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INTEGRATING PHYSICAL ACCESSIBILITY OF EMERGENCY ESTABLISHMENTS INTO EARTHQUAKE RISK ASSESSMENT

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Abstract:

Human being has always been in a continual struggle with disasters. They are mostly sudden and unexpected and cause irreversible damages to human life and property. Disasters are facts of life, but it is always possible to decrease the effects of disasters by preparedness.

In disaster case, accessibility is one of the most vital and important components of disaster preparedness and mean the difference between loosing a life or saving a life. That is why emergency accessibility, regardless if it is measured in time, distance, population or any other cost, is the most important variable that decision makers must consider in the early stages of planning for developing planning policies.

In the light of the above mentioned facts this study analyzed 3 different accessibility measurement techniques (Zone Based, Isochronal Based And Raster Based Techniques) within GIS environment for more efficient modeling of physical accessibility in Eskisehir urban area and for creating an accessibility vulnerability index as an input for a higher scale earthquake risk detection process. The results can also directly be used by emergency planners/city and regional planners as a part of a GIS based DSS (Decision Support System) in accessibility measurement or can be integrated into a more comprehensive disaster risk calculation processes.

KEYWORDS: Accessibility, Emergency Accessibility, Disaster Preparedness, Geographical Information Systems (GIS)

1. INTRODUCTION

Physical accessibility is defined as being able reach an intended point or location in spite of the hindrances like transportation and reflects the ease for travellers. Juliao (1999) states physical accessibility as a key variable for planning policies and territorial development. Policy planning and territorial development are concerned with equity and a better distribution of people and activities in the territory. That is why accessibility, regardless of its measure (e.g. time, cost, distance, or population) is the most important variable that decision makers must consider in the early stages of planning.

Accessibility analyses basically serve for checking the benefits of plans as a planning control tool, and helping decision makers to investigate the new locations of urban services, testing the benefits of the current locations of urban services, identifying thresholds about urban services, finding out the capacity and service area of urban services such as education, emergency, leisure, industry and shopping etc. (Kuntay, 1976; Kuntay, 1990). Halden et al (2000) also emphasize accessibility analyses as practical tools in evaluating the performance of transportation systems. Accessibility results can be used to check if urban services are highly accessible by walking, cycling or public transport etc., to identify critical regions that are out of current service range or to select appropriate sites for new services.

When emergency accessibility is considered, physical accessibility basically reflects emergency organization's readiness to respond to an emergency in a coordinated, timely and effective manner and helps to determine the extent to which a city is ready for any disaster. That is why, measurement and evaluation of physical accessibility of emergency services is one of the most vital components of disaster preparedness. A few seconds of delay by emergency response units may mean loss of human life, environment and property. Measuring and evaluating emergency accessibility can help decision makers, who are local authorities including civil defence, emergency service providers, department of planning, to test the current emergency service response performance, to identify critical areas that have low or no accessibility, and to find out solutions in order to improve the response to these critical areas (Badri et al., 1996). Different accessibility measurement techniques (Zone Based, Isochronal Based and Raster Based Techniques) within GIS environment for more efficient modeling of physical accessibility of emergency services is a vital concept in emergency preparedness and has a leading role in reducing casualties. In this study, physical accessibility in Eskisehir metropolitan area is evaluated by using various accessibility methods within geographical information system environment for various fire and health services, which have critical role during disaster emergency situations.

2. METHODS OF ACCESSIBILIY

At its simplest level, qualitative descriptions can be used to define the accessibility of a location. Terms such as "good accessibility", "average accessibility" or "poor accessibility" can be used as simple qualitative accessibility measures for describing the accessibility level of a location in meaning of the accessed population, accessed facilities, or sometimes the level of transport supply (Halden et al., 2000). However, accessibility measures will usually need a more comparative approach than qualitative accessibility measures in order to support practical decision making. There are three generic but overlapping techniques for measuring physical accessibility using GIS which are;

- Zone based technique
- Isochronal technique
- Raster based technique

Although there are various accessibility measuring techniques, the best approach for measuring techniques of accessibility does not exist. Different situations and purposes demand different approaches (Makri and Folkesson, 1999).

In zone based accessibility, the accessibility evaluations are calculated and presented in zone based units such as districts, quarters etc. Based on costs on a transportation network, the accessibility values are calculated for each zone separately from zone centroid to related urban service or vice versa. The disadvantage of this technique is that the same accessibility result is obtained for the whole zone. It has an advantage of producing easily comparable results with other urban based parameters.

The other accessibility measurement technique is the isochronal technique, where the accessibility evaluations are calculated and presented in an isochronal logic. An isochrone is a line on a map that connects points of equal travel time away from a single reference point. If an origin is defined as the reference point, isochrones can be drawn connecting points in all directions that can be reached in a threshold time or distance. The isochrone is irregularly shaped because of the structure of transportation network. Routes make it possible to travel faster in some directions than in others (Transportation Statistics Annual Report, 1997). The representation of the accessibility result can be either total of polylines having similar accessibility costs (polyline based representation) or simple polygons that connect the edges of related polylines (polygon based representation). Polygon based representation is mostly used to able to perform GIS based overlay analyses, on the other side polyline based

representation can also be chosen for visual representations. The basic disadvantage of this technique is that the detail of accessibility costs directly depend on the selected threshold intervals and the same accessibility value is obtained for the isochrones (Ertugay, 2003).

The raster based technique is similar to isochronal based technique, however in raster based technique, equal travel time or distance from a reference point is represented by the value of pixels in raster environment instead of isochrones which are lines in vector environment. An advantage of this technique is that; more detailed costs can be obtained based on selected pixel size. The traditional methods of accessibility evaluation do not consider the whole territory; and mainly based on node/arc logic, so accessibility evaluation can be done in raster environment in order to create a continuous model. The main disadvantage of it is that working in raster environment reduces the geometrical accuracy of the information (mostly preferred in regional studies which doesn't necessitate high spatial accuracy) but opens a wide range of new analysis capabilities (Juliao, 1999).

3. THE CASE STUDY:

In this study, the three different accessibility measurement techniques (Zone Based, Isochronal Based and Raster Based Techniques) are used within GIS environment for more efficient modeling of physical accessibility in Eskisehir urban area and for creating an accessibility vulnerability index as an input for a higher scale earthquake risk detection process. The results can also directly be used by emergency planners/city and regional planners as a part of a GIS based DSS (Decision Support System) in accessibility measurement or can be integrated into a more comprehensive disaster risk calculation processes.

There are 4 general steps in the study which are;

- Data collection,
- Calculation of accessibility costs,
- Analyzing physical accessibility of emergency services in 3 different accessibility measurement techniques (Zone Based, Isochronal Based and Raster Based Techniques),
- Creating emergency accessibility vulnerability indexes as an input for a higher scale earthquake risk detection process.

3.1. Data collection

The data used in the study:

- Digital transportation network data, their hierarchies and average speeds
- The location of emergency services of fire brigades and health services (There are 2 fire brigades in Eskisehir, one of which is Tepebası fire brigade located in the north part of the city, the other one is the Odunpazari fire brigade located in the south.)
- The administrative borders of district and quarters.

are obtained from Eskisehir Great City Municipality.

3.2. Calculation of accessibility costs

Although the techniques are different, the common structure of the accessibility evaluation can be summarized in 3 main phases;

- Data acquisition and integration (preparation of the geographical information)
- Cost calculation (calculating the impedance/resistance across each individual cell and/or network line segment)
- Accessibility analysis (measuring and visualizing the accessibility)

In zone based technique, average speeds extracted from Eskisehir metropolitan municipality travel survey is reduced by 30% assuming that in case of disaster emergency, the traffic speed will be less than the normal one. and used for calculating travel costs. The polygons of quarters are converted to centroids and the costs (distance and time) among each emergency services and centroids are calculated by using Arcview Network Analyst and Microsoft Excel and Matlab softwares (The accessibility results are calculated for single access, return access and capacity constrained access) (Figure 1). The results are linked with district database table and classified for final representation.

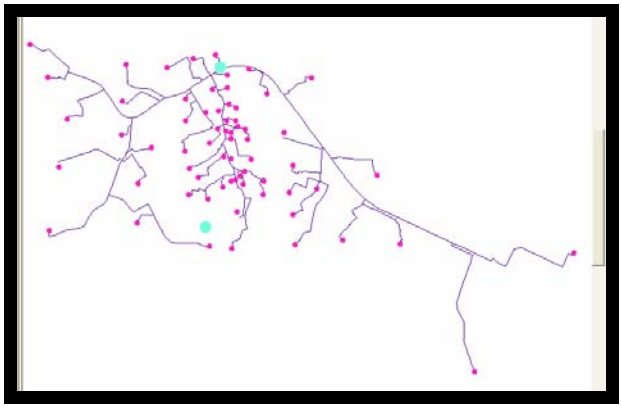

Figure 1: The distances from fire services to quarter centroids

In Isochrone based technique, average speeds extracted from Eskisehir metropolitan municipality travel survey is reduced by 30% (because of earthquake specific case) and used for calculating travel costs. Arcview network analyst is used to define the accessed networks from fire brigades (the accessibility results are calculated for single access).

In raster based technique, average speeds extracted from Eskisehir metropolitan municipality travel survey is reduced by 30% (because of earthquake specific case) and used for calculating travel costs. The vector transportation network is converted to raster and costs for each pixel are calculated based on average speed and pixel size (The 5km/h speed accepted for average pedestrian speed and attached to un-networked cells). The cost-distance function of arc map is used to calculate cumulative raster based accessibility results for final representation.

3.3. Analyzing physical accessibility of emergency services in 3 different accessibility measurement techniques (Zone Based, Isochronal Based and Raster Based Techniques)

There are two fire brigades in Eskisehir, one of which is Tepebasi fire brigade located in the northern part of the city, the other one is the Odunpazari fire brigade located in the south. There are also total of 36 hospitals in Eskisehir, 18 of 36 are local clinics.

The zone based accessibility costs for fire brigades are calculated for single access (fire brigade to quarter) (Figure 2). The zone based accessibility costs for ambulances are calculated for 3 different cases which are single access cost (hospital to quarter), return access cost (hospital to quarter to hospital) and capacity constrained access cost (Figure 3).

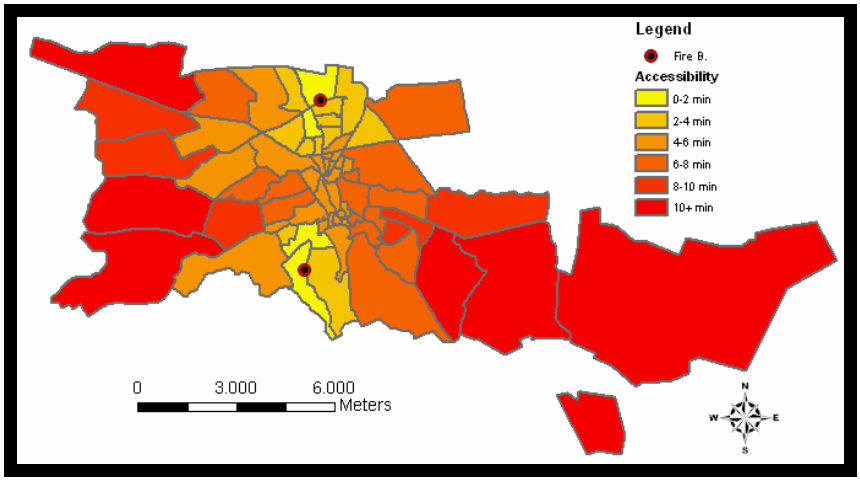

Figure 2: Zone based fire service accessibility

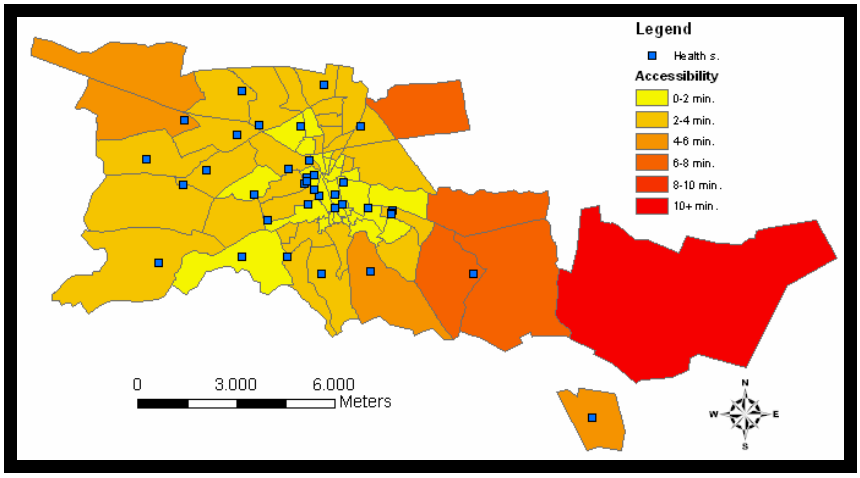

Figure 3: Zone based health service accessibility
*(when capacity constrained access costs are considered)

The isochronal based accessibility costs for fire brigades and health services are calculated for 0-5 minutes time intervals and 0-2,5 km distance intervals (Figure 4, Figure 5).

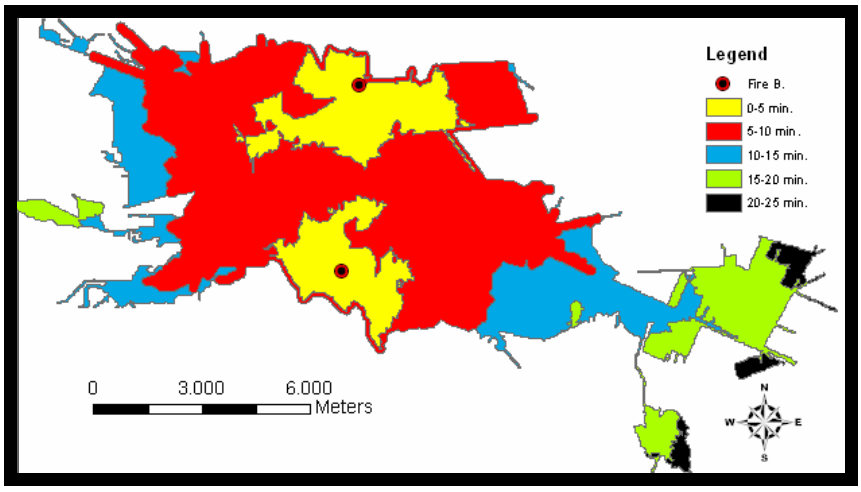

Figure 4: Isochronal based fire service accessibility (polygon based)

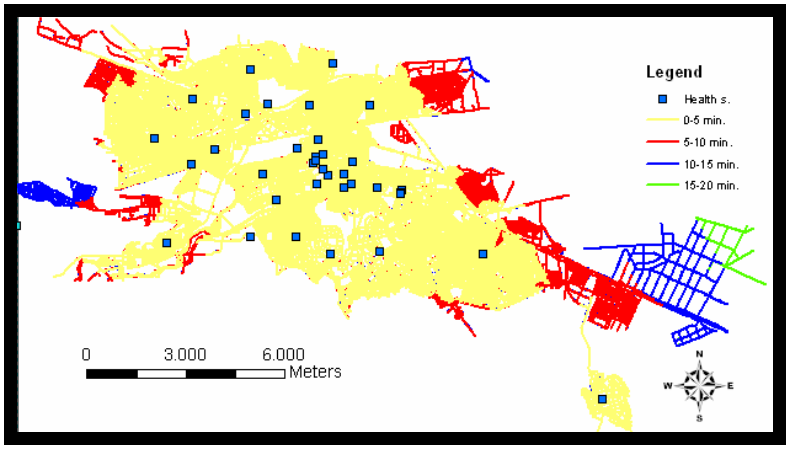

Figure 5: Isochronal based health service accessibility (polyline based)

The raster based accessibility costs for fire brigades and health services are calculated for each pixel continuously and classified 0-5 minutes time intervals and 0-2,5 km distance intervals (Figure 6, Figure 7).

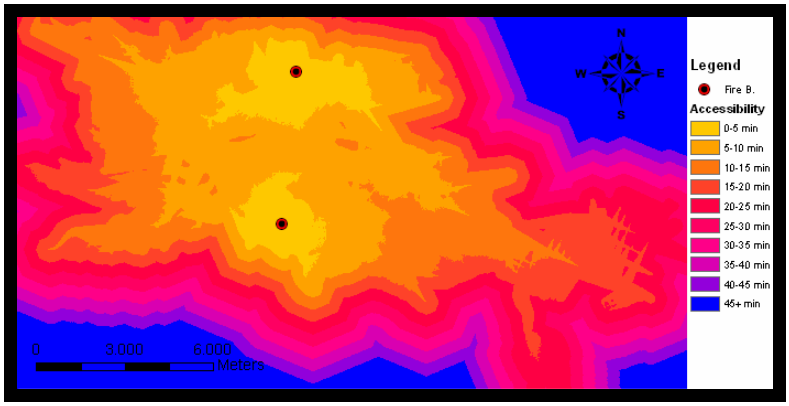

Figure 6: Raster based fire service accessibility

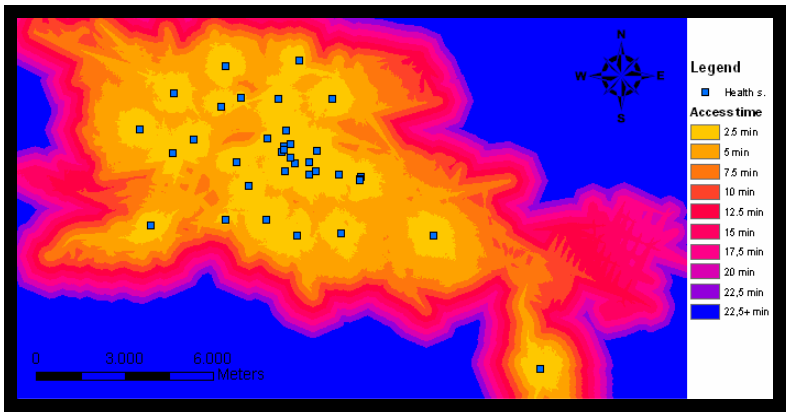

Figure 7: Raster based health service accessibility

3.4. Creating emergency accessibility vulnerability indexes as an input for a higher scale earthquake risk detection process

The zone based fire service and health service accessibility results are integrated and converted to zone based vulnerability indices (graded from 1 to 5 scale; 1:least vulnerable 5:most vulnerable) in order to able to create an accessibility vulnerability index as an input for a higher scale earthquake risk detection process (Figure 8, Figure 9). In vulnerability score calculation, the mean of fire service and health service accessibility costs are used. Health

service accessibility cost is considered separately for 3 different cases which are single access cost (hospital to quarter), return access cost (hospital to quarter to hospital) and capacity constrained access cost.

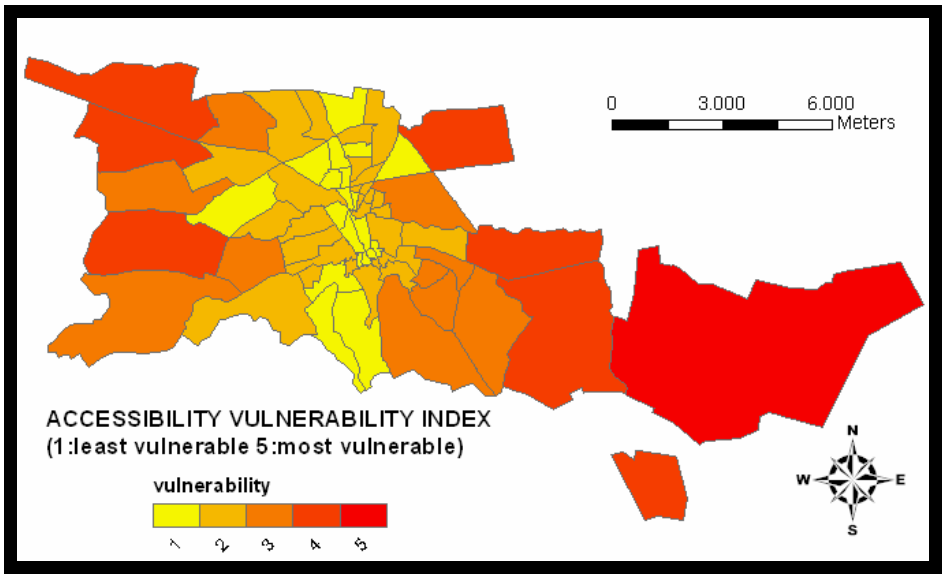

Figure 8: The vulnerability index of quarters in Eskisehir*

*(fire service accessibility cost + health service accessibility (return access) cost integration)

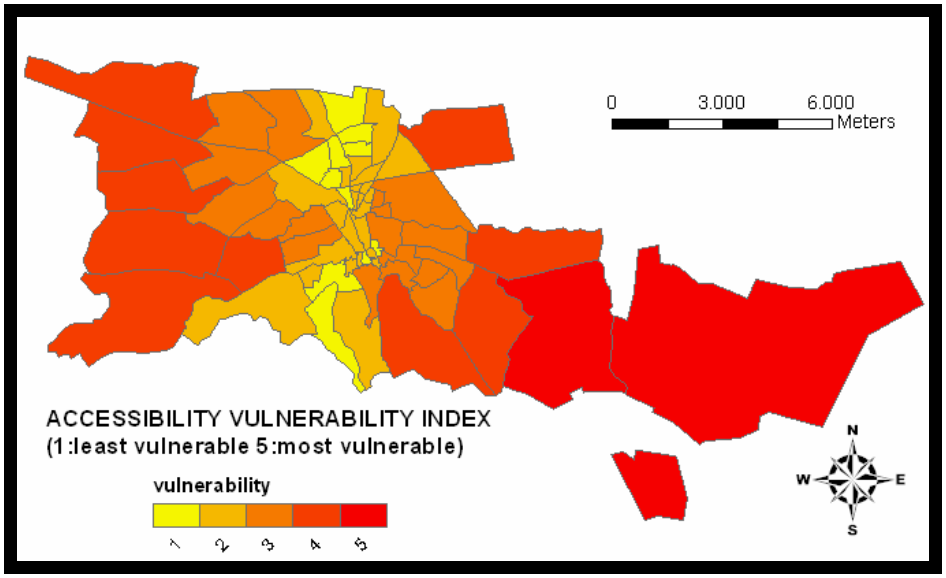

Figure 9: The vulnerability index of quarters in Eskisehir*

*(fire service accessibility cost + health service accessibility (capacity constrained access) cost integration)

4. CONCLUSION

Analysing different accessibility measuring techniques of emergency services and their integration into more comprehensive disaster risk calculation processes is a useful work for decision makers in emergency planning point of view and perform a basis or an example for the future studies in this area.

The fire service accessibility maps produced by 3 different technique show that most of the urban area are within 0-5 and 5-10 minutes fire service accessibility zones (they are within the acceptable time limits when the maximum national fire response time standard is considered as 10 minutes (Ertugay, 2003). However some partial urban regions are within 10-15 and 15-20 minutes which must be considered by decision makers from disaster preparedness point of

view. When the health service accessibility maps are considered; except for the eastern-outer parts (industrial zone) and western-outer parts of the urban area, most of the urban lands are within 10 minutes accessibility zone. However there are some low accessed outer urban regions which are over 10 minutes accessibility (10-20 min) and this can be considered as unsatisfactory for emergency situations. The low accessed regions by fire and health services can also be observed from the final vulnerability maps, produced from the integration of fire and health service accessibility values according to several access costs (single access cost, return access cost and capacity constrained access cost).

Finally it can be said that; although there are various accessibility measuring techniques, the best approach for measuring techniques of accessibility does not exist. Zone based accessibility measurement can be preferred by decision makers because the results are easier to compare with each other and with other urban based parameters however the process is difficult to perform and the results are not directly be obtained by using simple GIS software. On the other hand, isochronal based accessibility measurement is the fastest technique among the others. A disadvantage of this technique is that the detail of accessibility costs directly depend on the selected threshold intervals and the same accessibility value is obtained for the isochrones. Raster based accessibility measurement considers the whole territory and it is the only technique to create a continuous model. Working in raster environment reduces the geometrical accuracy of the information but opens a wide range of new analysis capabilities for decision makers.

REFERENCES

Kuntay, Orhan., (1976), "Planlama Kontrol Araci Olarak Fiziksel Erişilebilirlik Ve Cekim Gucu", Sehircilik Enstitusu Dergisi, 33-47, ITU, Istanbul.

Kuntay, Orhan., (1990), "Erisilebilirlik Kesin Bir Oncelik" Planlama Dergisi, Journal Of The Chamber Of City Planners, 90/1-2, 7

Badri, Masood A., Mortagy, Amr K., Alsayed, Colonel Ali., (1996) "A Multi-Objective Model For Locating Fire Stations" European Journal of Operational Research, 110, 243-260

Transportation Statistics Annual Report, (1997), "Mobility, Access And Transportation" http://www.bts.gov/transtu/tsar/tsar97/chap06.pdf visited on 23.12.2001

Makri, Maria-Christina., Folkesson, Carolin., (1999) "Accessibility Measures for Analyses of Land Use and Travelling with Geographical Information Systems" Department of Technology and Society, Lund Institute of Technology, Lund University & Department of Spatial Planning, University of Karlskrona/Ronneby, Sweden

Juliao, Rui Pedro., (1999) "Measuring Accessibility Using Gis" Geo-computation-99, http://www.geovista.psu.edu/sites/geocomp99/Gc99/010/ gc010.ppt visited on 17.12.2001

Halden, Derek., Mcguigan, David., Nisbet, Andrew., Mckinnon, Alan., (2000) "Guidance On Accessibility Measuring Techniques And Their Application", Scottish Executive Central Research Unit, http://www.scotland.gov.uk/cru/kd01/blue/guidance.pdf visited on 11.11.2001

Ertugay, Kivanc., (2003) "Measurement and Evaluation Of Fire Service Accessibility: A Case Study In Cankaya District of Ankara", Supervisor: Assoc. Prof. Dr. Oguz Isik, M.Sci. ODTU, Fen Bilimleri Enstitusu, Jeodezi Ve Cografi Bilgi Teknolojileri, Ankara