Using GIS for Defining Public Services
Catchment Area at Jeddah City

Abdulkader A Murad
Department of Urban and Regional Planning, Faculty of Environmental Design
King Abdulaziz University, P O Box 80210, Jeddah- 21589, Saudi Arabia
E-mail: amurad@kau.edu.sa

Abstract

The aim of this paper is to build a Geographical Information Systems (GIS) application for evaluating spatial locations of public services in Jeddah city, Saudi Arabia. The first part of the paper discusses previous studies that have applied GIS for planning public services worldwide. Meanwhile, the second part of the paper discusses the created GIS application which covers two types of GIS-based public services catchment models called customers distribution catchment area and drive time catchment area. The former is produced based on actual location of service visitors, and the latter is created using network analysis modeling technique. ArcGIS software was applied in this application and used for building these catchment models. Each catchment area model can be used further for market analysis of public services and for services demand identification purposes.

Keywords: service Catchment Area, GIS, services planning, Drive Time

Introduction

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth’s surface. GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships. GIS can use any information that includes location. The location can be expressed in many different ways, such as latitude and longitude, address, or ZIP code. Many different types of information can be compared and contrasted using GIS. The system can include data about people, such as population, income, or education level. It can include information about the land, such as the location of streams, different kinds of vegetation, and different kinds of soil. It can include information about the sites of factories, farms, and schools, or storm drains, roads, and electric power lines (Clarke, 1997) (Fig 1).

Geographic Information System is rapidly being developed and applied in a no-limit list of applications. Planning of utilities and services have greatly benefited from this very effective and efficient technology. In 2008 a study was conducted to identify the Quality of the Urban Environment around public housing buildings in Montreal, Canada an objective approach based on GIS and multivariate statistical analysis was used. To qualify the immediate urban environment around Montréal’s public housing buildings in its complexity, a methodological approach based on the use of several spatial databases in GIS was proposed: (1) the Montréal public housing database, (2) individual census data for the Montréal CMA, (3) a satellite image, (4) a land use map, and (5) location data on a series of public and private services and facilities. Use of these spatial data enabled the researchers to identify various combinations of advantages and disadvantages within the urban living environment in which Montréal’s public housing buildings have been located, according to three dimensions: the
social environment, the physical environment, and the accessibility of services and facilities (Apparicio et al., 2008).

A review conducted in 2007 in Alberta Canada evaluated the usefulness of GIS health promotion and public health, the contribution of this literature review generated a broader understanding of how GIS-related methodological techniques and tools developed in other disciplines can be meaningfully applied to applications in public health policy, promotion, and practice (Nykiforuk and Flaman, 2009). In the same year Murad, 2007, created a GIS application to cover three main health planning issues in Jeddah Saudi Arabia which are distribution of health demand, classification of hospital patients and the definition of hospital service area, each of which was covered using several GIS functions including network analysis and overlay analysis. The aim of the study was to help health planners in evaluating the spatial distribution of hospital demand and defining hospital service area (Murad, 2007).

Geographers, planners and public health officials are increasingly interested in working with community partners, organizations, and residents to engage in action oriented research designed to impact positive community change. One growing area of community-based research focuses on geographic examinations of aspects of social service accessibility. In 2013, GIS was used in a site suitability analysis of social services in Atlanta, Georgia, by communicating with multiple community partners in an urban area to examine the spatial distribution of social service providers. Public Participation GIS framework was utilized to create shared community resources and research deliverables for community partners, in addition to using GIS TO identify potential new locations for social service providers that can meet the unmet demands for such services (Case and Hawthorne, 2013).

GIS was used in several studies to identify services in Saudi Arabia, in 2001 a study titled “Application of GIS in Transportation Planning: The Case of Riyadh, the Kingdom of Saudi Arabia” relied on GIS to identify deficient facilities (i.e., tolerable, moderate, moderate to heavy and heavy road deficiencies) in the vital areas within Riyadh’s ring road. The deficiency analysis process was utilized to highlight streets where demand exceeded capacity. Moreover, GIS was integrated into the travel demands analysis process is to identify future areas of congestion. In 2009, GIS was used to identify the market size of retail centers, the demographic profile of the retail customers in Jeddah, Saudi Arabia. Several GIS functions and tools, such as address geocoding, feature query and identification, proximity and overlay analysis, were used (Murad, 2009).

Methods

ArcGIS software is used by the presented study to define public services supply and demand locations. This data is collected on a city district level. Therefore, a GIS coverage is digitized at the Arcmap application (which is one of the main ArcGIS applications) using polygon drawing tools that are located at the editor menu. After creating the required city district polygons, the following step was to enter the collected attributes about public services supply and demand. These include demand size, demand age-sex, and demand utilization types. All of these data are linked to the demand coverage and used for public services demand classification.

One of the main issues of the presented application is related to using GIS for defining service area. This issue is covered using network analysis which is one of ArcGIS modules that facilitates the modeling of spatial networks and can be used to determine the efficient paths and travel sequences. This module is used at the present study for determining and calculating drive time to services at Jeddah city. In general, a network is a system of interconnected linear features through which resources are transported or communication is achieved. The network data model is an abstract representation of the components and characteristics of real world network systems (Esri, 1992). The key to producing successful network models is in understanding the relationship between the characteristics of physical network systems and the representation of those characteristics by the elements of the network model.
Each network coverage is formed with several elements such as Links, Nods, Stops and Turns. These elements are used together to perform the required GIS functions. Therefore, before using any of network analysis functions it is necessary that all users should understand the process of these elements and make sure that the parameters of these elements are satisfied. One of the important elements that need to be covered before calculating network travel time is called the link impedance which refers to the cost associated with traversing an entire network link. The presented study has calculated travel time for each arc based on the average driving speed along each arc and based on the arc length. The resulted cost is saved as an arc attribute and used during the process of creating drive time catchment area public services.

The application geo-database falls into the three major vector data model types:

A Line data. This type of data is stored in GIS as a series of ordered X, Y coordinates and the segments of a line can be straight, circular, elliptical or splined (Zeiler, 1999). Road network of Jeddah city is an example of line data model that is created for the present study. This coverage has several attributes including road length, type and speed.

B Point Data. GIS softwares store point data as single X, Y coordinate with several attributes. This type of data model is used in this study to represent location of service centers and services customers with attributes including district name and purpose of services visits.

C Polygon data. This type of features is modeled at GIS as a series of segments that enclose an area and form a set of closed area (Zeiler, 1999). City districts coverage is an example of this type of GIS data that is created for the present study. This coverage includes attributes such as district name and area, and size of population and households for each district.

All of the above data were originally in a non-digital format. Therefore, manual digitizing and keyboard entry methods are used to convert all of these data into GIS digital formats.

Results

Customers-based Services Catchment Area

GIS has different tools which can be used by services developers and planners for the purpose of identifying and analyzing catchment area. This part of the study will discuss how to use these tools for a selected public service location which is a retail center located in Jeddah city, Saudi Arabia (Fig. 2). This center has 179 shops with a total of 25,000 sqm GLA, and provides 1500 car parking space.

There are several GIS methods that can be used for defining the primary catchment area of services. The most common one is related to customers spotting. Several studies have used this type of GIS function for defining service catchment and for demographic analysis (Reid, 1993, King, 1993, Moloney, et al, 1993, and Murad, 2003). For example, Jones et al, 1995, have defined primary catchment areas for retail centers based on the nearest 60% of retail center consumers. In order to define the primary catchment area of the selected public service, a survey is made on a sample of customers visiting this service location. The survey is made using a questioner that shows the address of customer, reason for visiting this center and the social economical background of each customer. All of the collected survey questionnaire are captured into the GIS using the address geo-coding function. This function use address information in the attribute table of a reference data (e.g. street network) to figure out where to locate address points (Ormsby et al, 2001). The output of this function is either a shape file or a geo-database having feature class of points with all the attributes of the address table, some of the attribute of the reference data and optionally some new attributes, such as the X, Y coordinates of each point (ibid).

Once the location of service customers are defined (Fig. 3), the following task was to select the nearest 60% of service customers. This was achieved using Query builder, select by them, and Dissolve functions.. Fig. 4 shows the output of this analysis which describes the primary catchment
area of the selected center. This catchment includes districts such as AlKhaldeyah at the west, AlSafa and Alrehab at the east, Al salamah and AlRabiayah at the north and Alandalus at the south of Al-Dawly center. One of the main uses of this catchment area is that it shows the city districts that are producing the major demand to this service location and it also shows the parts of the city that are less attracted to it e.g. Albalad district or Aljameah district.

Drive Time-based Services Catchment Area

GIS software provide various tools which can be used by services planners for defining catchment area. For example, ArcGIS software can define the following type of catchment/trade areas:

a. simple ring - created around store using a specified radius.

b. data-driven ring - created around store using a radius proportional to a store characteristic such as total sales, square footage, and GLA.

c. equal competition - creates trade area boundaries halfway between each store and its neighboring stores (Thiesen polygons).

d. drive time - defines areas accessible along the street network based on a specified maximum travel time or distance.

e. gravity model - predicts the sales potential of an area based on distance competition attractiveness factors, and consumer spending.

f. threshold ring - creates rings containing a specified population or household count (ESRI, 2004).

This part will discuss one of these catchment area types which is called the drive time catchment area that defines catchment area of any facility on a street network data based on the expected travel time to such facility. It is considered as useful technique for defining catchment area of emergency services where time to reach a location is very critical. One of the potential applications of this technique is related to retail centers which is considered by the present paper.

In order to create a drive time model for the selected service, network analysis module of ArcGIS is used which facilitates the modeling of spatial networks and which can be used for determining efficient paths and travel sequences. The network data model of ArcGIS consists of network links, network nodes, stops centers and turns. The network links are modeled as arcs. Each arc in the network coverage can have what is called link impedance which is referred to the cost associated with traversing an entire network link (ESRI, 1992). Distance, time, money or combinations of all are examples of costs that can be used as linked impedance. The present study has calculated travel time along every network link of Jeddah city and save it at the impedance attributes file. This calculation takes into account different road speeds which varies according to road type e.g. major road has 80 km speed average and local road has 30 km speed average. The calculated time cost also takes into consideration the network traffic over major road which gives them higher cost than other road of Jeddah city.

Once time to travel is calculated for every arc and saved as an impedance item, the following step was to decide about the desired travel time to the service location. A 20 minutes drive time catchment area is created and presented at Fig. 5. This output defines the total catchment area of the selected service.

Conclusion

Using GIS for services centers catchment area definition is one of the potential GIS applications in urban planning field. A service center was selected as a case study, and GIS is used to model its catchment areas. Two main types of catchment area are produced. The first one is created based on the actual distribution of customers. It is founded that there are some city areas that fall within the service catchment area but producing low demand. There areas should be reached first by service developers.
of the selected center to find out the reasons for not producing high demand to this center. The second type of catchment are model is created based on drive time technique. This model is useful for defining the city parts that can be reached within 20 minutes from the selected service.

References
Figure 1: GIS layers

source (Clarke, 1997)
Figure 2: Location of the selected service center at Jeddah City
Figure 3: Customer Distribution of service center
Figure 4: Primary Trade area of service Center
Figure 5: A 20-minutes Drive time Trade area