Davidoff P. 1965. Advocacy and pluralism in planning. Journal of the American Institute of Planners, 28: 331-338.

Ervin S. 2011. A system for GeoDesign. Proceedings of Digital Landscape Architecture. Anhalt University of Applied Science, pp. 145-154.

Innes J. 1995. Planning theory's emerging paradigm: communication action and interactive

practice. Journal of Planning Education and Research, 14: 183-90.

Harris B. 1989. Beyond Geographic Information Systems: computer and the planning professionals. Journal of American Planning Association. 55(1): 85-90.

Khakee A. 1998. Evaluation and Planning: two inseparable concepts. Town Planning Review, 69-4: 359-374.

Kingston R. 1998. Web Based GIS for Public Decision Making in the UK. Paper for the Project Varenius Specialist Meeting on Empowerment, Marginalization and Public Participation GIS, Santa Barbara, CA, http://www.ncgia.ucsb.edu/varenius/ppgis/papers/index.html.

Nyerges T., Ballal H., Steinitz C., Canfield T., Roderick M., Ritzman J., Thanatemaneerat

W. 2016. Geodesign dynamics for sustainable urban watershed development. Sustainable Cities and Society. Elsevier, 25: 13-24.

Rivero R., Smith A., Ballal H., Steinitz C. 2015. Promoting Collaborative Geodesign in a Multidisciplinary and Multiscale Environment: Coastal Georgia 2050, USA [In:] E. Buhmann, S. Ervin, M. Pietsch (ed.), Peer Reviewed Proceedings Of Digital Landscape Architecture 2015. Wichmann, Berlin/Offenbach, pp. 42-58.

Steinitz C. 2012. A Framework for Geodesign: Changing Geography by Design. Esri Press, Redlands, CA.

# ID 1559 | MULTI-CRITERIA DECISION ANALYSIS FOR PROMOTING BIKE-FRIENDLY CITY VISION OF IZMIR USING GIS

Sevim Pelin Özkan[1], Zeynep Özçam[2], Fatma Şenol[1]
[1]Izmir Insitute of Technology; [2]Middle East Technical University,
pelinozkan@iyte.edu.tr ; seplnz@gmail.com ; fatmasenol@iyte.edu.tr

**ABSTRACT:** Deploying GIS at its analysis of multilayered spatial data about Izmir (the third biggest metropolitan city in Turkey), this paper aims at suggesting ways of providing bicycle routes and roads in the already developed built environment of the densely populated cities. Focusing on multiple characteristics of topography, land use and population, the study deploys overlay analysis and network analysis respectively at city level and district level. Despite of the limited number and characteristics of data available about Turkish cities, this study has been limited to the lack of crime data and travel demand data of related neighborhoods.

## 1 INTRODUCTION

Bicycle use is widely promoted by many researches and policy initiatives of industrialized countries as the efforts related to sustainable development, carbon-free and non-motorized transportation and "healthy" cities. While some of these policies and researches relate to promoting changes in lifestyles and habits of physical activities (eg., Wendel-Vos, Schuit, De Niet, Boshuizen, Saris, Kromhout, 2004), others focus majorly on planning and design of built environment and of transportation systems (e.g., Huang & Ye, 1995; Rodriguez & Joo, 2004).

A major challenge is how to provide bicycle roads through the developed built environment of the densely populated cities that do not have any prior bicycle routes and infrastructure. This paper aims at answering this question, while deploying geographic information system (GIS) at its analysis of multilayered spatial data about the city of Izmir as being the third biggest metropolitan area in Turkey.

In recent years, making bicycle transportation a part of city life has become one of the main purposes of Izmir Metropolitan Municipality. With this purpose, Izmir aims to promote cycling routes in the following years and the Metropolitan Municipality has been making significant efforts for turning the city into a more bicycle-friendly city. However, availability of physical environment for cycling is an important factor to consider. To promote and upgrade cycling routes in a dense built environment is a challenging process. We claim that Izmir has a potential to offer alternative transportation types and networks prioritizing bicycle, despite its dense urban environment.

This study aims at promoting the bicycle-friendly city development efforts of Izmir. It tries to consider many different spatial factors while promoting bicycle routes within a dense built environment. At its analysis, the study interrelates various data about the characteristics of the natural and built environment and also the spatial distribution of population characteristics at the metropolitan, district and neighborhood scale. This study aims to combine different techniques of spatial analyze at different spatial scales in order to determine potential bicycle routes for areas with different land uses.

This study calls the determinant factors of bicycle facility planning as environmental assets. It mainly aims at taking into action the knowledge of the environmental assets by digitizing and visualizing them. Focusing on the metropolitan scale of Izmir with 30 districts at first step, this study considers environmental assets as parks, recreational areas, topography and analyzes them in the GIS environment. These are the spatial data infrastructure that would able us to reveal potential bicycle route networks. Additionally, some inhibitor factors such as population density and different age range groups are also taken into account. All these spatial data are used to detect the areas that high level of spatial infrastructure are embedded by using overlay analysis. Afterwards, focusing on central districts of Izmir, network analysis is performed between determined stops by taking into account the proximity and continuity at the road network level.

Study findings suggest that overlay analyze technique can be applied to detect neighborhood levels and network analysis can be performed to detect potential routes and to model spatial relations of local nodes. Not only local nodes but also transportation corridors are the basic unit of analysis within network analysis.

## 2 LITERATURE REVIEW

While promoting the use of bicycle and creation of bicycle networks within a city, it is important to give attention to recent bicycle transportation studies. Studies that relate to the question of how to determine bicycle roads in a city emerge in various fields (majorly urban geography, transportation, urban planning and urban design) and research areas especially about health, healthy living, sustainable transportation and non-motorized transportation (e.g., Huang & Ye, 1995; Wendel-Vos et al., 2004; Segadilha & Sanches, 2014).

Until now, studies related to bicycle network planning have focused primarily on route choice criteria and the factors affecting bicycle use which are giving very useful insights for designing bicycle routes within a city. These studies give emphasis on the factors that can affect bicycle use. These factors are mainly determined as the characteristics of the roadway and bicycle routes, automobile traffic, availability of public transport, and factors related to the built and natural environment (Aultman-Hall, Hall, & Baetz, 1997; Rodriguez & Joo, 2004; Segadilha & Sanches, 2014; Milakis & Athanasopoulos, 2014). Concerning the built environment, bicycle usage is very much related to the location of the areas with higher employment and population density and presence of schools, recreational areas, parks at the origin and the destination (Rodriguez & Joo, 2004, Rybarczyk and Wu, 2010). When it comes to the natural environment, topography and slope become major determinants of bicycle route planning (Rodriguez & Joo, 2004). In addition to all these, safety becomes another determinant of bicycle use (Allen-Munley et al., 2004; Parkin et al., 2007) which is related to characteristics of roadway and automobile traffic. According to Rybarczyk & Wu (2010) these determinants can also be categorized as demand based and supply based criteria for bicycle route planning; the demand-based criteria includes business and land uses such as schools, parks and recreation areas and supply-based criteria includes demographics, safety, public transportation, road characteristics and existing bicycle routes.

Overall, studies underline a set of group of factors that can direct the design and planning of bicycling roads. In particular, bicycle trips tend to increase in the presence of mixed uses of land, slight topography, improved street connectivity, direct routes without interruption and safe separation from motorized traffic

(Aultman-Hall, Hall, & Baetz, 1997; Rodriguez & Joo, 2004). High density areas, schools, parks and public transportation hubs are also anticipated as land uses that support the use of bicycle routes. Therefore, these factors should be taken into account in the planning of bicycle networks in a city.

All these information from prior studies offer the determinants for bicycle network planning however, these studies cannot offer a complete answer to where to develop new bicycle routes within an already developed built environment that lacks a well-connected bicycle network. Only a few studies have applied a comprehensive methodology to determine bicycle routes within a city (Huang & Ye, 1995; Rybarczyk & Wu, 2010; Milakis & Athanasopoulos, 2014). Additionally, as bicycle route planning requires many factors to consider, geographic information system (GIS) technology provides an excellent opportunity to process all available data for bicycle route selection. However, small number of studies have applied GIS in the planning of bicycle routes until this time (Huang & Ye, 1995; Rybarczyk and Wu, 2010). Even more, these studies were dealing with the existing routes in a city. This study, too considers various data about the characteristics of the natural and built environment and also spatial distribution of population characteristics at the city scale and neighborhood scale. While dealing with the data, GIS technology has been used. By this, it is aimed at promoting bicycle routes in the city of Izmir, while making contribution to the GIS based bicycle route planning in an already developed built environment lacking a complete bicycle network.

Relating to these research issues, the design and planning of built environment is discussed and promoted as a tool especially to motivate and assist people's use of non-motorized transportation modes, basically walking and bicycling (Rodriguez & Joo, 2004; Wendel-Vos et al., 2004). In other words, it is expected that if the built environment is designed and planned with adequate and suitable infrastructure, land use, natural assets and allocation of other resources for non-motorized transportation, people will be more willing to use such modes of transportation. Such kind of environments can provide opportunities with healthy living, sustainable living and transportation.

## 3 STUDY SITE

In recent years, the Metropolitan Municipality of Izmir has the goals of sustainable city development, including environmentally sensitive and sustainable transportation. As a part of these goals, the Municipality aims at promoting cycling routes and has been making significant efforts for turning the city into a more bicycle-friendly city. Accordingly, for providing mobility between districts and city center, the creation of nature-friendly corridors with cycling and walking routes has become a priority in the planning of Izmir (Izmir Metropolitan Municipality, TMP Revision, 2016). However, existing bicycle routes are incapable of providing a complete bicycle network for the city. There are no continuous bicycle routes to serve for the whole city except the coastal road, which is mainly used for recreational purposes. Additional routes are promoted for providing bicycle access to the residential, social and cultural spaces, major transfer stations, university campus areas and other major usages in the city center (See; Figure 1).

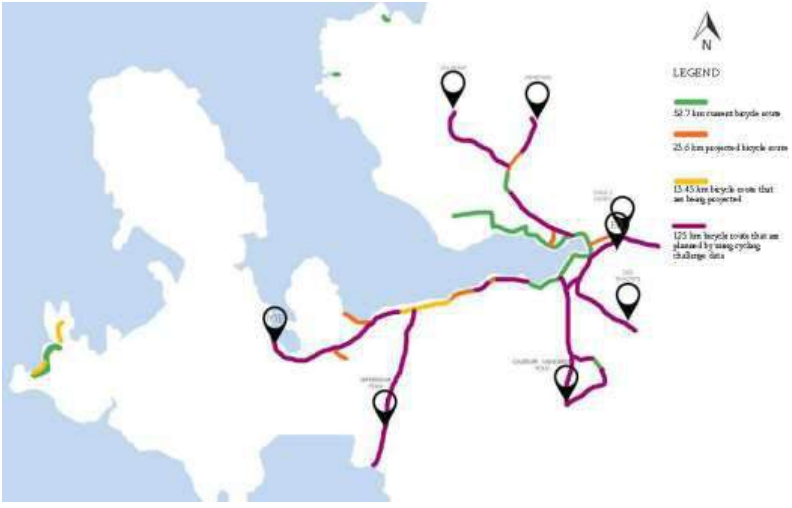


Figure 1 – Bicycle Routes

The third biggest metropolitan area of Turkey with a population near 5 million, Izmir is located on the Aegean coast, between the 37o45 'and 39o15' north latitude and 26o15 'and 28o20' east longitudes and covers an area of 12,012 km2 (See; Figure 2) (Izmir Governorship, 2017) with a mild climate during the year. Located on its bay area at the Aegean coasts, the city of Izmir has very high urban densities at central coastal neighborhoods and extends to hilly neighborhoods. With one of Turkey's densest urban population at its central districts at the coast, the city of Izmir has a metro system with its city line and regional line, a newly developing tramline, a limited level of sea transportation and very recently planned bicycle route infrastructure.

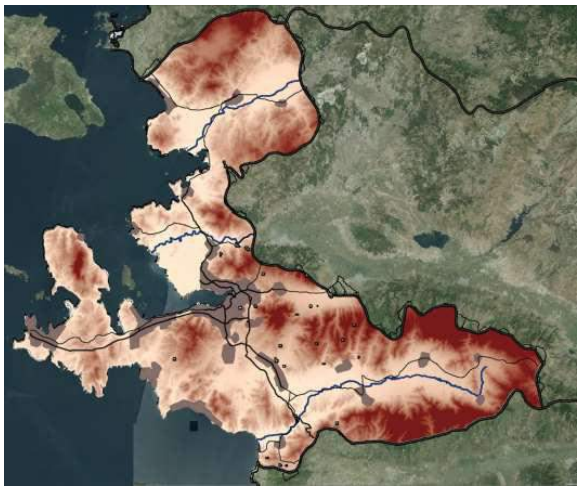

Figure 2 – Location of Izmir

In 2015, while the average age of Izmir's metropolitan population is 4.168.415, the average age in its central districts is 35-39 with an education levels higher than Turkey's average (Izmir Governorship, 2017). At a close examination of these 11 central districts, it can be seen that children (age 3—13) ranges are clustered in Karşıyaka, Bayraklı and Gaziemir districts, young (age 14—22) ranges are clustered in Karşıyaka, Bayraklı, Konak districts; while seniors (age 55+) are clustered in Karşıyaka, Bayraklı, Balçova and Konak districts (See; Figures 3).

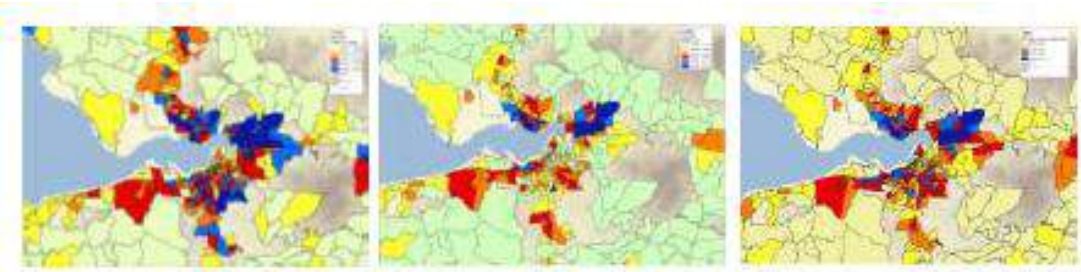

Figure 3 – Maps of age range of 3_13, 14_22, 55+

These age range thematic maps visualize and determine the clusters of different population groups demanding different spatial activity types. We admitted that we should pay attention to the accessibility of the local service areas, especially the neighborhood parks and bicycle routes, within the walking distance. Therefore, we used the "neighborhood ratio" of the age data as seen in the legends. We obtained this ratio by calculating the ratio of the number of each group of people in the neighborhood to the neighborhood population.

## 4 STUDY METHOD

As bicycle route planning requires many data layers to deal with, GIS can easily integrate these data layers in the form of digital information, thus can reduce the cost of data assembly. Furthermore, GIS can perform spatial operations, such as terrain modeling and network analysis, which are crucial to bicycle route planning; and its network analysis data model and path-finding algorithms make it a straight-forward

way to implement sophisticated cycling models that can incorporate factors such as traffic, topography, built environment attributes and socio-economic data at the same time (Huang & Ye, 1995).

The determining factors for walking and bicycle route planning has been differentiated as demand side and supply side (Wigan, Richardson & Brunton, 1998; Rybarczyk and Wu, 2010). While demand side talks about the spatial distribution of population characteristics such as age, education, gender, and health condition (e.g., Huber, 2003, Wigan et al., 1998), the supply side underlines the physical/environmental characteristics that include natural elements such as topography, slope and land use characteristics such as workplaces, green areas, housing, schools and transportation networks (Martens, 2007; Rodriguez & Joo, 2004). Within the supply side factors, green open spaces have great importance on bicycle route network planning. Recreation areas and parks are desirable destinations within a route (Wendel-Vos et al., 2004) as they generates high level of bicycle use. Lastly, population density provides an estimation of potential demand for and access to bicycle facilities (Huber, 2003; Allen-Munley et al., 2004).

This study calls the determinant factors of bicycle facility planning as environmental assets and takes into action the knowledge of the environmental assets in the GIS environment. Within the context of 11 districts of metropolitan area, this study considers environmental assets as parks, recreational areas, topography and roads that could be determined as supply side. These are the spatial data infrastructure that can reveal potential bicycle route networks. Additionally, some inhibitor factors such as population density, motor vehicle traffic volume and crime statistics are taken into account. All these spatial data are used to detect the hotspot clustering with high level of spatial infrastructure. Afterwards, network analysis is performed between potential clusters based on proximity and continuity. While detecting the clusters focuses on population density, parks, recreational areas, schools, weather and crime statistics, detecting the networks considers motor vehicle traffic volume, topography and main public transportation hubs.

The methodology of the study comprise of two main steps. First one evaluates metropolitan scale big data and determines subscales suitability for route planning. Available data at metropolitan scale are geo¬raster data consisting of the population density of each age range, park density, slope and digital elevation. On that aim, overlay analysis has been implemented as using population density of different age ranges, green space density, slope and elevation (srtm-dem of the Izmir province has 90 m of grid size resolution; 45 m of horizontal accuracy; and 15 m of vertical accuracy) data for neighborhood detection. Second one seeks for the bicycle route determination which may be varied based on the different activity within those neighborhoods. For this aim, network analysis has been implemented through road network, stream network and green areas.

## 5 FINDINGS & DISCUSSION

Within the context of overlay analysis, the population density raster of child and seniors, park density raster, slope and digital elevation data have been reclassified into three defined interval (See; Figure 4). The reclassified digital surface data have been overlapped in the ArcMap environment. The different age range maps have been used to generate different overlay maps. The different age groups have been related with the activity differentiation of bicycle users. Two synthesis maps as a combination of these factors shows the most suitable areas at neighborhood levels for bicycle planning. Within the most suitable areas of two overlay analysis; ‘Bostanlı’ neighborhood has been selected as the common area for the next step to generate the network analysis (See; Figure 5, 6).

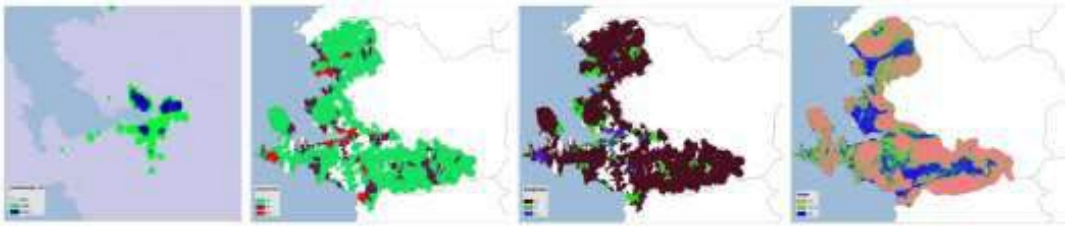

Figure 4 – Reclassified data

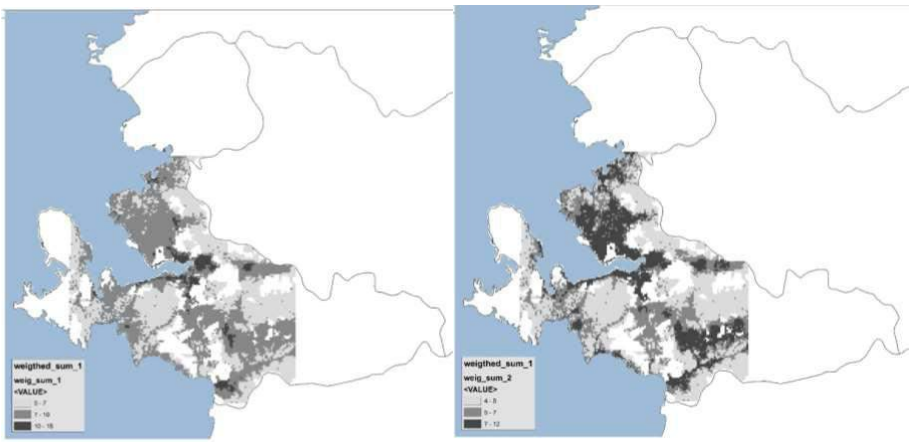


Figure 5 – Synthesis map 1 | Figure 6 – Synthesis map 2

Within the context of network analysis, road networks, work places, transportation hubs, stream networks and the parks have been used respectively for creating network dataset. While work places and road network are associated with the working age group based on transportation activity; the parks and stream networks are associated with the child and old age groups for mostly leisure activity. Therefore, the determinants of the different type bicycle usage have been defined and divided into two categories; the determinants for bicycle use for recreation, the determinants for bicycle use for mobility. Relatedly, analysis has been done according to this categorization.

As an outcome, two potential routes have been determined via network analysis that may serve for two different activity types (See; Figures 7, 8). The Figure 7 shows the route (1) passing through the few numbers of work places and parks starting from the ferry station targeting multi-modal transportation system. The other route (2) shown in the Figure 8 passes through the parks along the stream networks targeting the leisure activities.

This study aims to find out a methodology via GIS environment for detecting potential bicycle routes within the dense spatial contexts. While benefitting from digital visualizations and analyzes, we have used city scale big data to be able to determine the most suitable areas for bicycle route planning. Due to the limited data that is available about Turkish cities, this study has been limited in terms of some social characteristics of the population and the neighborhoods. Thus, crime statistics and travel demand data of the related neighborhoods have been lacked. Determining bicycle routes within the dense spatial context by using the geographical and physical data was another challenge of this study.

Figure 7 – Bicycle route (1) for mobility Figure 8 – Bicycle route (2) for recreation

## 6 CONCLUSION

The bicycle road infrastructure is gaining ground serving for healthy cities and well-being via non-carbonized, and sustainable mode of transportation. It has been taken as an important option both for physical activity and sustainable mobility. Therefore, the development bicycle road infrastructure becomes an important issue in urban planning agenda, especially in the era in which sustainability is a major goal for future development. As being one of the important metropolitan districts of Turkey, Izmir have also future targets on becoming bicycle-friendly city despite its dense and already-developed built environment with inadequate bicycle road infrastructure. This study aimed to contribute this target, while seeking for a methodology using digital analyzing techniques for new bicycle networks within dense built environments.

While doing this, the study tries to integrate different digital analyzing techniques. The determination of bicycle route has been done by overlapping many different big data at GIS environment. As bicycle route planning requires dealing with many different spatial data at the same time, GIS provided an efficient environment to make this analysis. As a result, two different bicycle routes have been suggested serving for different purposes; namely for mobility (route 1) and recreation (route 2), furthermore we have proposed a comprehensive bicycle route planning method using GIS for promoting the bicycle-friendly city vision of the city of Izmir.

## ACKNOWLEDGEMENT

This study is developed in relation to the data of a research project ("Evaluation of Existing Neighborhood Parks based on Need-Based Equity") (Project no: 215K239) supported by the Scientific and Technological Research Council of Turkey.

## BIBLIOGRAPHIC REFERENCES

Allen-Munley, C., Daniel, J., & Dhar, S. (2004). Logistic model for rating urban bicycle route safety. Transportation Research Record: Journal of the Transportation Research Board, (1878), 107-115.

Aultman-Hall, L., Hall, F., & Baetz, B. (1997). Analysis of bicycle commuter routes using geographic information systems: implications for bicycle planning. Transportation Research Record: Journal of the Transportation Research Board, (1578), 102-110.

Huang, Y., & Ye, G. (1995). Selecting bicycle commuting routes using GIS. Berkeley Planning Journal, 10(1).

Huber, T. (2003). Wisconsin bicycle planning guidance, guidelines for metropolitan planning organizations & communities in planning & developing bicycle facilities. Madison: Wisconsin Department of Transportation. 1–64.

Izmir Metropolitan Municipality (2016). Izmir Transportation Master Plan (TMP) Revision. Izmir Metropolitan Municipality Official Website.

Izmir Metropolitan Municipality (2017). Hedef 2030 (Target 2030). Izmir Metropolitan Municipality Official Website. Available at: https://www.izmir.bel.tr/HaberDetay/22192/tr, last visited on: May, 2017.

Governorship of Izmir (2017). Seçilmiş Göstergelerle Türkiye-İzmir (Izmir-Turkey with Selected Indicators). Governorship of Izmir Official Website. Available at: http://www.izmir.gov.tr/istatistiklerle-izmir, last visited on: May, 2017

Martens, K., (2007). Promoting bike-and-ride: The Dutch experience. Transportation Research Part A 41, 326–338.

Milakis, D., & Athanasopoulos, K. (2014). What about people in cycle network planning? Applying participative multicriteria GIS analysis in the case of the Athens metropolitan cycle network. Journal of Transport Geography, 35, 120-129.

Parkin, J., Wardman, M., & Page, M. (2007). Models of perceived cycling risk and route acceptability. Accident Analysis & Prevention, 39(2), 364-371.

Rodríguez, D. A., & Joo, J. (2004). The relationship between non-motorized mode choice and the local physical environment. Transportation Research Part D: Transport and Environment, 9(2), 151-173.

Rybarczyk, G., & Wu, C. (2010). Bicycle facility planning using GIS and multi-criteria decision analysis. Applied Geography, 30(2), 282-293.

Segadilha, A. B. P., & da Penha Sanches, S. (2014). Analysis of bicycle Commuter Routes using GPSs and GIS. Procedia-Social and Behavioral Sciences, 162, 198-207.

Wendel-Vos, G. W., Schuit, A. J., De Niet, R., Boshuizen, H. C., Saris, W. H. M., & Kromhout, D.

A. A. N. (2004). Factors of the physical environment associated with walking and bicycling. Medicine and science in sports and exercise, 36(4), 725-730.

Wigan, M., Richardson, A. J., & Brunton, P. (1998). Simplified estimation of demand for nonmotorized trails using geographic information systems. Transportation Research Record, 1636(1), 47–55.