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ARTICLE / ARAŞTIRMA

Bicycle Route Infrastructure Planning Using GIS in an Urban Area: The Case of İzmir

Kentsel Alanda CBS Kullanarak Bisiklet Altyapısı Rota Planlaması: İzmir Örneği

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ABSTRACT

As a case study about İzmir (the third biggest metropolitan city in Turkey), this paper focuses on how to determine bicycle routes in already developed built environments of densely populated cities. To do so, it identifies how to deploy certain geographic information system (GIS) tools for analyzing multilayered spatial data not only at the city but also at the neighborhood level. When interrelating multiple characteristics of majorly topography, land use and population with each other, the study deploys mainly the overlay analysis and also network analysis as complementary to each other respectively at the city level and the neighborhood level. The results confirms that the use of these GIS tools for analyzing socio-spatial data especially at multiple spatial scales can support policy-makers' decision-makings about route choices in the immediate future of their city even in a "data-poor" context," such as Turkey.

Keywords: Bicycle route planning; geographic information systems; multi-criteria analysis; sustainable transportation.

ÖZ

İzmir (Türkiye'nin üçüncü büyük metropol kenti) hakkında bir örnek olay incelemesi olarak gelişen bu makale, yoğun nüfuslu şehirlerin hali hazırda gelişmiş yapılı çevrelerinde, bisiklet rotalarının nasıl belirleneceğine odaklanmaktadır. Bunu yapmak için, sadece şehirde değil mahalle düzeyinde çok katmanlı mekansal verilerin analizi için, birtakım coğrafi bilgi sistemi (GIS) araçlarının nasıl kullanılacağını açıklamaktadır. Çalışma, büyük ölçüde topoğrafya, arazi kullanımı ve nüfusun özelliklerini birbirleriyle ilişkilendirirken, temel olarak şehir düzeyinde çakıştırma (overlay) analizi ve ve mahalle düzeyinde tamamlayacı olarak ağ analizini uygular. Sonuçlar, bu CBS araçlarının Türkiye gibi "veri yetersiz" bağlamlarda, sosyo-mekansal verileri çoklu mekansal ölçeklerde analiz etmek için kullanılmasının, mekansal politika üretiminde, özellikle ulaşım-rota planlaması konusunda, destekleyici mekanizmalar olduğunu doğrulamaktadır.

Anahtar sözcükler: Bisiklet rota planlaması; coğrafi bilgi sistemleri; çok kriterli analiz; sürdürülebilir ulaşım.

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Introduction

As part of the efforts related to sustainable development, carbon-free and non-motorized transportation and "healthy" cities, many researches and policy initiatives in most countries promote bicycle use in daily life. While some of these policies and researches encourage the changes in lifestyles and habits of physical activities (e.g., Wendel-Vos et al. 2004), others focus majorly on new understandings for planning and design of built environment and of different transportation systems, including how to determine bicycle roads in settlements (e.g., Huang and Ye 1995, Rodriguez and Joo 2004, Blečić et al. 2015). Among the latter deploying various tools of geographic information systems (GIS), most studies are about planning bicycle routes in newly developing settlements (e.g., Huang and Ye 1995, Milakis and Athanasopoulos 2014). However, as part of the urban development efforts concerning healthy and carbon-free environments, there is a need for investigation about how to determine bicycle routes in already developed built environments of densely populated cities. Relying on GIS tools, a few studies (e.g., Huang and Ye 1995, Rybarczyk and Wu 2010, Milakis and Athanasopoulos 2014) contributes to this aim. Meanwhile, some major world cities insist on car-free mobility (e.g., London, Paris, and Seoul) and diesel-free cars (e.g., Germany) policies to decrease air pollutants, while others (e.g., Oslo, Bogotá, and Hamburg) invest in bike lanes and bike "superhighways" by converting their boulevards into pedestrian plazas. Thus, next to banning policies, redesigning cities for creating public transit options and bike lanes too are important to cope with current environmental crisis (Barber 2018).

While deploying GIS tools, this study hopes to contribute to the discussion about how to determine bicycle routes in already developed built environments. Its case study area, İzmir is the third biggest metropolitan area of Turkey, whereas its central area is densely populated with limited infrastructure for bicycle use. Relying on multiple available GIS tools for its socio-spatial analysis, the study aims to build a bicycle suitable assessment (Emery et al. 2003) of the city of İzmir, and thus to determine the potential bicycle routes for this city's immediate future. We assume that the preferences for bicycling and other environment-friendly modes of transportation will increase among current dwellers, only if contemporary built environment is redesigned with adequate and suitable infrastructure for non-motorized transportation. Also, when determining the contemporary settlements' suitability for bicycle routes, GIS tools can be used as complementary to each other for analyzing various socio-spatial data at multiple spatial scales, even though the data on detailed demographic characteristics, users' preferences and physical infrastructure for bicycling might be limited, as in the case of Turkey. Exemplifying how to deploy multiple GIS tools as complementary to each other for analyzing the data at the city and neighborhood scales, this case study aims at providing policy-makers and community organizers certain basic tools for decision-making about determining bicycle routes as part of the efforts to redesign of their city.

At our analysis, we consider the interplays of, rather than separately, the city's physical and demographic characteristics as significant for determining the bicycle routes. Identifying these multi-layered socio-spatial characteristics as demand- and supply-side data determinants of bicycle routes, this investigation uses majorly available public data (without any user preferences) and focuses on both the city and the neighborhood level. At the first step of GIS analyses, our data at the city scale of İzmir metropolitan area (with total 30 municipal districts) include both supply-side data with environmental attributes (e.g., characteristics of parks and recreational areas and of slope) and demand-side data on the spatial distribution of age groups. We interrelate both groups of data through the overlay analysis to determine relatively the most, moderate and less suitable areas for cycling routes across the city. At the second step, the study examines the case of Bostanlı neighborhood area, one of the most suitable areas for the route, and analyses the available data at neighborhood level by using network analysis between determined stops by taking into account the proximity and continuity at street network. Moreover, the analyses pay attention to the purposes of cycling for recreation and for commuting to determine "the most efficient" bicycle route at the neighborhood level.

While determining the most suitable cycling routes, we surely need more data on, for instance, the volume of the existing cycling routes and vehicle routes, the crime statistics, safety indicators and comfort features of the street network and further demand survey of citizens. This study did not have access to such data. Still, the results of the study with the analysis of available data by GIS implementation (for instance, with overlay analysis) present relatively more and less bike-able city districts in respect to their physical and demographic characteristics. Moreover, the network analysis at the neighborhood level provides an easy management of determining the cycling route along with the selection of cycling purposes and also local land-uses as the (major) origin-destination of cycle trips. When investing in new cycling routes and stops, both results can guide the policymakers working in data-poor contexts to simulate their choices of city districts and land-uses.

How to Determine Bicycle Routes?

Studies about how to determine bicycle routes in cities emerge in various fields (e.g., urban geography, transportation, urban planning and urban design) and pay attention on the concerns about health and physical activity, healthy living, sustainable transportation and non-motorized transportation (e.g., Saelens et al. 2003, Huang and Ye 1995, Wendel-Vos et al. 2004, Segadilha and da Penha Sanches 2014, Blečić et al. 2015). Deploying GIS tools, the researchers about bicycle network planning emphasize the route choice criteria for bicycling in relation to the physical, infrastructural and natural characteristics of settlements (e.g., Rybarczyk and Wu 2010) and to the modelling of bicyclists' route preferences by GPS records as well as to cycling demand of population in terms of transport distance and quality of route utilities (e.g, Skov-Petersen et al. 2018).

Using GIS tools, the studies dealing with the data on the physical factors of settlements include the characteristics of roadways and cycling routes, automobile traffic volume, availability of public transportation, and physical characteristics of built and natural environment (Aultman-Hall et al. 1997, Rodriguez and Joo 2004, Segadilha and da Penha Sanches 2014, Milakis and Athanasopoulos 2014). Affecting individuals' physical effort for cycling, the characteristics of natural environment and especially of topography too, are considered as important determinants for bicycle route planning (Rodriguez and Joo 2004). Accordingly, it is expected that the bicycle trips tend to increase when these physical conditions are suitable for cycling. These conditions include a "slight" topography, improved street connectivity, direct routes without interruption and safe separation from motorized traffic (Aultman-Hall et al. 1997, Rodriguez and Joo 2004). These "ideal" physical conditions for cycling have measurable values. For instance, while the appropriate median trip length for commuting by bicycle is indicated as about 5 km by Ministry of Environment and Urbanization (2017) and the most suitable slope range for cycling is suggested between 0–2% (Ministry of Environment and Urbanization, 2017).

Moreover, it is expected that the location of areas with high number of employees and dwellers and also with schools, parks and recreational areas and public transportation hubs affect the origin and destination points of cycling routes. It is expected that the areas with these land-uses as well as mixed uses attract more bike trips (Wendel-Wos et al. 2004, Saelens et al. 2003, Rodriguez and Joo 2004, Rybarczyk and Wu 2010). All these determinants can also be re-categorized as demand-based and supply-based criteria for bicycle route planning. As part of the demand-based determinants, we can consider business districts, commercial areas, schools and parks and recreational areas. The supply-based determinants can include the data on demographics, level of safety, characteristics of public transportation, road characteristics and existing bicycle routes as these provide available conditions for cycling (Rybarczyk and Wu 2010). Sense of safety, for instance, can also relate to characteristics of the built environment in terms of crime rates, street network lighting and separation of routes from motorized traffic (Allen-Munley et al. 2004, Parkin et al. 2007).

When interrelating demand- and supply-side determinants to each other to determine bicycle routes, there are studies proposing separation based on the purposes for cycling in daily life (Heesch et al. 2015, Handy and Xing 2011, Rodriguez and Joe 2004). These purposes are majorly cycling for transport or commuting and cycling for recreation (Heesch et al. 2015) and are expected to associate with different determinants (Handy and Xing 2011, Heesch et al. 2015). Certain demographic characteristics (e.g., number of working population and children) and certain land-uses (such as with workplaces, schools, business districts and public spaces) create demand for cycling for transport, including daily commuting (Rodriguez and Joe 2004, Handy and Xing 2011). The recreational cycling is associated usually with high population density, rather than with particular age groups, since the recreational activity can be performed by all age groups and also with certain environmental assets, such as topographical features and green and recreational areas and their connection to residential areas (Heesch et al. 2015). However, these separation approach of bike trip purpose may result in neglection of important share of trips and travel patterns.

All these mentioned studies offer various determinants for bicycle network planning, but usually stay short in answering how to determine the location of bicycle routes within already developed built environments lacking well-connected bicycle networks. Only a few studies apply comprehensive methodologies with the consideration of simultaneously many different factors to determine bicycle routes within a city (e.g., Huang and Ye 1995, Rybarczyk and Wu 2010, Milakis and Athanasopoulos 2014). Even though there are some studies for coarse networks, some studies mainly consider transportation networks, rather than bicycle networks (Kibambe Lubamba et al. 2012). Additionally, as bicycle route planning requires many factors to consider, GIS technology with its tools provides an excellent opportunity to process all available data for bicycle route selection in the contemporary cities. However, a small number of studies apply GIS for planning bicycle routes in already developed built environment (e.g., Huang and Ye 1995, Rybarczyk and Wu 2010, Milakis and Athanasopoulos 2014). The studies using GIS as an analysis tool are mainly counted in the field of transportation planning and management that considers travel time modelling by network analysis and creating citywide travel-time surfaces (Kibambe Lubamba et al. 2012), travel behaviour (Biljecki et al. 2012) and accessibility of existing transportation networks (Blečić et al. 2015).

With the help of GIS based spatial analyses, the study underlines how to deal with different dimensions of demand and supply-side data both at the city and the neighborhood scale.

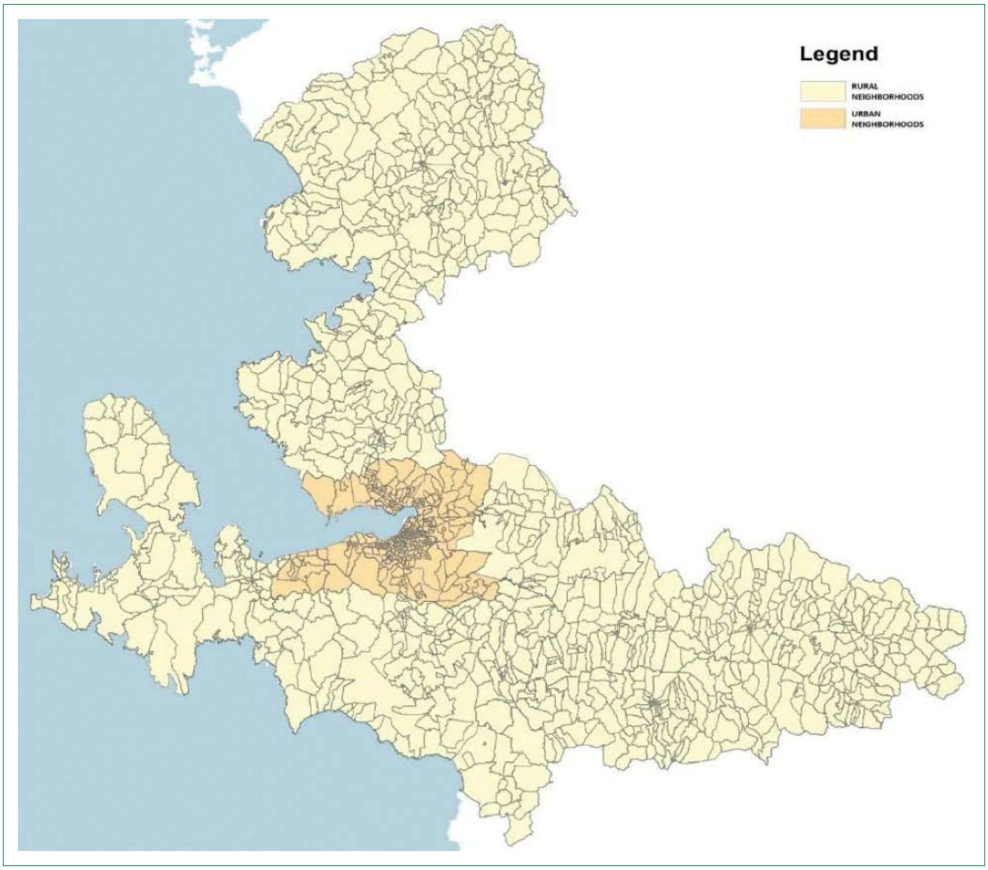

Figure 1. İzmir's central and peripheral districts.

In order to determine the most suitable location to build a bicycle route in the city of İzmir, this study aims to propose a multi-criteria spatial decision process at city scale considering available data about the characteristics of both natural and built environment as well as the demographic features of the population. While performing multi-criteria spatial decision analysis, the data are categorized as supply and demand side (Heesch et al. 2015, Handy and Xing 2011, Rodriguez and Joe 2004); where data about natural/built environment are mentioned as supply side and demographic data are mentioned as demand side. Apart from the interrelating various demand and supply-side data at city scale, our study also aim to include varied purposes of trip such as recreational, commuting, business and shopping at neighborhood scale. Considering various purpose of trips, the proposed route is integrated with the existing route, further it is supposed to pass through important land uses. These land uses can be classified as working places, commercial areas, important transportation hubs and recreational areas. Although the length of the route is not limited, break-way stops per 5 km is proposed during the route. Due to the high management budget to extend narrow existing roads between dwellings, the existing main arterial roads with 8–15m are preferred to provide separated bicycle line.

Study Site and Methodology

Study Site

Study site is the İzmir Province. İzmir, the third biggest metropolitan area of Turkey with a population near 5 million with a mild Mediterranean climate during the year, was chosen as the study area for this study. In the year of 2017, İzmir's annual population growth rate is higher than the average growth rate for Turkey (respectively, ‰13.2 and ‰12.4) (TurkStat 2017). With one of the country's densest urban population, İzmir province has 30 municipal districts, whereas 62% of the total population lives at the12 central municipal districts surrounding the bay (Fig. 1).

Of the provincial population, the most populated age groups are between 15–65 years old (69.84%), followed by the groups between 3–13 (or children with 9.64%) and 65 years old and over (or the elderly with 10.54%) (TurkStat 2017). The population is high especially in some of the central districts (Fig. 2), majorly Bornova and Karşıyaka followed by Karabağlar and Gaziemir holding neighborhoods with the population between 21.681 and 34.467 people, whereas in Konak - İzmir's central business district and port area, peripheral neighborhoods have low number of dwellers. However,

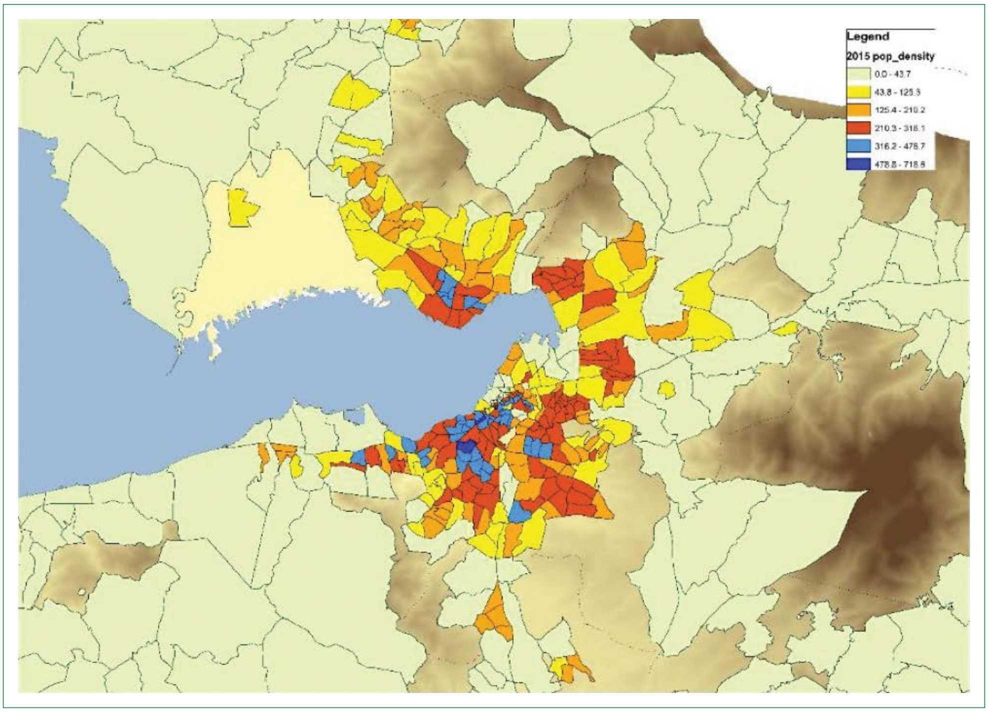

Figure 2. Gross population density of neighbourhoods in the central districts of İzmir.

Figure 3. Mediterranean Eurovelo Route and İzmir network.

the population density is high in Konak's inner neighborhoods as well as in Karabağlar and Karşıyaka, in contrast to low density in Güzelbahçe and also at some neighborhoods of Karşıyaka and Bornova (Fig. 2).

İzmir has varied modes of public transportation ranging from light rail and tram to ferry. The subway line runs through the central districts, a sub-urban light rail line runs through rural-urban districts, and a tramline runs along the bay area and sea ferries. Majorly for recreational purposes, there is also a cycling route and many public rent a bike points called as 'BISIM' along the bay area. However, it is inadequate for the size of built area and population of İzmir. In recent years, the Metropolitan Municipality of İzmir has been making efforts for turning İzmir into a cycling city and a member of European cycle route network (EUROVELO) (Fig. 3). With the campaigns of the cycling supporters and the efforts of local people, the city became the winner of The European Cycling Challenge 2017 – ECC2017 with 972678.3 km with various road types within the city (Fig. 4) (İzmir Metropolitan Municipality 2016). Within the context of worldwide contest of "One World Cities' organized by

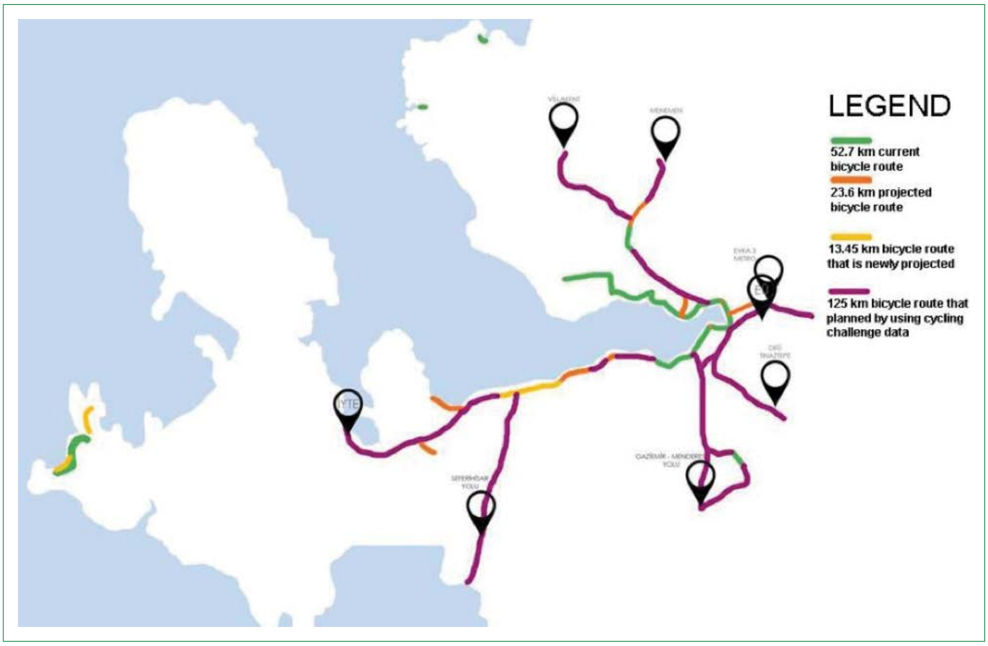

Figure 4. Present and projected bicycle routes in the central districts of İzmir.

WWF, İzmir became a national champion of environment in Turkey. İzmir Metropolitan Municipality aims to reduce greenhouse gas emissions by 20% by 2020 in order to cope with the climate change. Many energy efficiency targets are determined such as achieving extensive use of public transportation, promoting the use of electrical vehicles and buses, and increasing the share of pedestrian and cycling infrastructure (WWF 2018).

Study Method

This study develops a comprehensive bicycle route suitability assessment. It considers GIS procedure as a spatial decision support system via multiple criteria analyses with spatially referenced datasets for detecting suitable areas for the allocation of bicycle routes. For this investigation, we consider the significance of both the interplays of demand- and supply-side determinants as well as the analysis at city- and neighborhood-scale (Fig. 5).

We develop our analysis at two main steps, as exemplified in the next section. First, with the help of overlay analysis, we interrelate the supply- and demand-side data at the city scale, following the preparation of the existing data on demographic (basically, age-related) characteristics, natural (e.g., slope characteristics) and build environment attributes including street network, variety of modes of transportation and major types of land uses. Then, in the case of a selected neighborhood (Bostanlı) by the help of overlay mapping, we focus on the detection of the route at neighborhood scale by using network analyses.

Determination of Bicycle Routes at City and Neighborhood Scale

Available Data

For this study, the available data are geo-raster of population distribution of age groups, total population density, locations of parks and schools, and the slope levels of streets and the distribution of major land uses across the city. These data are sub-categorized as demand and supply side, where population size is used as demand-side and the size of green area as supply-side data. We identify the supply-side data in relation to the attributes of natural and built environment of İzmir. These are the maps of slope levels (Fig. 6), the seashore parks and recreational areas (Fig. 7), the schools weighted by their number of students (Fig. 8), and the street network, tram - metro network, existing bicycle route and stops (BISIM stops), transportation hubs of ferry and tramway stops (Fig. 9).

Moreover, we associate the demand-based data with the age characteristics of population and the major land uses (workplaces, housing and schools) to determine the potential characteristics of both users and the destination points (Huber 2003, Wigan et al. 1998). Population density of particular age groups and workplaces as a land-use provide an estimation of potential demand for bicycle facilities (Huber 2003, Allen-Munley et al. 2004). For the major land-uses, the spatial data are about the distribution of schools weighted by their student numbers, commercial areas, residential areas, public facilities, the locations of public bicycle stores and public transport interchange stops (Fig. 10, 9). For population char-

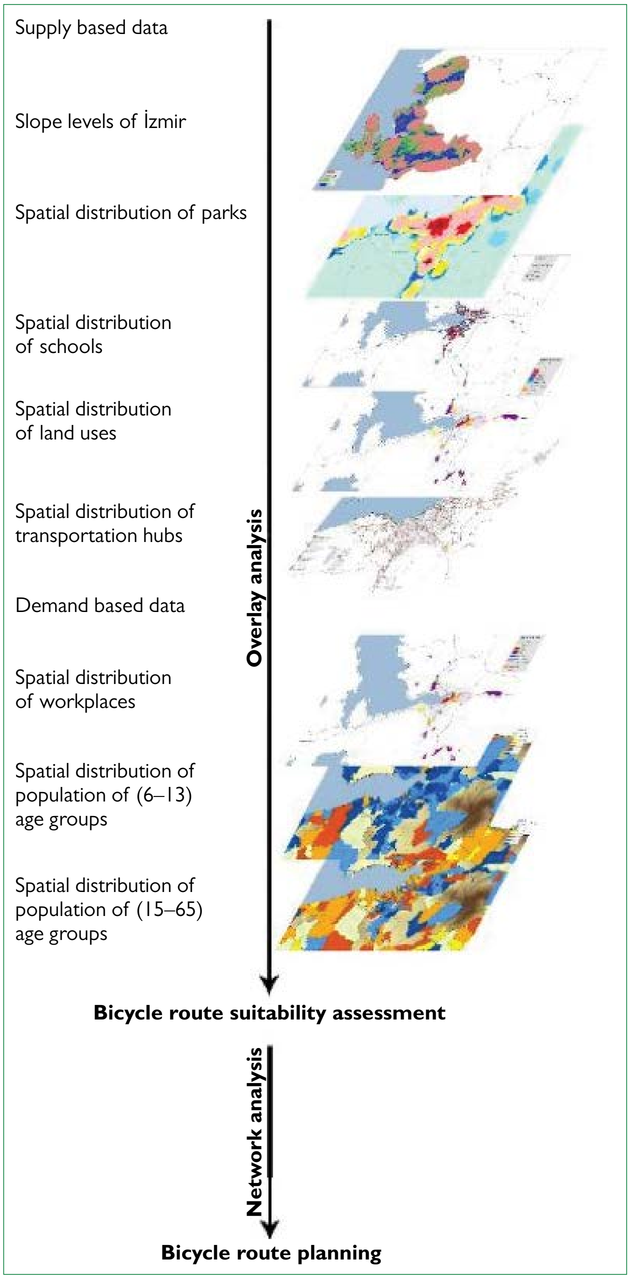

Figure 5. The flow chart of GIS procedure.

acteristics, we use the spatial distribution of age groups' populations (6–13 and 15–65 neighborhood ratios) (Fig. 11, 12).

Data Preparation for GIS-based Spatial Analysis

In order to make spatial decisions by using multi-criteria in GIS, it is required to make spatial data identical. The spatial data are reclassified into three intervals in the form of thematic map. Reclassification of numeric data is performed based on the k-means algorithm and this classification labelled as "not suitable," "moderately suitable" and "most suitable" for cycling.

Within the supply side, the data on slope is re-categorized based on the expert knowledge on cycling comfort. For the slope levels, we consider "the most suitable" areas with the slope level of 2% and below, whereas the areas with the slope level 7% and above is considered as "not suitable" (the intervals for slope: 0–2, 3–7, 7+) (Fig. 13). Similarly, the bigger park areas are accepted as more attractive for cycling. Thus, the park areas bigger than 8000 m^2 are mentioned as "most suitable", because of sustaining adequate wide and length for bicycle route and bicycle stops (the intervals for parks: 8000, 16000, 30000+) (Fig. 13). Moreover, the street data of İzmir is transformed into network dataset including tram and ferry stops and public bicycle stores (BISIM stops).

Within the demand side, the data on the spatial distribution of population and the land use characteristics are used. The population data is categorized based on the k-means algorithm calculation of the total population. The "most suitable" areas in terms of population are determined as the "most" populated areas with 12.058 people and above (Fig. 13), and with the "highest" children population. On the other hand, it is assumed that the areas with highest density of non-residential uses including business districts, commercial and schools creates more demand for cycling as destination points (Fig. 13).

GIS-Based Analysis at City Scale

This part explains the process of multi-criteria spatial decision using reclassified demand and supply-side data at city scale. In order to detect most suitable areas to build bicycle route, we perform overlay analysis using city-scaled thematic maps in GIS. The overlay map detects the most suitable areas by summing the highest level of suitability of each data for bicycle route across the city.

The results reflect the areas with the highest level of suitability for cycling (in red in Fig. 14), where with low degree of slope, highest level of park size, certain land uses and by relatively with high number of total and children population. Moreover, these "most suitable" areas are spatially clustered in the city at certain districts, especially in Karşıyaka, Bornova and Buca (Fig. 14).

GIS-Based Analysis at Neighborhood Scale

According to suitability assessment analysis at city scale, the "most suitable" areas for cycling of İzmir correspond to Karşıyaka, Bornova and Buca central districts, shown also in "red" in Fig. 14 respectively from north to south. Due to the availability of large-scale public green areas and existing bicycle route along the seashore and high population, Bostanlı neighborhood of Karşıyaka district is chosen to perform network analyses for building a bicycle route at neighborhood

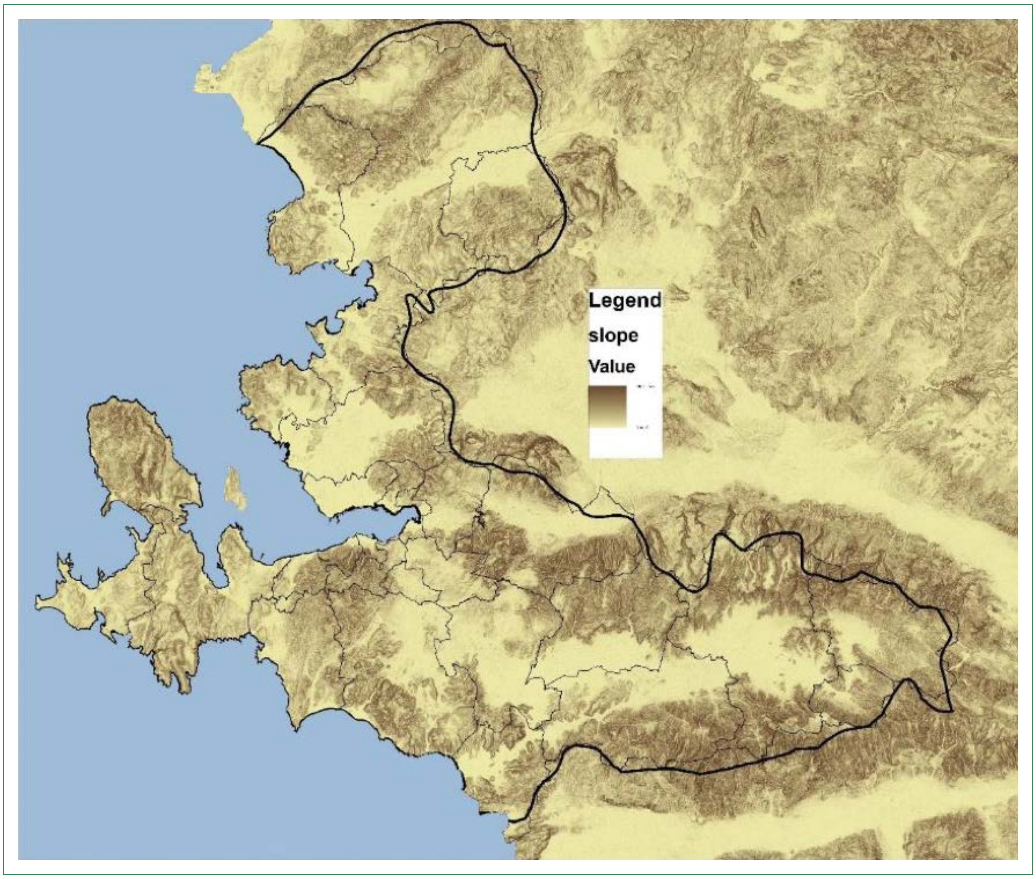

Figure 6. The slope levels across İzmir province.

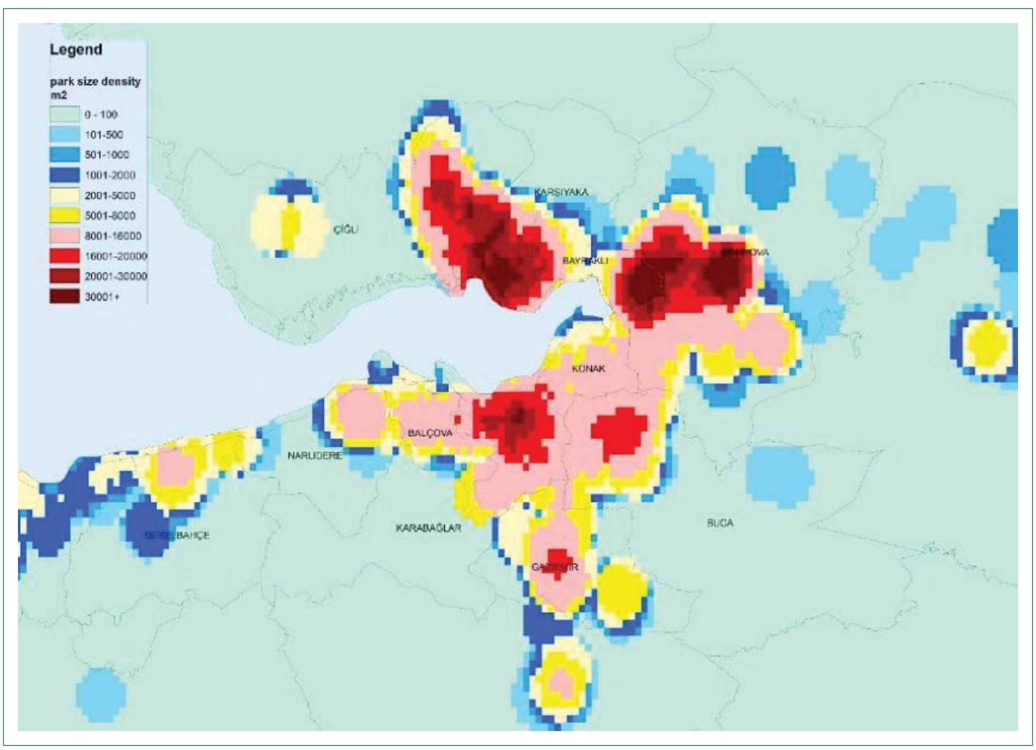

Figure 7. Distribution of the park density in the central districts of İzmir by point-density analysis.

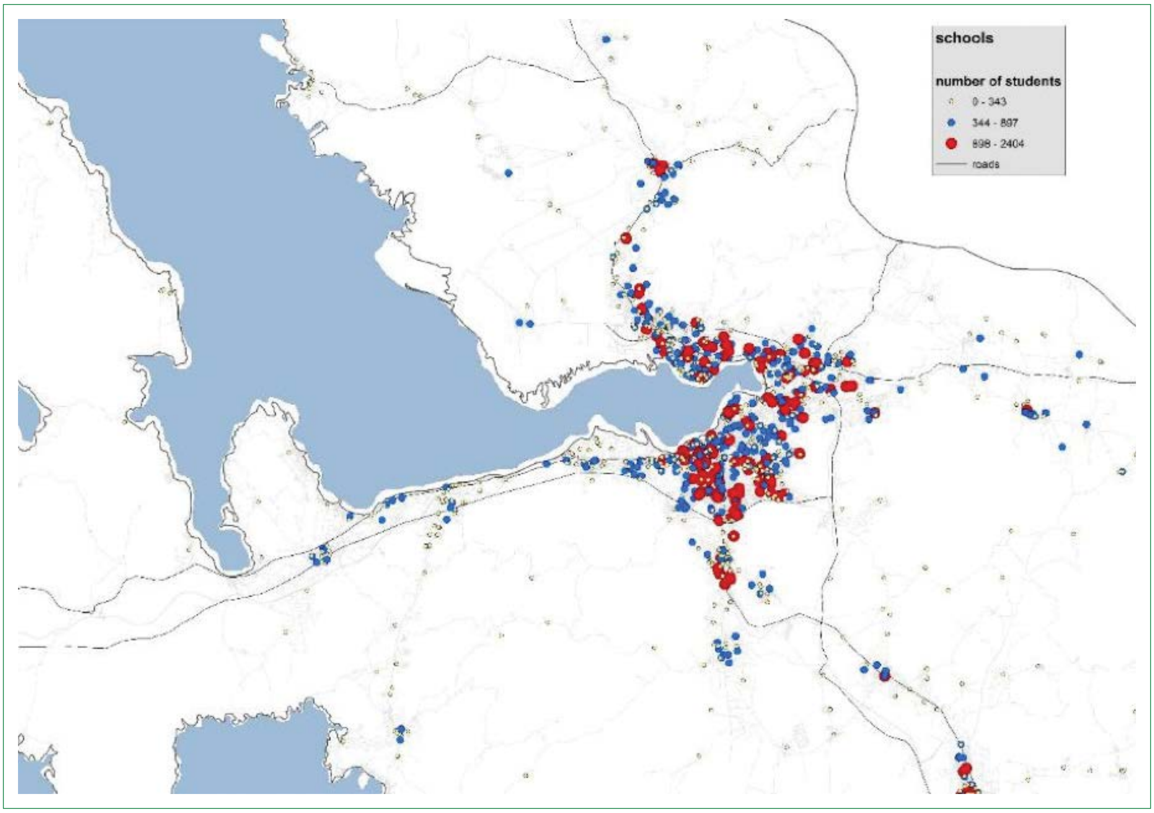

Figure 8. Distribution of the schools in terms of their number of students.

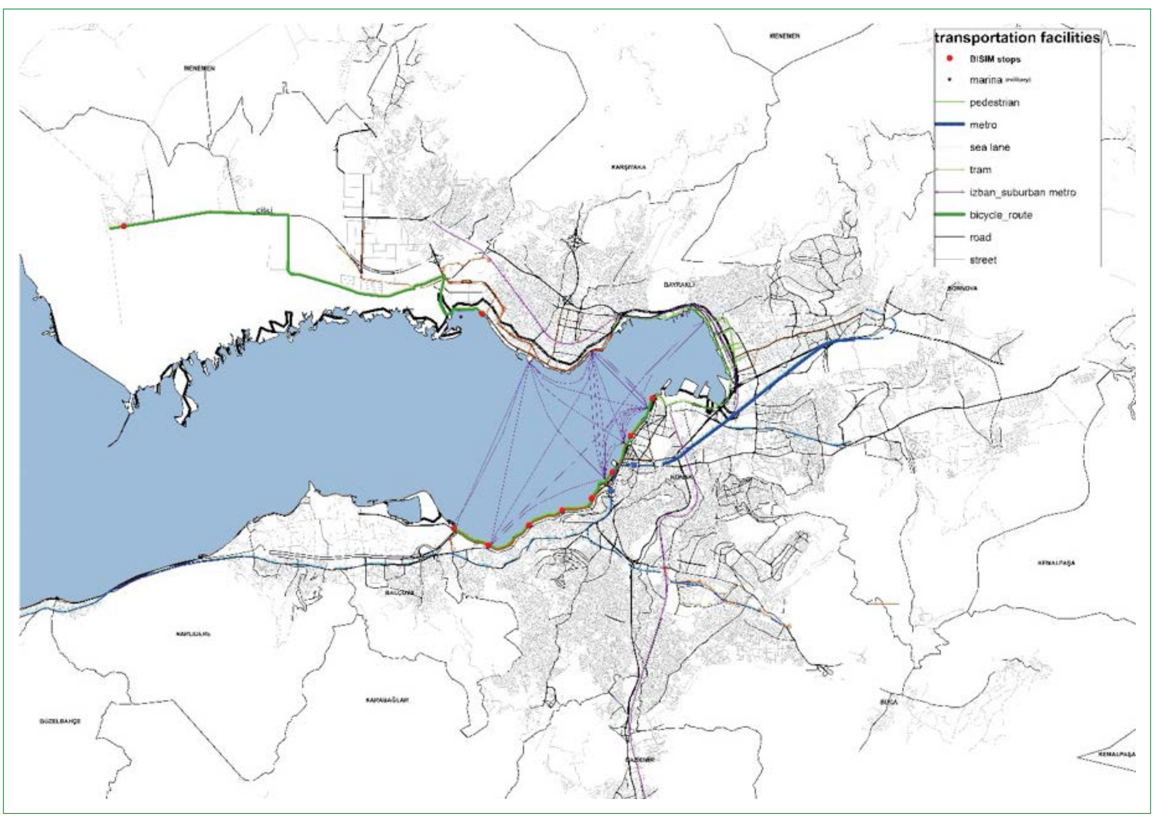

Figure 9. The street network and major transportation facilities in the central districts of İzmir.

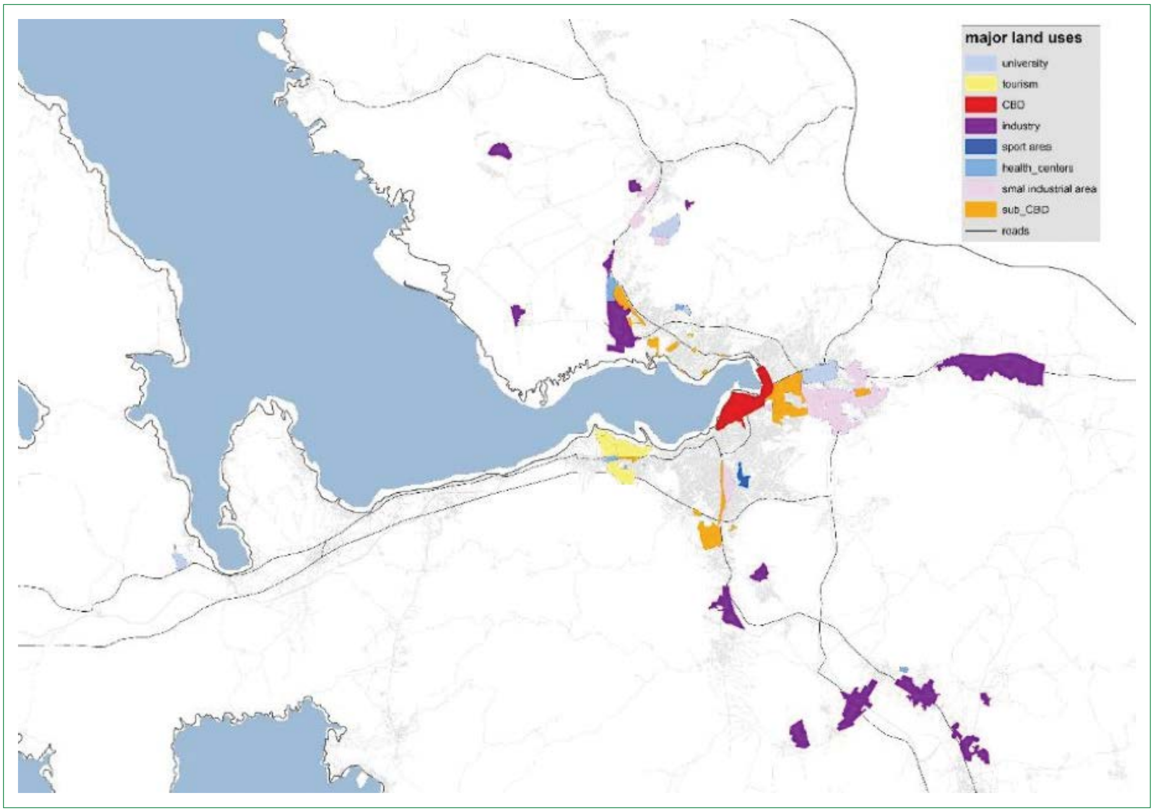

Figure 10. Distribution of the major land uses in the central districts of İzmir.

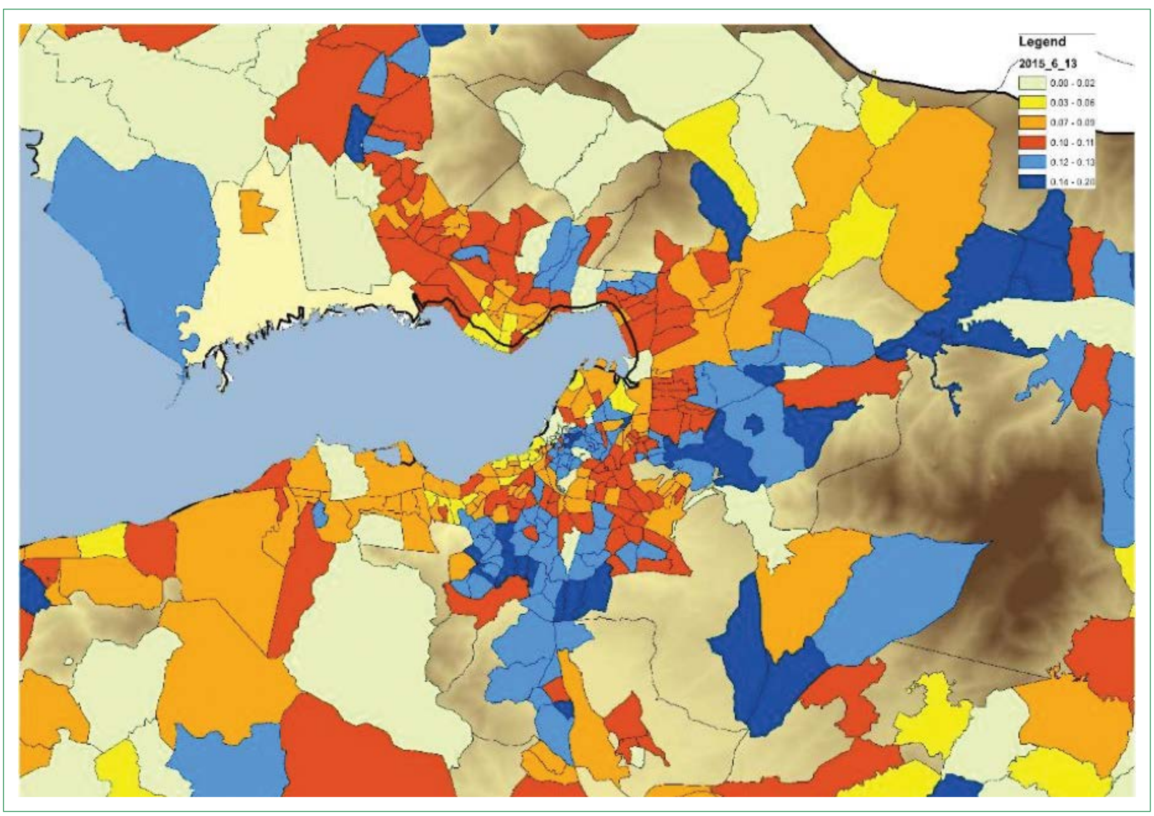

Figure 11. Distribution of the neighbourhood ratio of the 6–13 age groups' density in the central districts of İzmir.

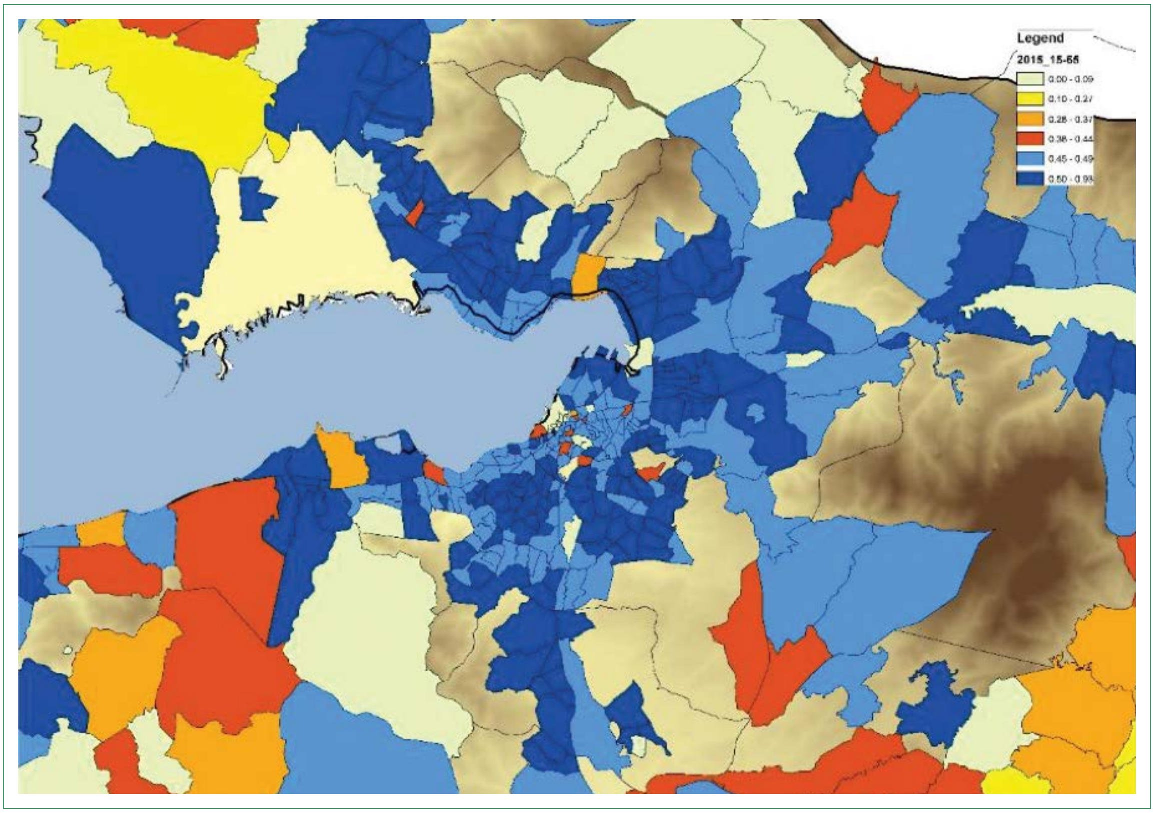

Figure 12. Distribution of the neighbourhood ratio of the 15–65 age groups' density in the central districts of İzmir.

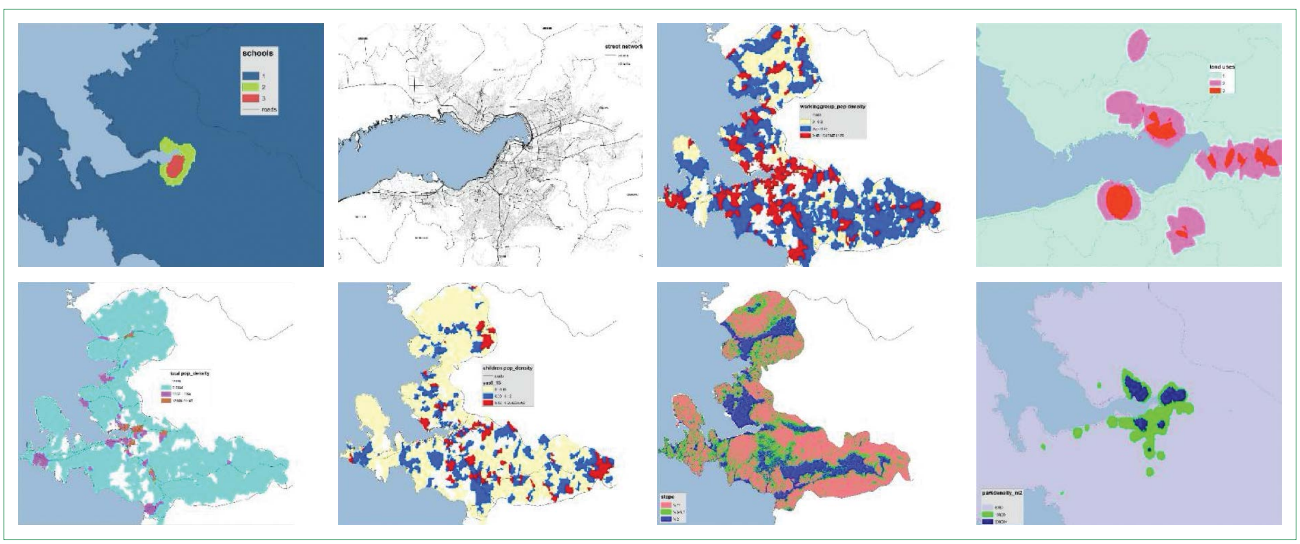

Figure 13. Reclassification of the thematic maps and network datas.

scale. The total population of Karşıyaka is 309790 people and the district is the 5th populated district of İzmir. Karşıyaka is located at the northern part of İzmir's central city and has 11 km seashore along İzmir Bay. Bostanlı, one of the neighborhoods in Karşıyaka, is one of the most populated neighborhoods of İzmir with 33.078 (2017) dwellers, of which 23% is children, 21% is elderly and 46% is working age population.

The urban area – The central core of the neighborhood has various land uses including residential, commercial, university, parks, schools, shopping malls, natural conservation areas, and organized industry area and the core is also fed by various types of public transportation modes of ferry, bus, tram and existing cycling routes. The high density of varied land uses and high population of potential bicycle users in Bostanlı

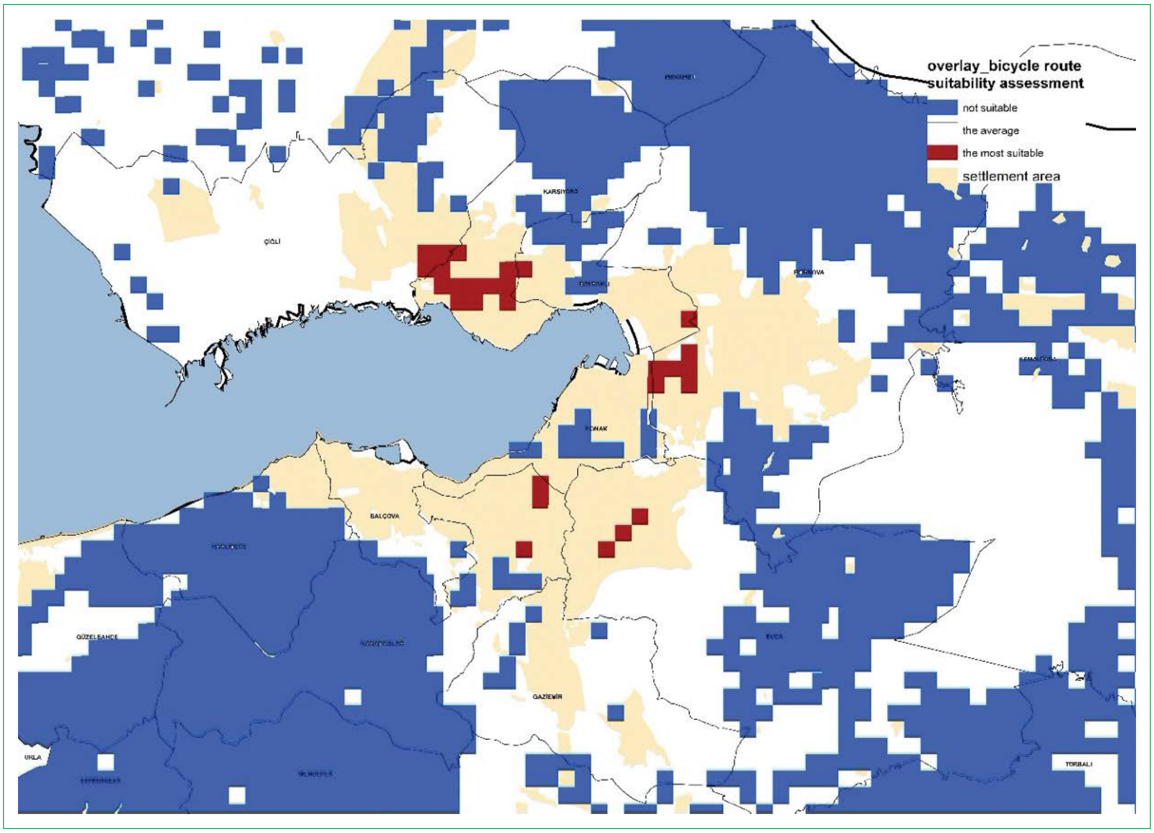

Figure 14. The most suitable areas of cycling within the built environment of the central districts of İzmir.

neighborhood are considered as important dimensions to choose this neighborhood as a potential suitable area to establish a bicycle route at neighborhood scale.

At this scale, we deploy Network Analysis to determine the route for cycling, by using major streets and the geographical locations of major land uses including working places, ferry-tramway stops, BISIM stops, commercial areas with shops and shopping malls. Not only these local nodes but also the existing street network are the basic units of Network Analysis. Each land use type and each mode of public transportation (Tram and Ferry) are similarly weighted in network analysis to achieve the aim of serving for different trip purposes.

Moreover, we propose a bicycle route with a purpose of strengthening the connection between inner parts and the seashore of the Bostanlı neighborhood, that would strengthen integrated and multi-modal transportation system of İzmir. According to the network/new route analysis, the proposed bicycle route passes through the schools, industrial area, the university and shopping malls, commercial areas and locations of public bicycle stores (BISIMs) towards the ferry station which is the main origin/destination point that provide connection to the other parts of the city. These important land uses along the route are called as points of attraction in the Figure 15. In order to sustain safety, the seashore parks and existing arterial roads with 8–15m are prioritized in the analysis to build the bicycle route. A single lane is proposed for traffic ways and double lanes is proposed for pedestrian way at the seashore. The minimum width is proposed as 1.3 m at single lane with 60 cm separator from the traffic way (Fig. 16). The route is designed to pass over the major traffic junctions as pointed in the Figure 15. The total length is proposed as 73 km for the total route, which starts from Ulukent IZBAN (suburban train) Station and goes to Naldöken IZBAN Station towards Bayraklı seashore, having bike and ride stops per 5km along with it (Fig. 15).

Conclusion

Providing bicycle road infrastructure have significance for the purposes of creating non-carbonized and sustainable mode of transportation as a part of the efforts to achieve healthy cities and well-being of people. This attempt also becomes essential not only in new settlements but also – and especially, in already-developed built environments and populated cities. As an important metropolitan city of Turkey, İzmir is trying to become a bicycle-friendly city with the efforts of local policy-makers, despite of its dense and already-developed built environment with inadequate bicycle road infrastructure. This study aims at contributing similar targets of policy-makers in

Figure 15. Bicycle route planning in Bostanlı neighbourhood.

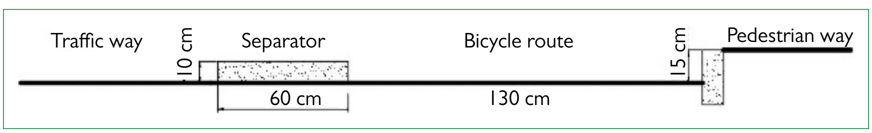

Figure 16. Road section of bicycle route.

cities working with limited data on physical and social characteristics of their cities. The study also seeks to provide a case with a methodology using digital analyzing techniques for determining new bicycle networks within dense built environments. To do so, the study tries to integrate different digital analyzing techniques and use them as complementary to each other in analyzing the data with differing features both at the city and the neighborhood scales.

The study determines the "most suitable area" for bicycle route using multi-criteria decision analysis GIS environment. As bicycle route planning requires dealing with many different spatial data at the same time, GIS provides a versatile environment to analyze all these data simultaneously and interrelatedly, even though the data on demographic characteristics, users' preferences and physical infrastructure for bicycling are limited, as in the case of Turkey. We produced all spatial data in the case of İzmir to perform suitability assessment at GIS. While city scale analyses are performed by using overlay method, it is required to use network analyses to manage detailed data of built-environment at neighborhood scale. Spatial distribution of major land uses, green areas, schools population, total population, population of age groups and slope level are summed by overlay method to detect most suitable area at city scale. After detection of the site, the network of the bicycle route is developed by Network Analysis using the detailed data of street network and points of tram and ferry stations, BISIM stops, work places, green areas and commercial areas. The geo-referenced point-data are used as points of attractions affecting the direction of the bicycle route (Fig. 15). The other determinant of the direction is the width of existing roads. Considering all spatial determinants in the Network Analysis, the bicycle route and bike and ride stops per 5 km in the Figure 15 are proposed. In further development decisions, the proposed bicycle route should be extend towards Alsancak seashore passing through Bayraklı in order to continuously connect with existing bicycle route.

This case study aims to provide certain basic tools to policymakers and community organizers to manage spatial decision-making process in the case of bicycle route. The study findings suggest that the overlay analysis can be applied to investigate various big data in relation to each other at the city scale, while the network analysis can be performed to detect potential routes and to model spatial relations of local nodes at neighborhood and lower spatial scales. The results of this study with the overlay analysis present relatively the most, moderate and less bike-able urban areas at city scale in respect to their physical and demographic characteristics. Also, the network analysis at the neighborhood level provides an easy management of determining the cycling route along with the local land-uses as the major points of attractions for bicycle trips. Both results can guide local policymakers, especially in data-poor contexts to simulate and strengthen complex spatial decisions and location detection for new development projects on a city in varied spatial scales.

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