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Active Living For Sustainable Future: A model to measure "walk scores" via Geographic Information Systems

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Abstract

In 2007 a private firm in Seattle, Washington began to measure and publish walkability maps of cities, neighborhoods, and streets via "walkscore.com". Although "walkscore" have been criticized for its parameters, no alternative have been provided so far. More over, such maps have been published for developed countries. No such initiative has been undertaken in developing countries. This study aims to introduce and discuss an alternative model to measure walkability on street level via Geographic Information Systems (GIS). About 6500 street segments in nine districts of Izmır, Turkey have been digitized as well as the land use. A walkability score (based on betweenness / centrality scores derived from street network and accessibility scores derived from landuse) for each street segment was measured via GIS and its extension Spatial Design Network Analysis (SDNA).

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Keywords: Active living; environment and behavior studies; walkability; geographic information systems

1. Introduction

According to World Health Organization (WHO) Report in 2012, about 1.4 billion adults were overweighed and about 500 million were obese (http://www.who.int/mediacentre/factsheets/fs311/en/; last accessed 21.02.2013). WHO also claimed that obesity and overweight could be prevented by encouraging physical activity and active living among populations. In other words, active living is a

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necessity for a sustainable future. General and scientific knowledge provides evidence for this claim. Research also showed that active living projects could achieve success when public participation in such projects could be satisfied (and vice a versa) (Hamamoto, Derauf & Yoshimura, 2009). Awareness for such projects could be increased through effective communication strategies (like walkability maps of neighborhoods).

Active living is described as "a way of life that integrates physical activity into everyday routines, such as walking for transportation". However, in the last decade people tend to do less exercise in their daily routine and rely on automobiles for transportation (rather than walking for transportation). This decline in mode share of walking is a global problem (Cubukcu, 2013). Leather, Fabian, Gota and Mejia (2011) reported the following striking findings for walking mode share changes in some Asian cities (Table 1):

Table 1. Walking mode share declines in Asian Cities (Leather, Fabian, Gota and Mejia, 2011, page 4)

City	Year	Before (%)	Year	After (%)	(%) Mode with Greatest Gain (Motorized)
Bangalore	1984	44.00	2007	8.33	Two-wheeler and car
Changzhou	1986	38.24	2006	21.54	Two-wheeler and car
Chennai	2002	47.00	2008	22.00	Two-wheeler
Delhi	2002	39.00	2008	21.00	Two-wheeler and car
Xi'an	2002	22.94	2006	15.78	Bus
Nanchang	2001	44.99	2005	39.11	Car
Shanghai	1986	38.00	2004	10.40	Two-wheeler and bus

Given that, encouraging walkability through design is a major concern in Asian cities as well as developed countries. Although the majority of research on walkability of various physical settings have been held in developed countries, studies in Asian cities could not be underestimated (Azmi & Karim, 2012; Azmi et al. 2013; Azmi, Karim & Amin 2012; Abd-Latif et al. 2011; Sapawi & Said, 2013; Cubukcu, 2013).

In developed countries, encouraging active living (and walking for transportation) has been declared as the main goal of municipalities. To that end, several municipalities have been trying to measure walkability of various settings and collect standardized data to understand the current condition to investigate the ways to improve and encourage walkability in the neighbourhood. As William Thomson put it out in his writings in 1883:

"…when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind..." (http://en.wikiquote.org/wiki/William_Thomson; last access 15.01.2014)

In 2007 a private firm in Seattle, Washington began to measure walkability score of cities, neighborhoods, streets, and any address. Since then, they have been publishing maps via "walkscore.com". With that publicly viewable open data, municipalities and public institutions found themselves in a kind of race to improve walkability in their area. In fact some municipalities claim that those walkability maps have been effecting the real estate market and leading the planning process. Although the maps produced via "walkscore" have been criticized for the parameters they used, no alternative have been provided so far. More over, such scores have been published for cities in United States, Australia, and England. However, such maps for Asian cities or developing countries have not been produced yet. This study aims to describe an alternative model to measure and understand the walkability at street level. The study was held in accordance with Izmir, Karsiyaka Municipality. The decision makers in Karşıyaka Municipality commit to the project and plan to use the outcomes in planning in general and urban design and urban transformation projects (http://yerel.iha.com.tr/karsiyakanin-yuruyus-haritasi-cikariliyor-izmir-20140111AW000127) in particular. In other words, the study is still an ungoing project. Preliminary finding would be shared with this manuscript.

2. Methodology

2.1. Site

The study was held in Izmir Turkey, third largest city on the west coast of Turkey (Figure 1). About 6500 street segments in nine districts of Karsiyaka, Izmır were digitized. The districts involved planned and unplanned areas for upper middle, middle and lower middle social class residents.

The location of commercial activities, green areas, schools, bus stops, ferry, light rail stops have been obtained from the archival data of Karsiyaka Municipality and updated via Google Earth, Yandex and on site visits. Using Geographic Information Systems and its extension Spatial Design Network Analysis (which was developed by Cardiff School of Planning & Geography and the Sustainable Places Research Institute) walkability score of each street was measured.

Fig 1. The study was held in Izmir, Turkey

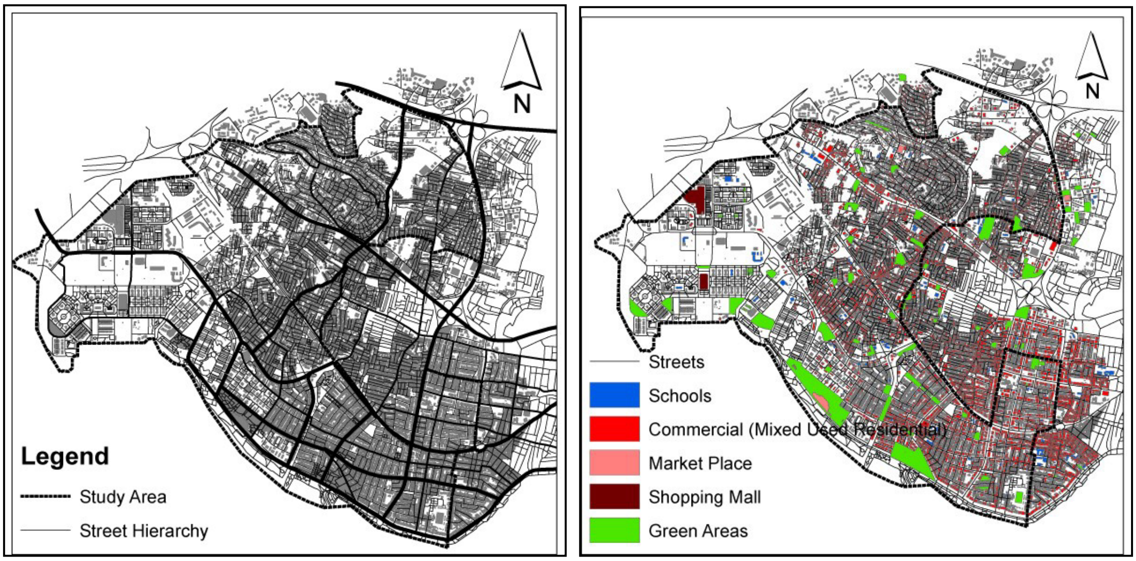

Figure 2 About 6500 street segments and landuse in nine districts were digitized.

2.2. Measuring Walkability Scores

A voluminous number of research listed a voluminous number of parameters as related to active living. An extensive review of literature on those parameters grouped them under seven headings: (1) landuse, (2) accessibility, (3) traffic safety, (4) crime safety, (5) walking and cycling comfort, (6) environmental aesthetics & upkeep, (7) others (e.g. social relations within the neighborhood) (Cubukcu & Hepguzel, 2013). In order to calculate walkability of streets and neighbourhoods related to landuse and accessibility, researchers measured density, non residential diversity, presence of recreational, commercial areas and schools, connectivity and interaction scores per street based on Space Sytntax analyses, network distance to non residential areas, commercial areas, public transportation. On the other hand, "Walk Score", which is a patent-pending system, measures walkability of regions, neighbourhoods and streets based on distances to amenities (such as green areas and commercial areas). This study attempts to develop a similar model for a different geography and measure walkability per street segment. The measure developed in here is based on two main parameters: (1) network design (centrality and betweenness scores), (2) accessibility to amenities (network distance to shopping malls, market place, mixed use areas, schools, green areas, bus stops, ferry, and light rail stops).

Network design was evaluated via betweenness and centrality scores for each street segment using "Spatial Design Network Analysis" extension for ArcGIS. The software offers two main analyses types: euclidian and angular. Euclidian analyses minimizes the distance (based on shortest path) and angular analyses minimizes the number of turns (minimum turn). The measures used in this study are based on Euclidean measures. Betweenness score measures the number of times the link (street segment) lies on the shortest paths between other pairs of street segments. In other words, it measures the number of paths that pass a street segment. Centrality score measures the difficulty (on average) of navigating to all possible destinations (links street segments) from each link (street segment). Figure 3 shows the betweenness and centrality ratings for each street segment. Scores increase from dark green, light green, yellow, orange to red. Centrality scores ranged between 2.02 and 7.56. Betweenness scores ranged between 0.99 and 1214.29. Higher betweenness sores (orange and red lines) indicated that the street segment lies between the shortest path of more links. Higher centrality scores (orange and red lines) indicated that it is easier to reach to all other links in the network (higher in centrality).

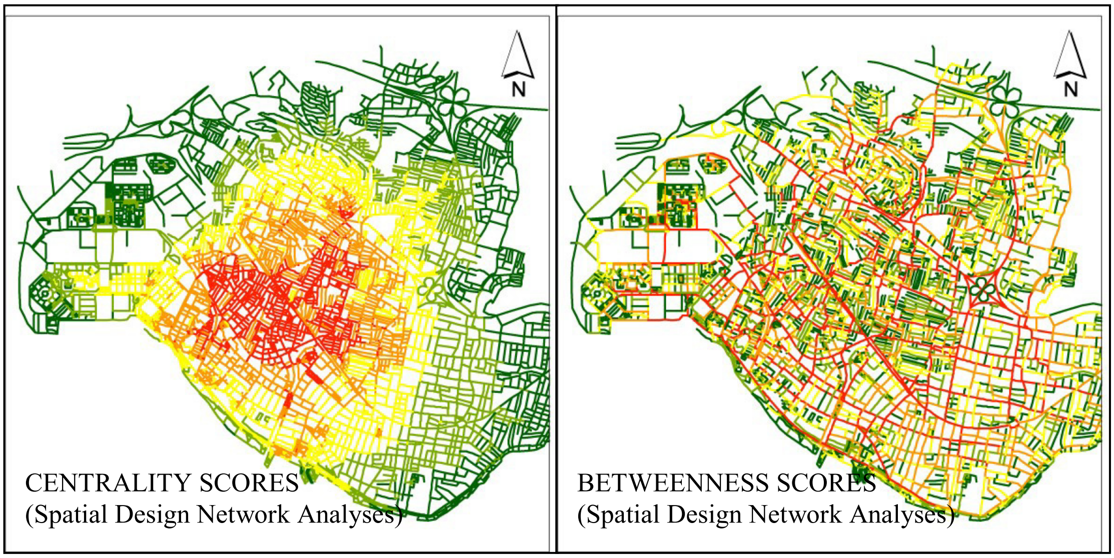

Fig 3. (a)Left: Centrality Scores; (b) Right: Betweenness scores

Accessibility to amenities was evaluated via "Network Analysis" extension for ArcGIS. The closest facility analysis tool was used to measure the shortest network distance from each street segment (center point) to each amenity (center point). Three types of commercial areas (large scale shopping malls, market places, and small scale commercial activity in mixed used areas) were specified. Building layer was classified for each commercial type. Figure 4 shows the accessibility from each street segment to closest amenity. Scores increase from dark green, light green, yellow, orange to red. Network distances to closest large scale shopping mall ranged between 4.95 and 5873.45 meters. Network distances to closest commercial building in mixed use areas ranged between 0 and 1443.87 meters. Network distances to closest market area ranged between 17.73 and 3429.16 meters. The scores were normalized for each commercial activity and added up to measure a composite score for accessibility to commercial areas. For the composite measure, the scores ranged between 0 and 1. Higher sores (orange and red lines) indicated higher network distances, lower accessibility.

For accessibility to public transportation three measures were used: network distance to closest bus stop, ferry, and light rail. The location of stop was specified as point. Figure 5 shows the accessibility from each street segment to closest public transportation stop. Scores increase from dark green, light green, yellow, orange to red. Network distances to closest bus stop ranged between 0 and 1433,71 meters. Network distances to closest ferry ranged between 7 and 5369,96 meters. Network distances to closest light rail transit stop ranged between 4.99 and 3562.23 meters. The scores were normalized for each public transportation stop and added up to measure a composite score for accessibility to public transportation. For the composite measure, the scores ranged between 0 and 1. Higher sores (orange and red lines) indicated higher network distances, lower accessibility.

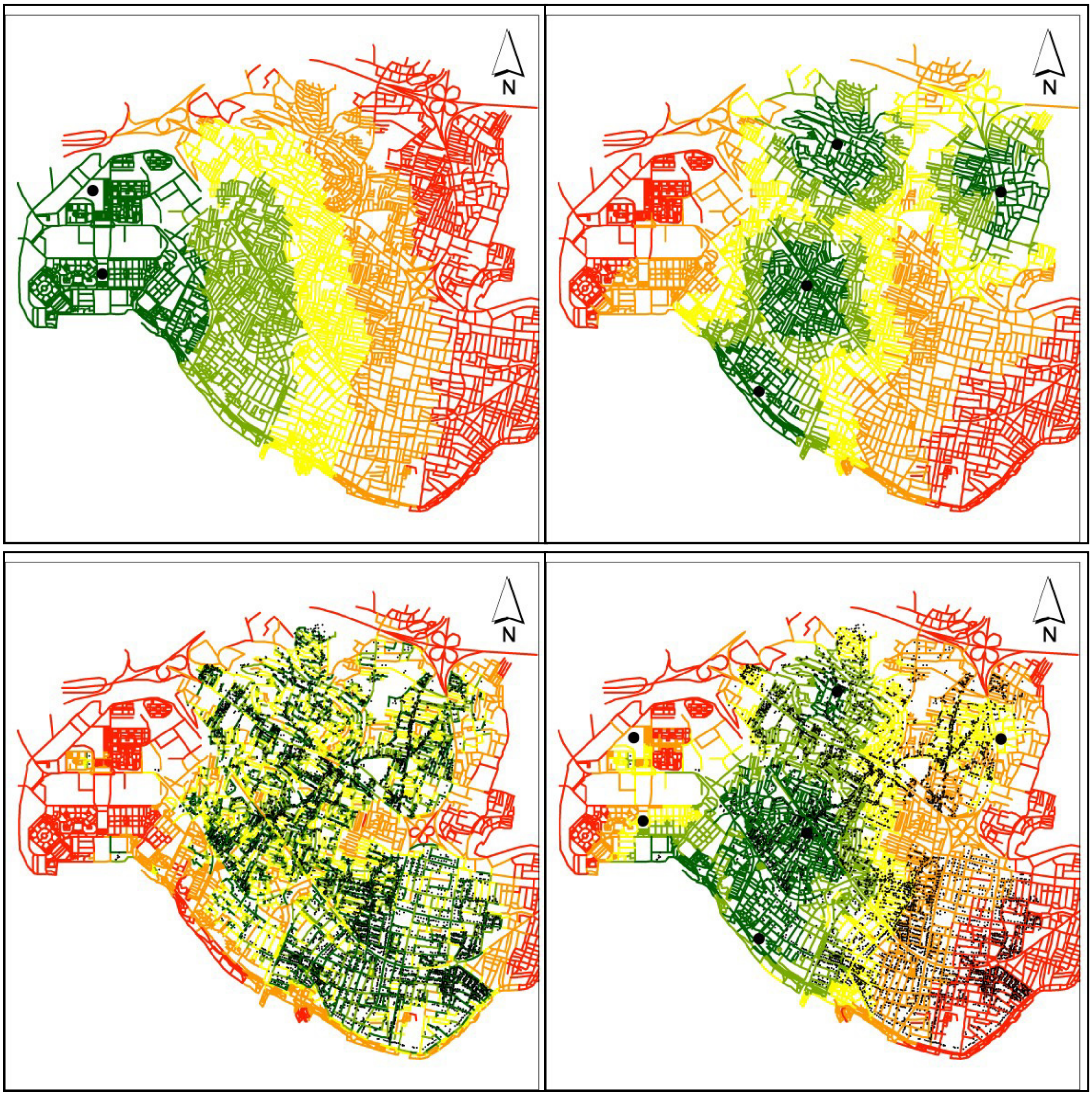

Fig. 4 Upper Left: Network distance to shopping malls, Upper Right: Network distance to market areas, Lower Left: Network distance to commercial areas in mixed landuse, Lower Right: Composite score for accessibility to commercial areas. The black dots in each map shows the location of each commercial activity for each type.

Figure 6 shows the accessibility from each street segment to closest school and green area. Scores increase from dark green, light green, yellow, orange to red. Network distance to closest school ranged between 0 and 1429.24 meters. Network distance to closest green area ranged between 0 and 1912.68 meters. The scores were normalized and ranged between 0 and 1. Higher sores (orange and red lines) indicated higher network distances, lower accessibility.

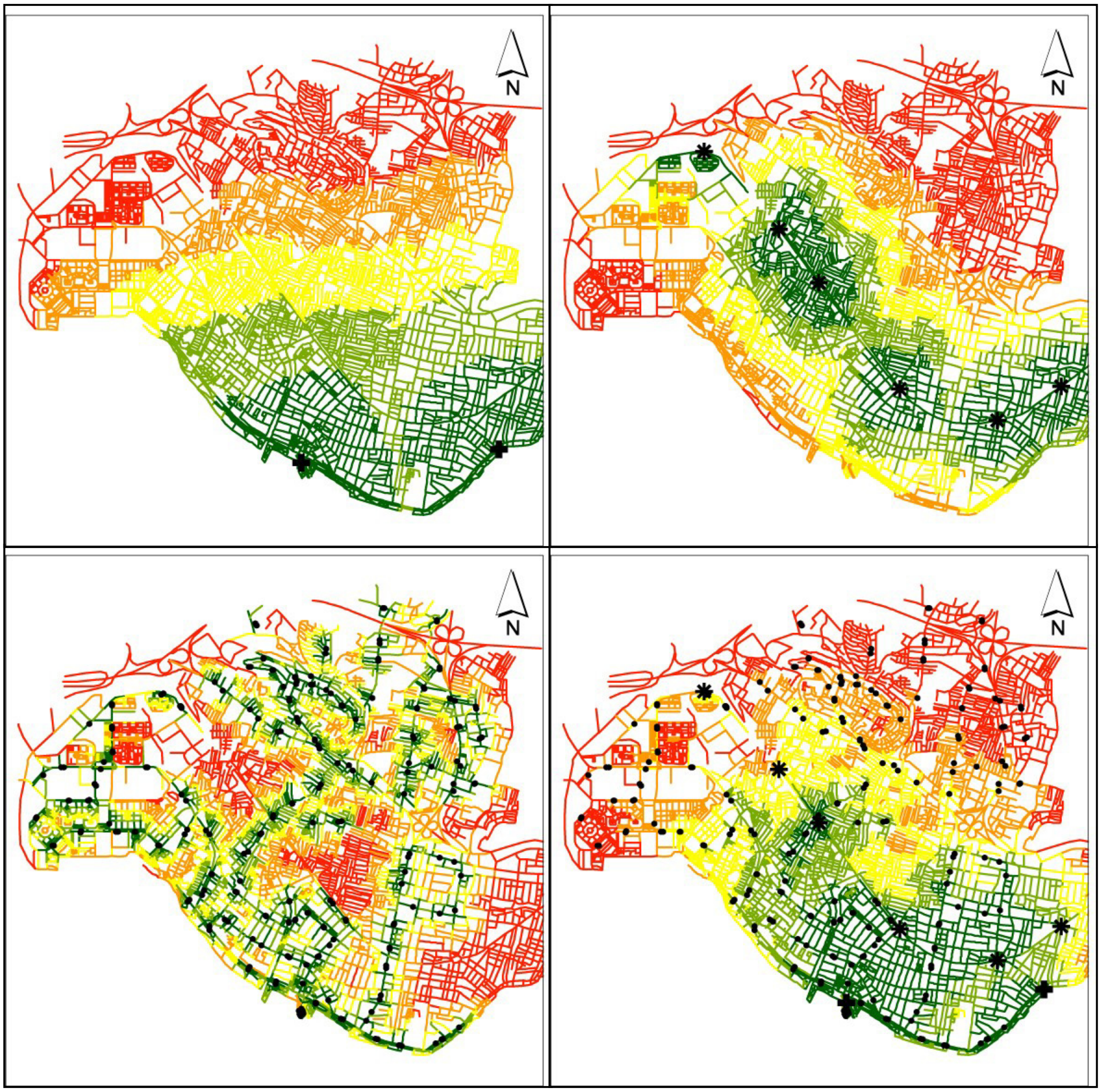

Fig. 5 Upper Left: Network distance to ferry, Upper Right: Network distance to light rail transit stops, Lower Left: Network distance to bus stops, Lower Right: Composite score for accessibility to public transportation. The black dots in each map shows the location of each public transportation stop for each type.

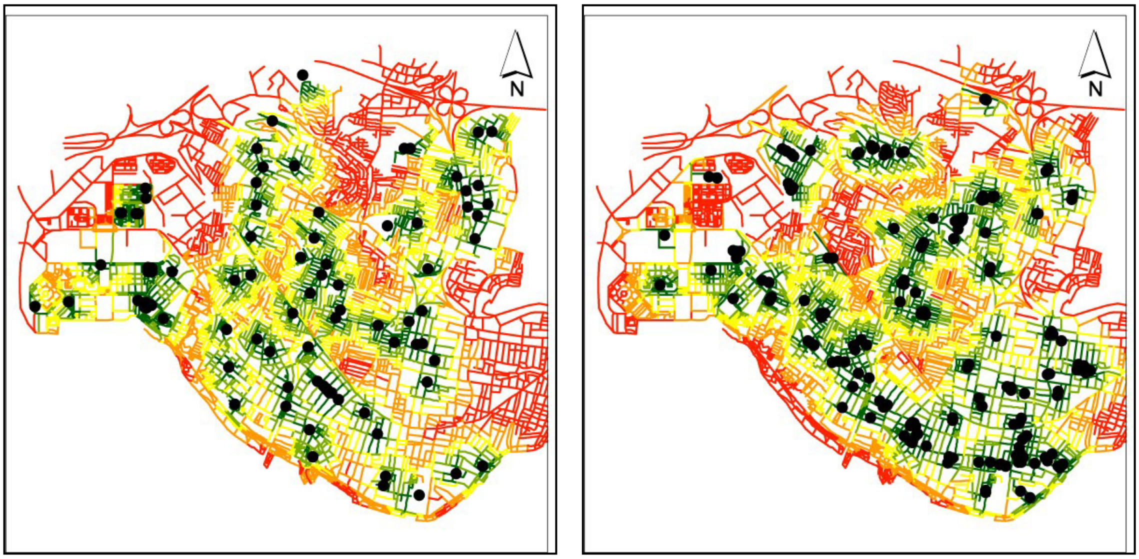

Fig. 6. Left: Network distance to green areas, Right: Network distance to schools.

3. Findings

A composite walkabililty score was measured based on above criterias. Each score was normalized and the sum of normalized network design scores were subtracted from the sum of normalized accessibility scores to various amenities score as higher scores for betweenness and centrality scores have positive meaning for walkability and higher scores for accessibility have negative meaning for walkability. Figure 7 shows the walkability map for nine districts in Karsiyaka, Izmir. Higher scores (orange and red lines) indicated lower walkability, lower scores (green lines) indicated higher walkability.

4. Conclusion

This study aims to describe a model to measure walkability of street segments and develop walkability maps. The methodology described in here is computation intensive, yet it is possible with available software. We used two macro scale parameters to measure walkability of street segments: network design and accessibility to various amenities. The model is open to improvement; data collected via street audits (presence of sidewalks, traffic safety, environmental aesthetics etc.) could be integrated into the model. Moreover, in the present model, the parameters used to evaluate walkability of each street segment was evaluated equally. With this model it is possible to weight the importance of each parameter and achieve alternative maps by changing the weight of each parameter in the model.

More research is on call to investigate the relation between actual walkability in the area and walkability maps based on specific parameters. In other words, next step is to test the accuracy of these maps. A good direction for future research is to examine to what extend these maps shows the actual situation to discuss the strengths and limitations of this model.

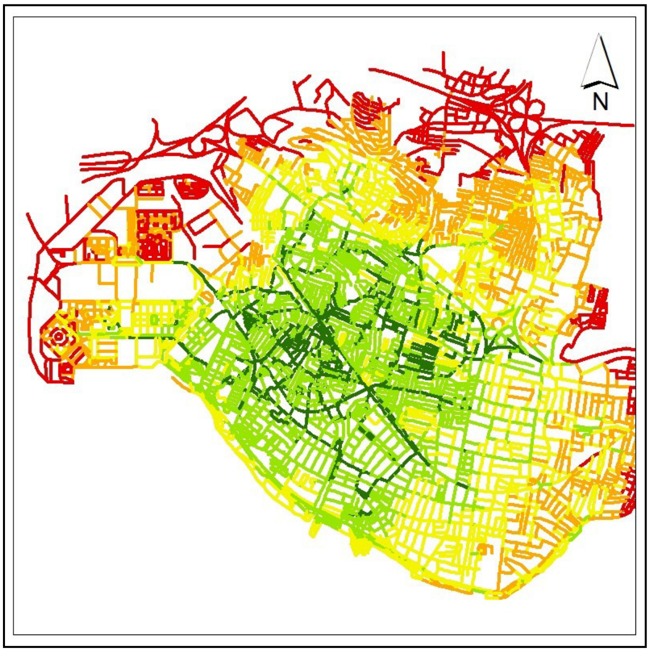

Fig. 7. Walkability scores based on betweenness, centrality and accessibility to various areas.

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