

# EMERGENCY STATE HEALTH SERVICE ACCESSIBILITY VISUALIZATION IN A 3D CITY ENVIRONMENT

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## ABSTRACT:

In urban emergency management, in order to generate decisions from heterogeneous information types, decision makers must be able to identify relations between information types. The perception of the decision makers and the visualization of the abstract information are tightly interrelated, and must be considered and understood together. Visualization is the graphical presentation of information to improve the viewer's understanding of the information. In this study, a set of effective 3D visualization tool for emergency state health service accessibility in an urban area is established by using 3D visualization in Geographic Information Systems (GIS). The pilot model area is Cumhuriye neighborhood of Eskisehir, Turkey. 1/25.000 scale digital elevation contour maps, Stereo Ikonos Satellite images, building facade images and 2D vector layers of the study area are the data sources of the model. A series of raster and vector GIS operations are performed for the development of virtual 3D city model. The computed emergency accessibility results of each building are visualized in order to create better cognition of accessibility conditions of pilot area by the decision makers. The emergency state health service accessibility of buildings are visualized for various scenarios, which are components of spatial decision support system for emergency accessibility.

## 1. INTRODUCTION

In all phases of the emergency management framework; decision makers face with huge data sets including spatial and temporal components. In an urban emergency management domain, in order to generate decisions from heterogeneous information types, decision makers must be able to identify relations between the information types. The perception of the decision makers and the visualization of the abstract information are tightly interrelated, and must be considered and understood together by all stakeholders.

Emergencies occurring in urban environments could cause damages, such as fatalities, injuries, damage to buildings and urban infrastructure, etc. The amount of damage could be reduced by using effective risk management strategies. These strategies have to be associated with the recent technological and scientific developments. GIS and RS can support decision-making throughout all phases of emergency management cycle. Decision makers should be well introduced to the problem so that they could generate applicable strategies (Godschalk et al., 1998).

The disaster risk reduction framework has many action fields. However the basic action fields can be summarized in 4 groups as;

- Risk awareness
- Knowledge development
- Application of measures
- Early warning systems (ISDR, 2002)

Effective visualization properties could play important roles in all 4 fields of this framework.

In the light of the above mentioned facts; this study concentrates on the 3d visualization of the emergency state health service accessibility as an example for the better cognition of emergency management related conditions by the decision makers. The better perception and understanding of any emergency management factor could mean better organization in terms of minimizing the amount of damage. The basic aim of this paper is not to reach a conclusion about any emergency management factor but to provide a road to the decision makers for the usage of 3d visualization techniques and framework in better understanding of the abstract information in minimizing the casualties.

## 2. OVERVIEW OF 3D CITY MODELS AND ACCESSIBILITY MODELING

### 2.1 3D city models

3D city modeling is an active research topic. Main focus lies on the management of multi-scale, large area, and geo-referenced 3D models. Architecture, engineering, construction, and facility management (AEC/FM) domain addresses more detailed 3D models. On the other hand computer graphics concentrates on the visualization of 3D models in which geometry, topology and data management and manipulations are the main focus. Geometry and topology issues of 3D objects has been investigated in detail by Molenaar (1992), Zlatanova (2000), Herring (2001), Oosterom et al. (2002), Pfund (2002), and Kolbe and Gröger (2004). The management of multi-scale models was discussed by Coors and Flick (1998).

3D city models generally used by government agencies for urban planning, public safety studies such as fire propagation,

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commercial usages including phone, gas or electric companies etc. Most of these examples are interested in modeling buildings, terrain and traffic network in the city model. Models, used for visualization, could be grouped into three with respect to their data acquisition methods: Photogrammetric, active sensors and hybrid sensors (Hu et al., 2003).

Photogrammetric methods are cost effective in large scale 3D urban models. Terrestrial, panoramic and aerial image methods are in this group of modeling. There are some example models that are created from panoramic photos. The basic data source for photogrammetric methods is aerial images which provide reliable footprint and roof height information for each building in the model area. Today 3D city model from aerial image studies generally focus on extracting accurate roof models from images, Lin and Nevatia's model predefine L, T and I shaped roofs and assign most suitable roof shape to the examined building's roof (Lin and Nevatia, 1998). Stereo aerial images could also be useful tools for extracting 3D objects (Baillard and Maître, 1999). Lack of building façade information requires additional sensor data to be acquired for visual realism. Manual and semiautomatic methods give more mature results than fully automatic systems. Knowledge based and machine learning algorithms are another hot research area for the atomization of that kind of systems. Bellman and Shortis, (2002) and Nevatia and Huertas, (1998) are two examples application of this kind. Both of them used knowledge and machine learning algorithms to improve the performance of the automatic building extraction.

Active sensor could be defined as; a detection device that emits energy capable of being detected by itself. Basically there are two kinds of active sensors used for 3D city modeling: Ground-based and airborne-based. Ground-based systems are ideal for vertical textures especially for historical structure façades (Frueh and Zakhor, 2001). However, they provide less accuracy for upper portions of tall buildings and these systems could not obtain roof and footprint data. Light detection and ranging (LIDAR) technology is typical airborne-based sensor and used for 3D city modeling studies. LIDAR technology has great potential for the atomization of modeling issues.

Most city model applications use various data sources, which require hybrid usage of different sensors. Each of these data sources and corresponding modeling technique have advantages and disadvantages (Ribarsky et al. 2002). Today 2D GIS data are often available in most cities. Many model applications use these data for their application (George, 2001 and Norbert and Anders, 1997) 2D CAD data provide accurate urban features and boundary data. Mainly boundaries are very usable data sources for image segmentation. Limitations for CAD systems could be listed as data management capabilities, spatial data management and spatial modeling. Main strengths of the CAD systems are clear and detailed graphical presentation controllability and editing capability of graphical features, Graphical presentation is important for the proposed purposes of the paper and CAD properties are used for the generation of the 3D city model and the visualization of the related data.

## 2.2 Accessibility modeling

The definition of accessibility is being able to reach an intended point or location in spite of the hindrances like transportation and reflects the ease for travelers. Juliao (1999) states accessibility as a key variable for planning policies and

territorial development. Planning policies and territorial development are concerned with equity and a better distribution of people and activities in the territory. That is why accessibility, regardless if it is measured in time, cost, distance, or population, is the most important variable that one must be considered in the early stages of planning.

Accessibility analyses have a wide usage to check the benefits of plans as a planning control tool, and help decision makers to investigate the new locations of urban services, to test the benefits of the current locations of urban services, to identify thresholds about urban services, to find 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 state health service accessibility is considered, accessibility basically reflects emergency organization's readiness to respond to an emergency in a coordinated, timely and effective manner and help us to determine the extent to which a city is ready for any disaster. That is why, measurement and evaluation of emergency state health service accessibility is one of the most vital components of disaster preparedness. A few seconds of delay by emergency response units may mean a lot of loss of human life, environment and property. Measuring and evaluating emergency accessibility can help decision makers, who are local authorities including civil defense, 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).

## 3. STUDY AREA AND DATA SETS

### 3.1 Study Area

For 3D city model generation a pilot area is selected from Eskisehir metropolitan area in Turkey. This pilot model forms the basis of a complete 3D city model. Cumhuriye quarter in the central business district of the Eskisehir city (Figure 1), with 4113 population according to the 2000 census is selected. There are 434 buildings within the quarter.

### 3.2 Data Sets

Five main data sets are used in the study,

- Vector layers from Eskisehir Municipality,
  - Street layer of the whole city
  - Building layer of the Cumhuriye Quarter (pilot area)
- Building façade images collected by field survey
- Building heights collected by field survey
- Digital transportation network data, their hierarchies and average speeds
- The location of emergency health services

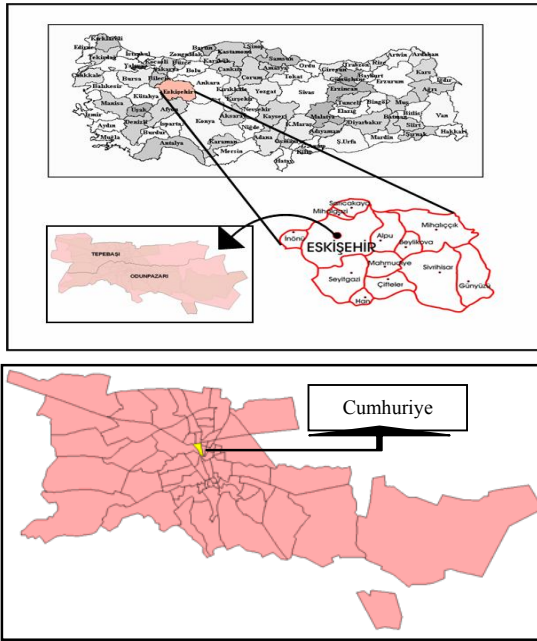


Figure 1: Cumhuriye Quarter at Eskisehir / TURKEY

#### Façade Images:

To improve the realism of the 3D model in CAD environment building façade images are used. These façade images are collected from the related buildings from the pilot area. The model of the digital camera used to collect façade images is Canon Powershot Pro1.

Technical specification of the used digital camera is;

- 8-Megapixel CCD for images up to 3264 x 2448
- 28-200mm equivalent f/2.4-3.5 7x zoom
- 15 - 1/4000 sec shutter speed

#### Building heights:

2D building foot prints is extruded by using building heights. To measure the building heights TruPulse professional rangefinder is used. This is a compact and lightweight laser instrument that calculates the height of the target by using its height routine.

#### Digital transportation network data, their hierarchies, average speeds and the location of emergency health services::

The 2005 year transportation network data, their hierarchies, average speeds and the point location of emergency health services are obtained from Eskisehir municipality and used in calculating the emergency state health service accessibility costs from health services to buildings in Cumhuriye quarter (Figure 2).

## 4. METHODOLOGY

### 4.1 Accessibility modeling methodology

At its simplest level, qualitative descriptions can be used to define the accessibility of a location. Terms such as “good

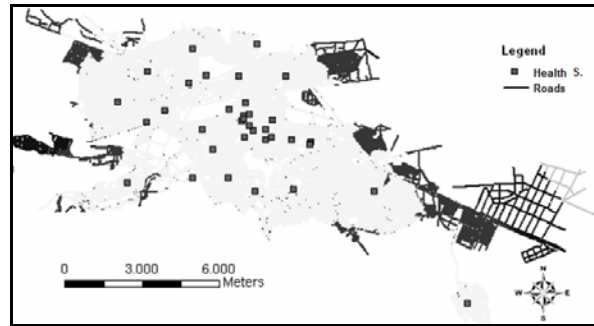


Figure2: Location of emergency health services and transportation network data

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 basically three accessibility measuring techniques:

- a) Zone based technique,
- b) Isochronal technique,
- c) Raster based technique,

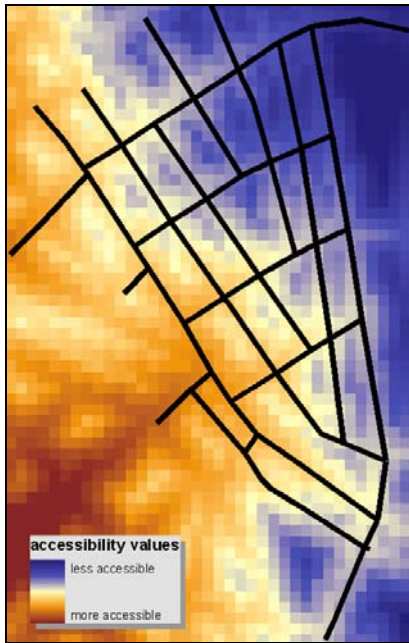
The best approach for measuring techniques of accessibility does not exist. Different situations and purposes demand different approaches (Makrí and Folkesson, 1999).

In this study, raster based emergency service accessibility is used, as it is more suitable for creating a continuous accessibility model and visualizing it in a 3D environment.

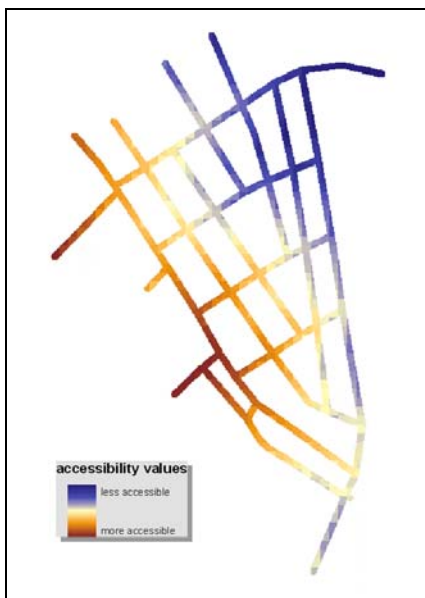
#### The following steps are used for calculation of emergency service accessibility costs:

- Average speeds extracted from Eskisehir metropolitan municipality travel survey is reduced by 30% assuming that in disaster situations there will be considerable amount of decrease in the speeds.
- The vector transportation network is converted to raster and costs for each pixel are calculated based on average speeds 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.

Cumhuriye Quarter raster based emergency service accessibility analysis results could be seen in Figure 3. Muddy colors represent less accessible places than flaming colors. With respect to the analysis results north-east part of the quarter is the least accessible and south-west part is the most accessible areas of the quarter. About 1 minute accessibility difference is occurred in the study area.



(a)



(b)

Figure 3: Emergency service accessibility analysis results, continuous grid representation (a) and results masked with road network (b)

#### 4.2 3D City Model Creation Phases

Concerned with the city model creation phases, two different model creation environments could be mentioned. First, for the creation of the 3D city model CAD functions are used. And the generated city model and the accessibility results are integrated in GIS environment. Today the integration of CAD and GIS visualizations methods could be possible by using new import functions from CAD based model environments to the GIS environments.

GIS intrinsically use tabular and geographic data. This characteristic is the main superiority of GIS environment than CAD. On the other hand, CAD environment provides advanced visualization properties. This advanced visualization improves decision maker's perception level and this property constitutes the main benefit of the CAD.

The 3D city model in CAD provides a Virtual Reality (VR) environment. In order to create VR environments, first of all digital 3D scenes have to be constituted. For digital 3D city scenes creation 2D vector data (building foot prints and road) are used. This foot prints is extruded by using building heights (Figure 4), measured with the laser rangefinder by field survey.

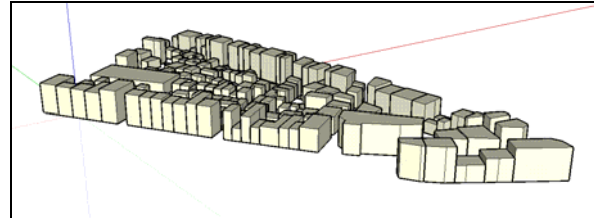


Figure 4: Building solid model

After the solid CAD model is created by using building heights; the façade images, collected from the field by using a digital camera are utilized to map for the external surfaces of the 3D solid buildings. Different aperture values are used to gain homogeneous exposures of all images. Several difficulties are also faced during field data collection, which is listed as:

- Difficulty of taking photographs of some buildings which have official secrecy (i.e. police and military buildings),
- Dense and tall buildings in narrow roads, with perspective distortions on the façade images.

The collected images need to be corrected for geometric, atmospheric, radiometric and angular distortions. For this purpose post processing techniques are applied to remove these distortions.

Before mapping the field images to the building surfaces, to improve the image quality and remove the distortions, image rectification functions are applied (Figure 5). Depending on the 3D city model generation aim, the accuracy level of the model varies. Because of the fact that our study did not have any photogrammetric goal, there is no photogrammetric network study for each façade image. Each image is manually rectified to be a façade image for 3D city model. After image rectification operation, four corner points of images are used for coordinate system transformation of the related façade image.

After image rectification operation, four corner points of images are used for coordinate system transformation of related façade image. Applied image rectification functions could be listed as; cropping, contrast enhancement, rotating and perspective adjustment. Figure 6 represent the result 3D city model, extruded buildings and mapped façade images.



Figure 5: (a) Before and (b) after image rectification of an example façade image from the study area



Figure 6: General view from the 3D city model

#### 4.3 Integration of the city model and the accessibility results

The accessibility analyses results can be visualized in two ways: The first one is continuous grid representation and the second one is the continuous grid representation with masking of road network. These two representations are integrated with generated 3D city model to improve the decision makers' perception. Figures 7, 8 show the integration result of accessibility analysis and 3D city model.

Continuous grid accessibility result could be suitable for 2D visualizations. Its continuous surface is penetrated with buildings.

For the 3D walk-through views, accessibility results masked with road network give more drastic effects. This representation seems like facing material for road network.

### 5. CONCLUSIONS AND FUTURE WORKS

Effective visualization properties could play important roles in all fields of the disaster risk reduction framework. Emergency state health service accessibility reflects emergency organization's readiness to respond to an emergency and this is an effective indicator for decision makers in a spatial disaster decision management construction.

Concerned with the city model creation phases, two different model creation environments could be mentioned. Firstly, for the creation of the 3D city model CAD functions are used. Then, the generated city model and the accessibility results are integrated in GIS environment. Both environments have their pros and cons. GIS intrinsically use tabular and geographic

data. This characteristic is the main superiority of GIS environment than CAD.

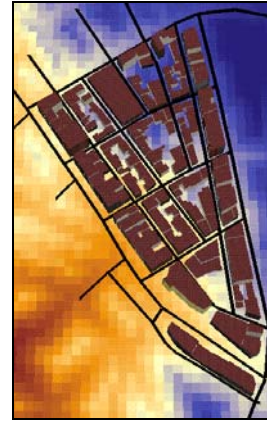


Figure 7: 3D city model with the continuous grid emergency state accessibility results.

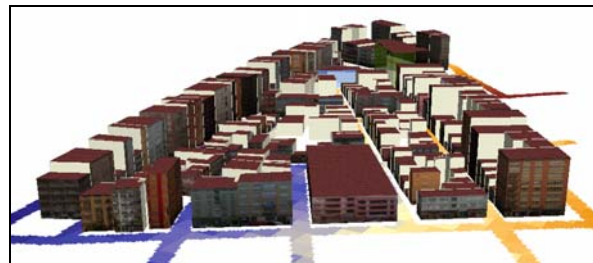
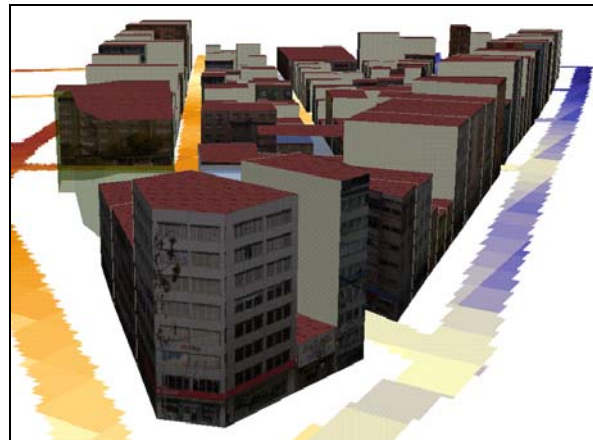


Figure 8: Views from 3D city model with masked emergency state accessibility results.

For the 3D city modeling integration of CAD and GIS visualizations will be searched in future studies. Other disaster vulnerability indicators like physical or socio-economic vulnerabilities and visualization of all these indicators in a spatial database will also be searched in the future studies of the authors.

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