GIS Based Accessibility Assessment for Public Services: Istanbul Case

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SUMMARY

The concept of accessibility is significant in accessing to many functions such as works, social facilities, and accommodation in developing urban areas. Transportation facilities and land use of a city affect the daily life of all the individuals dwelling in the city. Development of effective accessibility strategies makes the life of people in cities more habitable. The fact that number of vehicle owners increases result in many problems. Some of these main problems are environmental pollution, parking lot problems, traffic jam and accidents, physical inactivity and obesity.

Accessibility to urban functions must be analyzed and planned firstly in order to have livable cities. Understanding public transportation accessibility is important to encourage shifts to reduce car and using public transportation. There are 14.160.467 people living in Istanbul (Turkey) according to 2013 data. The number of travel is considerably high and private vehicles carry out most of these travels. Access to public transportation will pave the way for the decrease in the number of private vehicles in the traffic.

In this study, Geographic Information Systems (GIS) techniques were used to assess transportation accessibility. Network analyst techniques support determining zone-based, isochronal, raster-based accessibility assessment on transportation network. 9 different metro and train lines of Istanbul that 400 million people travel annually were analyzed as the case study. Thus, approaches for the effective use and planning of transportation infrastructure were examined to reach urban functions.

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1. INTRODUCTION

Accessibility can be considered as one of the prior needs of the urban functions in the growing and developing cities. A city becomes accessible, if urban function and transportation infrastructure integrated city population and urban dynamics. There is no single definition and explanation of the concept of accessibility. For, number of fields and study use accessibility definitions are different. Although accessibility is commonly defined as; "potential for interaction" (Hansen, 1959)", "Freedom of individuals to participate in different activities" (Burns, 1979)", "the ease of an individual to pursue an activity of a desired type, at a desired location, by a desired mode, and at a desired time" (Bhat, et al., 2001), "the ease with which any land – use activity can be reached from a location using a particular transport system (Dalvi, 2010), "interaction with the activity or activities of time and location and its access quality. (Ersoy, 2012), "The ease with which activities at one place may be reached from another via a specific travel model'' (Liu & Zhu, 2004).

Accessibility of public transportation becomes more important because of two reasons. The first is high level of usage private car and its unwanted results (Increasing greenhouse gas, Emission, Traffic congestion, Physical inactivity and obesity e.g.). The second is the principle of equality. Equality issue is about the fact that whole society can be use equal level of travel in view of comfort, price, and time. (Movoa, Witten, McCreanor, & o'Sullivan, 2012).

In the city of Istanbul, the daily journey is very high and a large part of this journey is made by road. This causes considerable traffic congestion in Istanbul. The most important reason of traffic congestion is excessive use of private car and train system (Metro) does not meet with the current demand of city dwellers (İstanbul Büyükşehir Belediyesi, 2011). In addition the transportation problem of Istanbul is; increasingly number of the private car, rapid urbanization, and lack of traffic safety. (Sağlam, 2014). A public survey applied to 9132 people shows that transportation and traffic (%18) are the primary problems of Istanbul (Ilıcalı, 2014).

In this study, by considering the concept of accessibility, Geographic Information Systems (GIS) in the scope of applicability of network analysis techniques were examined. Accessibility of subway (metro) can be mapped in the case of Istanbul province.

2. ACCESSIBILITY FOR PUBLIC TRANSPORTATION

2.1. Network Analyst in GIS

A network is a system of interconnected elements, such as edges (lines) and connecting junctions (points) that describe possible routes from one location to another (ESRI, 2015). The line based geographic data such as highway network, water and sewerage system, electric and triangulation line network and etc. are interconnected with each other and they show continuity. A network analysis can be defined as; making decision as a result of analyzing line based on geographic connections (Yomralıoğlu, 2000).

In network analysis decision maker or user need to use two factors. These are impedance (Lloyd, 2010) and supply – demand values (Heywood, Cornelius, & Carver, 2006). Even if these effective values can be defined as distance between the nodes, travel cost and duration can also be calculated. Due to this fact, it is important to calculate the impedance value before making any network analysis (Lloyd, 2010).

For instance, the impedance factors of a cargo company are time, gas, and the charge for drivers. In addition, this factor can change road conditions and delivery time. Road conditions can be affected by topographic structure of land, weather conditions and highway (dual or single lane) structure. Delivery time may change at the time of day. For example, metropolitan cities have traffic congestion peak time (07:30 – 8:00 and 18:30 - 19:30). These conditions and factors can define impedance factors of network analysis. Supply is the second important value that follows the impedance factor. When the supply demand conditions are known, the desired places arrival and requests of these places will be known too. For example, total number of beds in a hospital represents the supply, and the number of people who need to stay in the hospital shows the demand (Heywood, Cornelius, & Carver, 2006).

There are four important steps to create a network (Sağlam, 2014):

- Establishment of a data set and layers.
- The role setting of layer and connection values will be determined; travel time, Z values, and direction of data will be defined in attribute table.
- Returning data will be added to network.
- Network will be created.

A variety of possibilities can be possible to produce in multi-transport models. Figure 1 shows the railroad, highway, and bus layers that are connected to each other. It makes restrictions and hierarchies based on the connections among them. Network analysis has various functionalities such as finding the best route, finding closest facility, service area, location – allocation, O – D cost Matrix, and vehicle routing problem. (ESRI, 2015).

Figure 1: Network analysis and multi-transport models

2.2. Accessibility Components

Accessibility consists of use of land use, transportation systems, temporal and individual components (Geurs & B, 2004);

Land Use Component: Land use components investigated in 3 groups:

- Number, quality and spatial distribution of opportunities such as work places, stores, and health and recreation facilities in destination. At the end of the journey there is a direct ratio between the number of the places, level of importance it's for person and closeness between them.

- Need for facilities: In network analysis origin and destination locations are important. In this way workplace – employee, student - school can be given as an example.

- Capacity restriction of the facilities: Facilities with limited supply affect accessibility level. Even if a person reaches the destination, facility may not meet the demands of the person. As an example, there is not enough bed capacity in the hospital or no more movie tickets in a theatre when you reach the required facility.

Transportation Component: It includes activities causing losses during the journey depending on the type of transport. The activities are divided into 3 groups. First: the waste of time during the journey. It consists of travelling, parking, and waiting time for the transport. The second one is cost of journey and the third one is journey attractions such as safety, comfort, and accident risk.

These activities are related to supply and demand. Supply is concerned with the location and properties of the person, like speed of transportation and variety of transportation vehicle. Demand are concerned with both the person and cost of journey.

Time component: It **r**efers to the time constraints in terms of access to the facilities. Time dimension of accessibility depends on the usability and available time of facilities during the day.

Person Component: Accessibility depends on needs, capacity, and opportunities of the person. Personal needs depend on the age, education level or incomes whereas the capacity depends on the physical conditions and availability of transportation system. Opportunities depends on the incomes and budget for travelling.

2.3. Accessibility Measures and Public Transits:

The availability of the public transportation system is one of the main issues for both local government and researches. Public transportation system contributes to social equality and decreases emission damages. Using public transportation decreases the level of carbon dioxide released to atmosphere, physical inactivity and related diseases such as obesity, cardiac disease, and cholesterol.

In this study, the availability of transportation is divided into 3 groups: access to transit stops, public transit travel time, and access to destination by public transportation.

2.3.1. Access to Transit Stops

In many studies the power of access to transit stops researched in GIS. These studies summarized proximity of first location and destination of travel. Using this proximity, accessibility will map the accessibility of transit stops.

The accessibility of transit stops calculated by using Euclidean and Network analysis tools. Another way in calculating accessibility transit stop is describing number of step to walk to the transit stop. These calculate should use survey result (Movoa, Witten, McCreanor, & o'Sullivan, 2012).

2.3.2 Duration of Public Transit Journey

Although access to transit stops is important, the duration of public transit journey is also an important factor of accessibility measure. Time interval between first and target destination affects the quality of accessibility.

The accessibility is calculated by the researchers by making isochrones analysis, calculating the public transit travel time and making models to show transit service frequencies.

2.3.3. Access to destination by Public Transport

The transit stops and duration of journey as much as destination differences (opportunities) and activity diversity will affect the accessibility.

Researches generally showed that it differs to reach the destination by using different transportation vehicles and accessibility level may vary depending on the destination location. For example, Huang and Wei, Wei (Huang & Wei, 2002) calculated access via public transit to urban opportunities.

In their study, access to destination was calculated by using public transit model GIS based Land and public Transport Accessibility Index (LUPTAI). The LUPTAI combines

accessibility calculated for walking distances, transit service frequencies and public transit travel time.

3. CASE STUDY

Istanbul metropolitan area was chosen as a pilot area. According to Turkish Statistical Institute, Istanbul is the most crowded city of Turkey with 14.160.467 population. Istanbul contributes to Turkish economy more than any other city in Turkey. Thanks to geopolitical position of Istanbul, it has numerous transportation modes. The transportation demand of Istanbul is increasing day by day. For an accessible city, transport infrastructure and traffic services should be developed with an integrated approach (Bozdoğan, Seyrek, Özçelik, Tırlı, Yalçınkaya, & Çiftçi, 2004).

The railroad system of Istanbul started to be used in 1989 firstly and 993.742 people were carried by railway line. There are 9 different rail system network now in Istanbul and served to 112.046.120 people in 2014. (İstanbul Büyükşehir Belediyesi, 2014).

Application can illustrate walkability from the transit stops of person according to neighborhood. If the walking distance to metro or railroad station is less than 600 meters it is considered at a High accessible level, if between 600 - 800 meters considered as medium accessible level, if between 800 -1000 meters considered as low accessible level and lastly 1000-1200 meters as a poor accessible level. (Yigitcanlar, Sipe, Evans, & Pitot, 2007).

Public Transportation	Train
High	Up to 600 m. walk
Medium	Up to 800 m. walk
Low	Up to 1000 m. walk
Poor	Up to 1200 m. walk

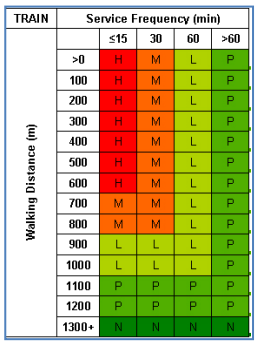

Figure 2. Public Transportation Accessibility Measures

3.1. Data Collection

In this paper, the data based on social-economic information depend on the transportation, construction, county, neighborhood, and traffic analyze zone under the scope of application of Istanbul Metropolitan Department was used. These data was integrated by using ArcGIS10.1 software in a geographic database.

In order to make a network analysis from the data depending on the arc - node topology rules, road systems and connections were studied. The Snap tools, an Arc GIS software, was used to connect the available data of roads within 10 meters of the area of investigation in order to carry the point data to nearest edge. After topologic corrections, network analysis was done to make the assay of walking availability of transport stops. In the network data, which

represents the feature of road, meter was used as a unit of length and minute as a unit of time. After finishing the network installation, the walking availability from the public transport station to determined points was investigated.

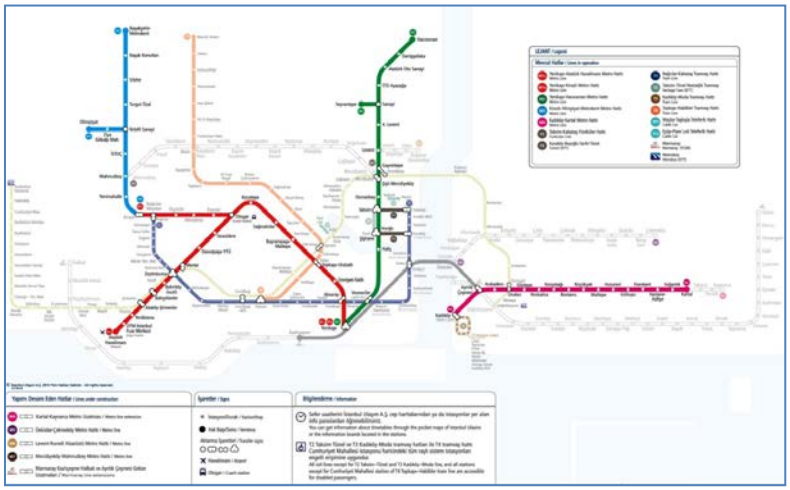

Figure 3: Istanbul Railway Network Map

3.2. Application

During the implementation phase of the study, Metro transportation is classified into their own in the group. In the grouping system, it is used Transport Accessibility Index (LUPTAI). Figure 5 demonstrates LUPTAI, and it is divided high, medium, low and poor area of subway transportation accessibility.

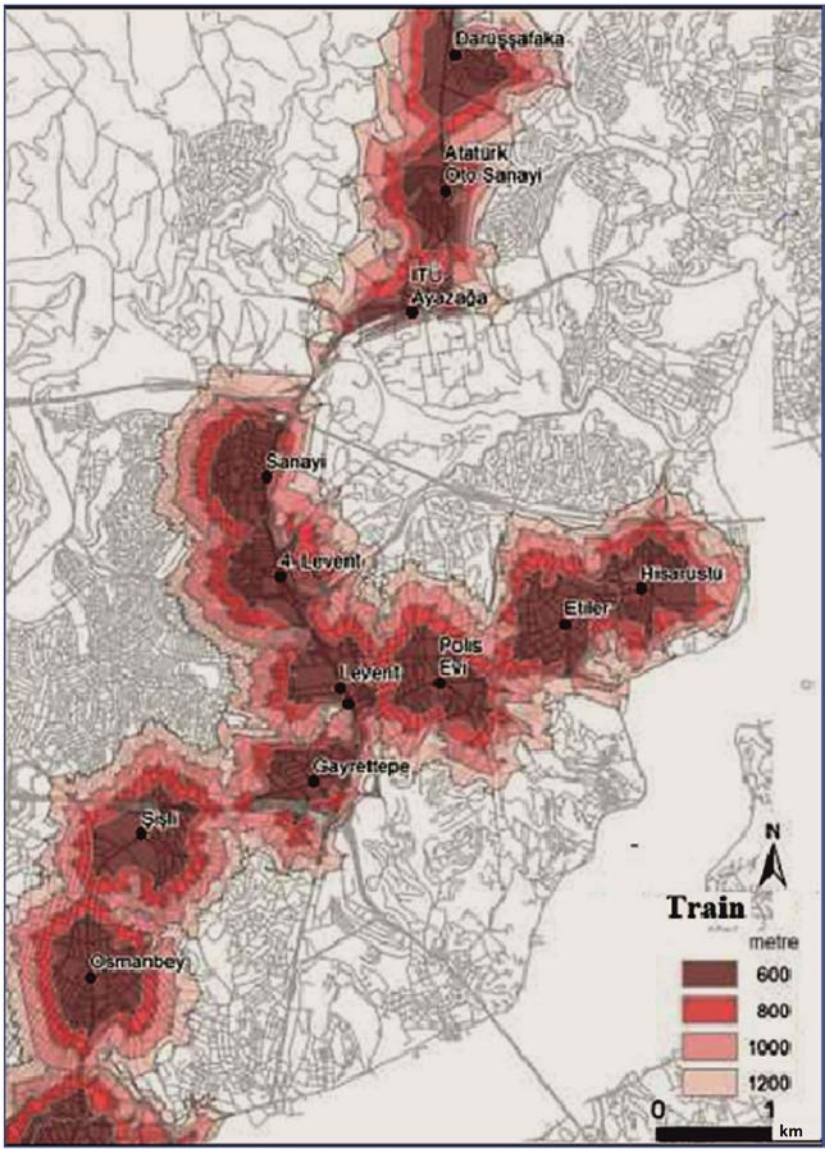

Figure 4: Accessibility of Subway in Istanbul

4. RESULT

In metropolitan cities such as Istanbul, enabling people to lead to improve the quality of life and activities should develop their accessibility levels. In addition accessibility of public transportation is the key of independence and equality of whole community. Subway (Metro) public transportation is safe, modern, in addition, it is ecofriendly (protects the environment from gas emissions, and air pollution).

Subway public transportation must be dense in highly populated neighborhoods in Istanbul. After this, road transport and traffic problems intensity may be reduced. As a consequence of the study, 788 neighborhoods out of 371 is access to subway. The target of Istanbul Metropolitan Municipality for the period following 2023 is to increase the length of Rail System above 776 km.

According to the Istanbul Transportation Master Plan, 615 km rail network and 37 pipeline projects will be completed until the year 2023. As a result of this evolution, 788 neighborhoods out of 514 will acquire high accessibility level (< 600m. walk).

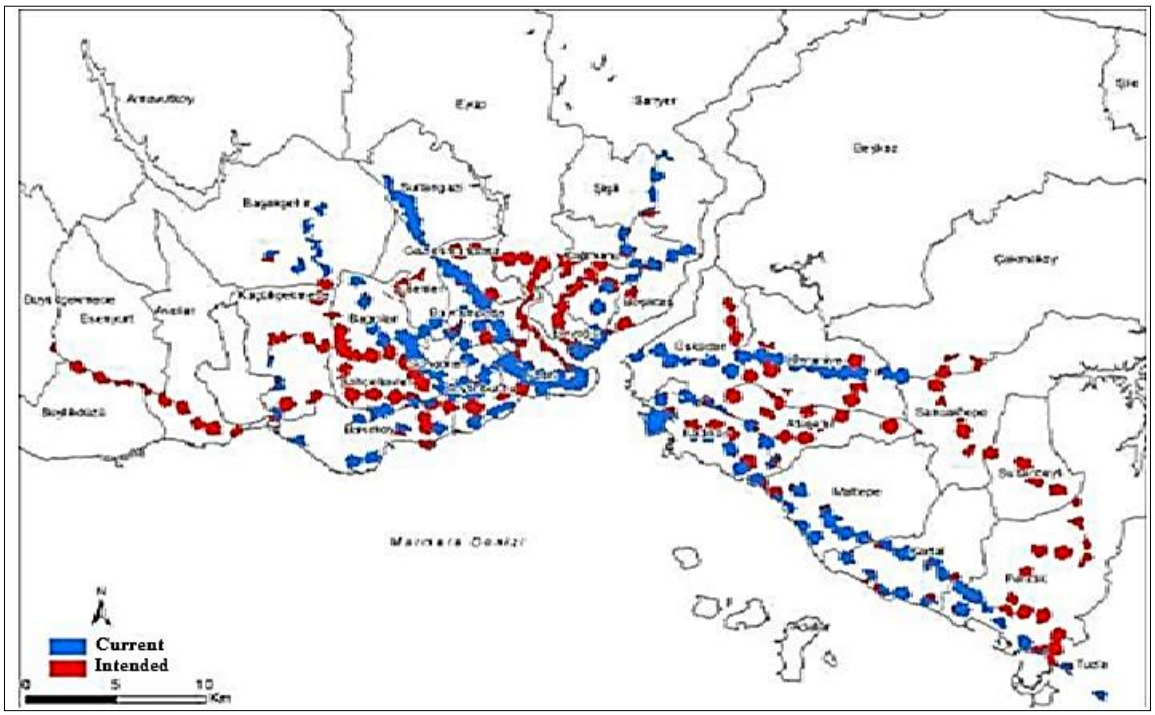

Figure 5. Current and Intended Train Station

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BIOGRAPHICAL NOTES

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