Grand Bazaar and its surrounding Tahtakale, Sultanhamam, Sirkeci region); the Galata, Taksim, Beyoğlu and İstiklal street zones; and the Mecidiyeköy and Levent zones (the new central attraction zone of the city attracting modern business centers, shopping malls and foreign companies) are widely accepted as the major/primary attraction zones or in other words 1st degree hot spots of İstanbul city.

In this context, the widely known attraction zones were overlaid by the results of kernel density analysis and hot spot analysis which are obtained by the help of the pixel centroids approach (see related part for details) and the results were discussed in order to provide a guidance for the decision makers to be able to understand how the proposed methodology provide a success in determination of the location and size of the attraction zones and their hierarchical levels relative to each other.

As the attraction zones of a city which are mostly composed of central business districts (CBD), other commercial zones, service zones, touristic corridors and/or other types of people's concentration areas etc., they are more illuminated areas compared to other zones of a city. Hence their location, size and hierarchical information related details were significantly improved by the help of the proposed methodology.

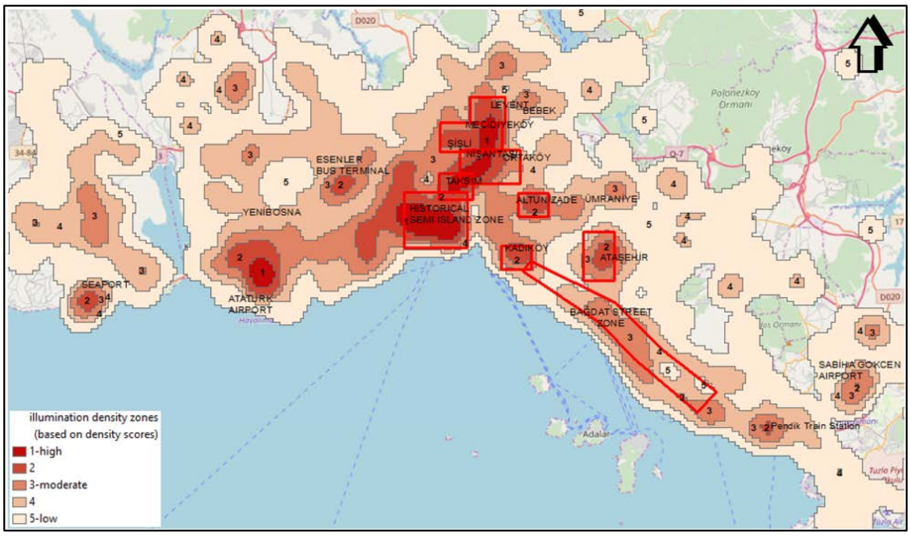

Figure 11. The widely known attraction zones, overlaid by the results of kernel density analysis (widely known attraction zones are represented in red rectangles)

The overlay of the widely known attraction zones by the results of kernel density analysis demonstrated that the zones obtained by the proposed model were significantly coincides with the approximate location of the widely known attraction zones (Figure 11). For example, the 1st degree illumination density zones mostly overlapped with the attraction zones of the city such as the Historical Semi-Island zone, Taksim zone, Nişantaşı zone, Mecidiyeköy zone etc., and their surroundings. Similarly, the 2nd degree illumination density zones also overlapped with the widely known attraction zones of the city such as the west part of the Historical Semi-Island zone, Kadıköy zone, Ataşehir zone, Altunizade zone, Şişli zone, Levent zone etc., and their surroundings. The Bağdat street zone, starting from Kadıköy zone and spread throughout the Pendik zone, which is also one of the widely known attraction corridor in Istanbul was represented between 3rd and 5th degree illumination density zones in the model. Moreover, the overlooked, unknown or unpredictable attraction zones could also be detected by the proposed model which are the Ambarlı Seaport (2nd degree illumination density zone), Atatürk International Airport (1st degree illumination density zone), Esenler Bus Terminal (2nd degree illumination density zone) and their surroundings in the west part of the Istanbul city, and Sabiha Gökçen Airport (2nd degree illumination

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density zone), Pendik Train Station (2nd degree illumination density zone) and their surroundings in the east part of the Istanbul city.

It is also possible for the decision makers to extract hierarchical differences among widely known attraction locations by using the mean value of the illumination density scores within each of the approximate attraction zone boundaries. In that respect, the hierarchical differences within each of the widely known attraction zone boundaries (which was previously an unknown parameter) was calculated and presented below (Figure 12).

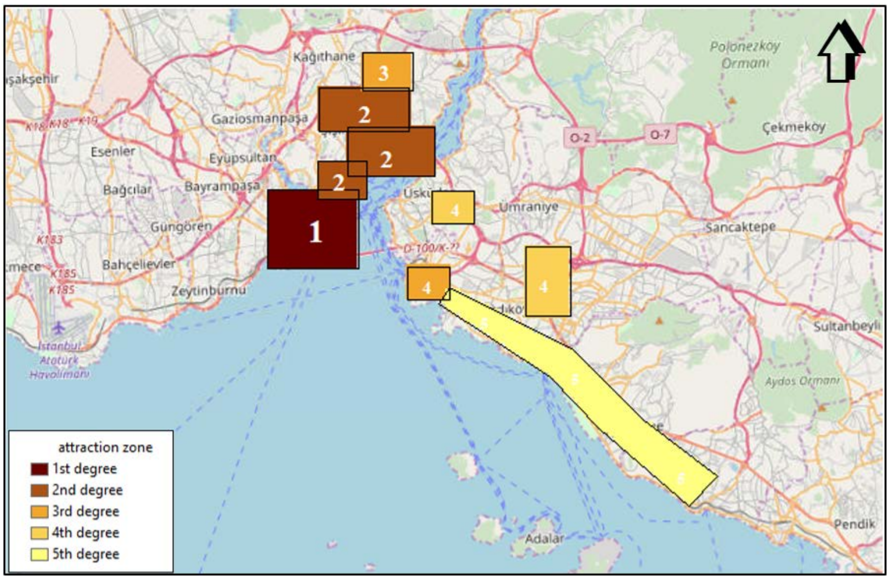

Figure 12. The hierarchical differences among the well-known attraction locations extracted by using the mean value of the illumination density scores within each of the approximate attraction zone boundaries

According to figure 12; the Historical Semi-Island zone and their surrounding is the 1st degree attraction zone, the Taksim zone, Şişli zone, Nişantaşı zone, Mecidiyeköy zone and their surrounding is the 2nd degree attraction zone, the Levent zone and their surrounding is the 3rd degree attraction zone, the Kadıköy zone, Ataşehir zone, Altunizade zone and their surrounding is the 4th degree attraction zone, and finally the Bağdat street zone, starting from Kadıköy zone and spread throughout the Pendik zone is the 5th degree attraction zone.

In the next step, the widely known attraction zones overlaid by the hot spot locations on fishnet grids (after dissolve operation were presented. Based on the figure, although there are many partial (minor) hot spot zones in the study area, there were 5 dominant (major) hot spot zones observed in the study area which mostly (4 of 5) overlap with the 1st degree illumination density zones (Figure 13).

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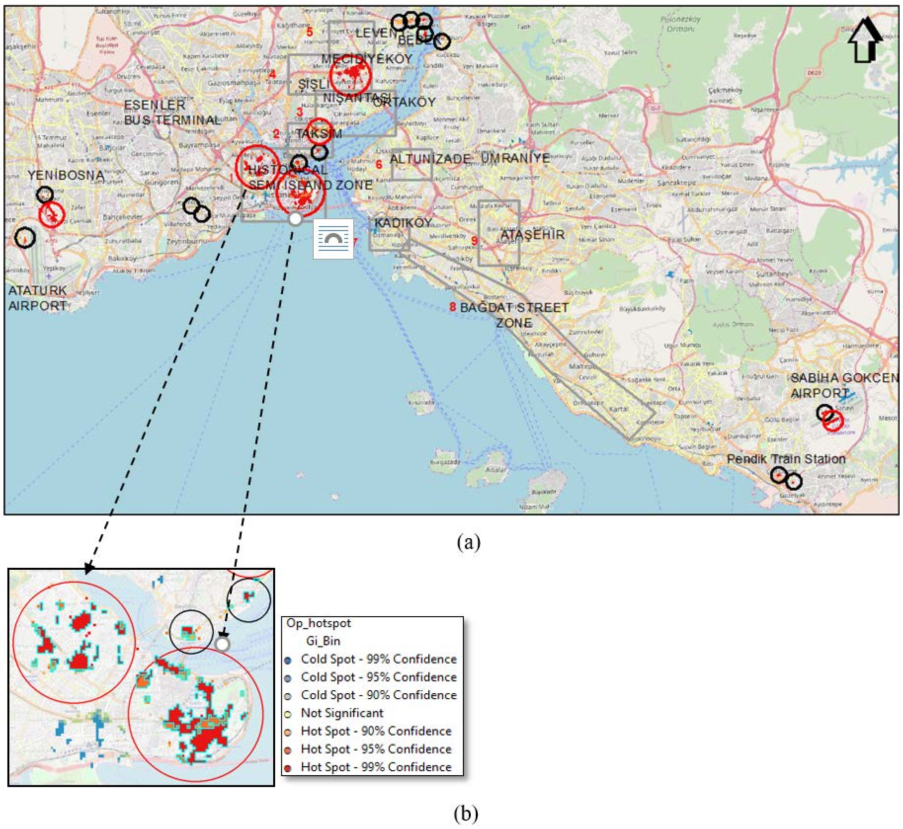

Figure 13. The widely known attraction zones (grey rectangles), overlaid by the results of hot spot locations boundaries of major and minor hot spot zones (major ones are represented with the red circles and minor ones are represented with the black circles) (The hotspots with higher than 95% in confidence level and that are relatively the largest in size are considered as major) (a), and an example of representation of hot spot boundaries in detail (b)

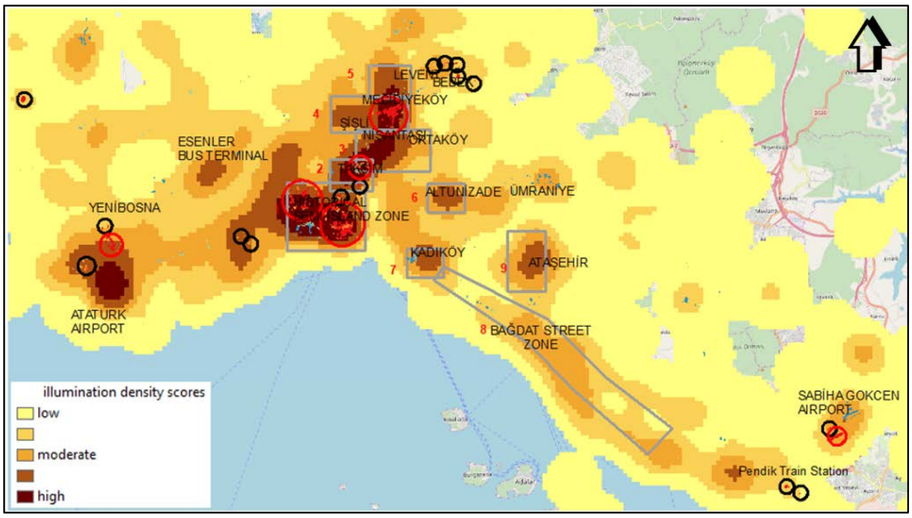

Figure 14. Overlay of density maps and hot spot maps with the well-known attraction locations (the well-known attraction locations are represented as grey rectangles; major hot spots are defied as red circles, and minor hot spots are represented as black circles)

According to Figure 14; the four dominant hot spot zones determined by the model are the Historical Semi-Island zone, Taksim zone, Nişantaşı zone, Mecidiyeköy zone etc., and their surroundings. The overlay of the well-known attraction zones by the hot spot analysis demonstrates that 4 of the hot spots obtained by the model coincides with the well-known locations. The only exception is the 5th hot spot located in the Yenibosna zone which is one of the previously unknown hot spots in the north of the Atatürk International Airport (in the west part of the study area).

Similarly, it is also possible for the decision makers to extract the hierarchical differences among hotspots by using the size and

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confidence level of the hotspot polygons. Classification of the hotspots according to their confidence level (e.g., 90%, 95%, 99%) and according to their size (e.g., larger than 5 hectares, 10 hectares, 15 hectares) could provide important clues to the decision makers about the hierarchy of the hotspot locations in a comparable manner. With the use of GIS's ability to calculate geometry, the hierarchical differences within each of the hotspot boundaries was calculated and presented below (Figure 15).

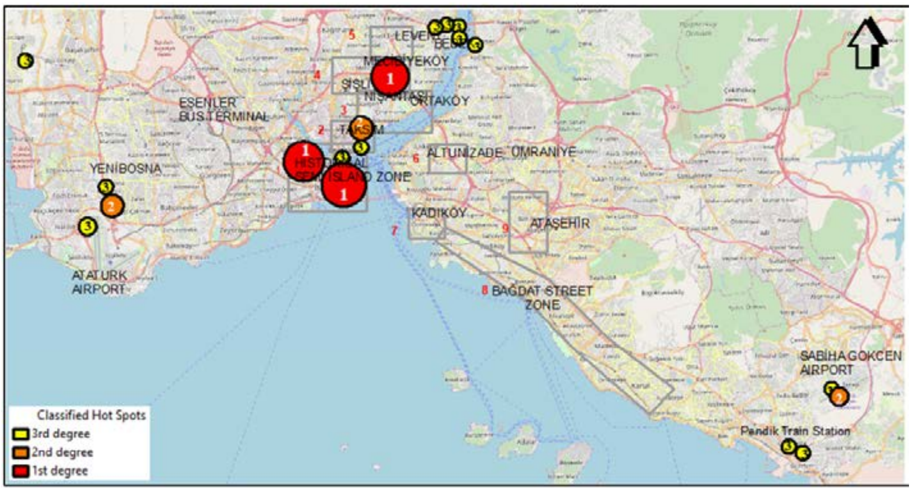
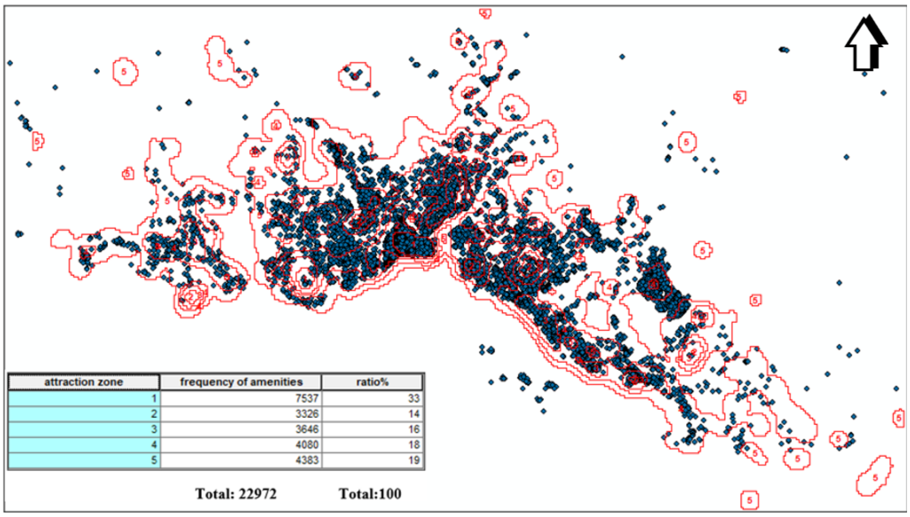


Figure 15. The hierarchy of hot spots locations according to their confidence level and size (the well-known attraction locations are represented as grey rectangles)

According to Figure 15, Historical Semi-Island zone (2 hot spots), Şişli, Nişantaşı, Mecidiyeköy and their surroundings are inside the 1st degree hot spot locations, Taksim, Yenibosna, Sabiha Gökçen airport zone and their surrounding are inside the 2nd degree hot spot locations, Bebek, Karaköy, Pürtelaş Hasan Efendi, Rumeli Hisarı, Anadolu Hisarı zone, Atatürk airport zone, Pendik train station zone and their surrounding are inside the 3rd degree hot spot locations. Although there are slight differences among the results obtained; it was observed that the results obtained by the model were generally compatible both with each other and with the well-known attraction locations. Moreover, the overlooked, unknown, or unpredictable attraction zones could also be detected by the proposed model in a significative manner.

In the second stage of the validation part, the obtained results were tested with the help of the Geofabrik's free download server; open street map dataset (Web 8) which extracts spatial distribution of all types of desirable or useful amenity/facility/service data (building or place) such as cafes, restaurants, shopping centers, pharmacies, malls, terminals, supermarkets, fast food shops, universities, schools, place of worships, monuments etc. (normally updated every day) of cities. The amenity database composed of nearly 24.000 features in point format was used for the validation process to understand percentages of the extracted attraction zones obtained.

As pixel centroids approach could be considered as more realistic compared to polygon centroids approach, the validation process was applied for the pixel centroids approach. In this context, the count/frequency ratio of the amenities within each of the attraction zones obtained by pixel centroids approach were extracted by the help of the spatial join/zonal statistics function of GIS both for the attraction zones obtained by the kernel density analysis and for the Gi_bin locations obtained by the hot spot analysis (Figure 16). Nearly 1.000 of the 24.000 amenities were not taken into consideration as they were outside of the study area.



attraction zone	frequency of amenities	ratio%
1	7537	33
2	3326	14
3	3646	16
4	4080	18
5	4383	19
	Total: 22972	Total:100

Figure 16. The count/ frequency ratio of the amenities within each of the obtained kernel density-based attraction zones (black points represent the location of amenities; red zones represent the kernel density analysis-based boundaries of the illumination zones)

According to Figure 16 it could be said that; nearly %33 (the highest percent) of the total amenities (7.537 of 22.972 amenities) fell into 1st degree attraction zones and %50 of the total amenities (10.863 of 22.972 amenities) fell into 1st and 2nd degree attraction zones which also supported the findings of this paper. On the other hand, %19 of the amenities (4276 of 22972) fell into hot spot analysis-based boundaries of the Gi_bin zones. %34 of these amenities (1453 of 4276), or %6 of the total amenities (1453 of 22972) fell into hot spot boundaries where Gi_Bin scores are greater than 1 (in other words; confidence level of hotspots is equal to 90%, 95%, 99%). When the Gi_bin scores of “0” and “below 0” was composed of statistically “not significant” locations called “cold spot” locations, the highest percent of the amenities could be seen to coincide with the hot spot locations.

RESULTS & CONCLUSION

In this manuscript, possible usage of night-time data was proposed in urban and regional planning discipline for the purpose of determination of the location, size, and hierarchy of the attraction zones in urban scale. In the context, a methodology based on GIS & RS integration and spatial and statistical analysis capabilities of GIS was proposed in the study to determine the boundary and size of the attraction zones and their hierarchical levels by using the night-time photo. The proposed methodology was applied in the city of Istanbul. Authors expected to provide up-to-date, precise, and more detailed information about the distribution of attraction zones in urban scale with their location, size and hierarchical level in a fast and reliable manner and could create an

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important decision support for the decision makers working on urban and regional planning discipline. As the attraction zones of the cities need to be planned in a more specific and detailed way, detailed and realistic manners could provide an important decision support for the decision makers especially working in urban and regional planning discipline.

Although there are several different types of research efforts on night time imagery such as determination of location and size of settlements, urban macro forms, estimation of socioeconomic parameters, etc., the proposed research could be considered to be unique to Turkey in terms of its possible usage in urban and regional planning discipline.

In the light of the above-mentioned facts, a few major findings of the research could be summarized as in below.

- Higher resolution nighttime photos (e.g aerial photograps) could be more representative and give more reliable results to that kind of studies, thus it should be examined in detailed in the feature.
- Stepwise unsupervised image classification is an effective way to categorize the illuminated cells in nighttime data.
- Visual exploration of the classified night-time images could give some significant clues to the decision makers about the spatial distribution of the important attraction zones. However, since there are hundreds of different levels of illuminated areas with fragmented scattered structures, it is not possible to differentiate the location, size, and hierarchy of these illuminated areas by just visual exploration process.
- Kernel-density method with pixel-centroid approach provided more reliable results than polygon-centroid approach.
- Alternatively, hot spot analysis could be performed as supportive analysis to understand the location of statistically significant hot spots, where a point feature has a high illumination value and surrounded by other points with high illumination values as well.

To understand the efficiency of the proposed methodology, two-stage validation process was performed in the study; one of which is by using the widely known attraction zones in urban scale, and the other is the Geofabrik's free download server; open street map datasets (Web 8). As a result, both validation process supported the reliability and usability of the proposed methodology. In this way up-to-date, precise, and more detailed and reliable information about the distribution of attraction zones in urban area with their location, size and hierarchical level could provide an important decision support for the decision makers especially working on urban and regional planning discipline. Besides all these advantages, authors also suggest that further research are necessary to evaluate the nighttime photos in a detailed manner.

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Resume

Asli Ozdarici-Ok received her Ph.D. degree in 2012 from Middle East Technical University in Ankara, Turkey. She is currently an associate professor at the Academy of Land Registry, Ankara Hacı Bayram Veli University. Her research interests include "object detection in airborne and spaceborne images", "image classification for remote sensing", and "applications for land and mass evaluation".

Kivanc Ertugay received his Ph.D. degree in 2012 from Middle East Technical University in Ankara, Turkey. He is currently an associate professor in the Faculty of Architecture, Urban and regional planning department of Akdeniz University. Some of his research interests include "usage of GIS technologies in urban and regional planning processes", "urban transportation planning", "physical accessibility modeling" and "spatial data analysis in GIS".

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