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An analytic network process approach for locating undesirable facilities: An example from Istanbul, Turkey

Gülfem Tuzkaya*, Semih Önüt, Umut R. Tuzkaya, Bahadır Gülsün

Department of Industrial Engineering, Yildiz Technical University, Barbaros Street, Yildiz, Istanbul 34349, Turkey

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Abstract

Locating an undesirable facility is a sophisticated problem, for the evaluation procedures involve several objectives and the solution to the problem calls for some compromises to be made between probable conflicting criteria. This paper addresses the problem of undesirable facility location selection using the analytic network process (ANP), a multi-criteria decision-making technique. The ANP technique enables us to consider both qualitative and quantitative criteria as well as the interdependencies and feedbacks. A number of criteria (benefits, opportunities, costs and risks) and their sub-criteria are considered for siting a new facility with which this study has dealt. The questions of what criteria would be considered and what the interdependencies between these criteria and their weights would be were discussed and determined via interviews with some competent authorities of the Istanbul Municipality and of two environmental organizations. Four representative locations were evaluated and the most convenient one was selected. This was followed by the sensitivity analyses of the results.

Keywords: Undesirable facility; Location selection; Multiple criteria decision making; Analytic network process

1. Introduction

A location problem deals with the choice of a set of points for establishing certain facilities in such a way that, taking into account different criteria and verifying a given set of constraints, they optimally fulfill the needs of the users (Perez et al., 2004). Facility location models are used in a wide variety of applications. These include, but are not limited to, locating warehouses within a supply chain to minimize the average time to the market, locating hazardous material sites to minimize exposure to the public, locating railroad stations to minimize the variability of delivery schedules, locating automatic teller machines to best serve the bank customers, and locating a coastal search and rescue station to minimize the maximum response time to maritime accidents (Hale and Moderg, 2003).

Facilities may be categorized in a general fashion as being either desirable, in which case they should be close to the users or undesirable when they should be far away (Rodriguez et al., 2006). Such facilities as garbage dump sites, landfills, chemical plants, nuclear reactors, military installations and polluting plants are undesirable for the surrounding population, which avoids them and tries to stay away from them (Colebrook and Sicilia, 2007). Undesirable facilities can be distinguished as noxious and obnoxious facilities (Erkut and Neuman, 1989). Noxious facilities, such as nuclear power plants or hazardous waste storage sites, involve a potential risk to public health and safety. Obnoxious facilities are less of a health risk, but are not necessarily more desirable than noxious facilities. They can be defined as facilities that can be useful to the whole population but that generate negative externalities in the surrounding environment (Flahaut et al., 2002).

Selection of the appropriate undesirable facility location is a complex problem and requires an extensive evaluation process considering with the requirements of municipal, governmental, environmental regulations, etc. Inappropriate

*Corresponding author. Tel.: +90 212 2597070 2349; fax: +90 212 2610674.
E-mail address: gbiyik@yildiz.edu.tr (G. Tuzkaya).

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and inefficient selection causes several problems, such as social opposition, environmental problems, cost increases, etc. Selecting the undesirable facility locations is one of the most complicated problems for local governments because of the availability of several potential locations for a certain type of facility in general. The determination and evaluation of positive and negative characteristics of one location relative to others is a difficult task. The increase in the popularity of using environmental design criteria in municipal planning has brought about the need to fully identify the principles to determine the best location of this kind of undesirable facilities. This environmental management issue has received considerable attention because of its applications in urban and rural infrastructure planning, industrial development planning as well as health, housing, transportation and agricultural schemes. Furthermore, many potential criteria, such as closeness to residential area, distance from the main roads, investment costs, climate, land slope, etc. must be considered in the selection procedure of an undesirable facility location. Therefore, undesirable facility location selection can be viewed as a multiple-criteria decision-making (MCDM) problem.

Many researchers have studied to determine the suitable location and the transportation routes in the location selection problem of undesirable facilities using mathematical and heuristic models or MCDM methods. Decision making processes where multiple conflicting criteria are involved can be classified into two types: (i) multiple objective problems, which have an infinite number of feasible alternatives and (ii) multiple attribute problems, which have a finite set of alternatives (Cheng et al., 2002). The first study pointing out the multiple objective nature of the problem has been proposed by Erkut and Neuman (1992). In this study, three objectives were considered to minimize total costs, to minimize total opposition to nuisances and to maximize equity. Similar to these objectives, there were some other most common objectives as the minimization of cost, the maximization of distance between facilities and customers and the equitable treatment of customers, i.e. the equitable distribution of the disutility imposed by the facilities (Avella et al., 1998).

Some other studies utilizing multiple objective techniques are as follows: Giannikos (1998) proposed a multiple objective model for locating disposal or treatment facilities and transporting hazardous waste along the links of a transportation network. In this study goal programming is used for the satisfaction of the multiple objectives. Rakas et al. (2004) developed a multiple objective programming model utilizing from fuzzy linear programming for determining undesirable facility locations. Alumur and Kara (2007) proposed a model for hazardous waste location-routing problem and a large-scale implementation of the model in the Central Anatolian region of Turkey. Al-Jarrah and Abu-Qdais (2006) proposed a methodology for municipal solid waste landfill siting using fuzzy sets. In this study, a set of criteria has been chosen for the selection procedure. Some of the other authors who have utilized multiple objective techniques in the undesirable facility location analysis are as follows: Revelle et al. (1991), List and Mirchandani (1991), Stowers and Palekar (1993), Erkut and Verter (1995) and Current and Ratick (1995).

Multiple attribute decision making techniques has also been widely used for the undesirable facility site selection problem. Salminen et al (1998) presented an analysis of the use of ELECTRE III, PROMETHEE I, II, and SMART decision aids in the context of different real applications to environmental problems such as land use planning problem, waste treatment facility location problem, and the choice of a municipal solid waste management system in two districts of Finland. Cheng et al. (2002) addressed the need for using MCDM methodologies in solid waste management systems because these systems can have complex and conflicting impacts on different stakeholders. This study compares and attempts to rank simple weighted addition method, weighted product method, TOPSIS, cooperative game theory and ELECTRE methods. Mahler and De Lima (2003) proposed a methodology for assessing and ranking a predefined universe of objects to assist in the selection of suitable areas for the construction of sanitary landfill. This study was based on value analysis and fuzzy eigenvector method. Vasiloglou (2004) presented a decision-making process for the potential location of new landfill areas with the wide community participation and acceptance. This study proposed a comprehensive set of criteria for the candidate landfills. In addition to these studies, Takeda (2001), Hung et al. (2006) and Cram et al. (2006) provided a view point for the use of multi-attribute decision making techniques in the related research area. Also, several articles presented comprehensive literature review such as Erkut and Neuman (1989), Boffey and Karkazis (1993) and Avella et al.(1998). In addition to the above-mentioned techniques, Sener et al. (2006) used geographic information systems (GIS) for landfill site selection. In this study the GIS and MCDA are integrated. According to Sener et al. (2006) this integration is a powerful tool to solve the landfill site selection problem, for GIS provides efficient manipulation and presentation of the data and MCDA supplies consistent ranking of the potential landfill areas based on a variety of criteria. Malczewski (2006) is a rich source as far as GIS-based MCDA literature goes.

As mentioned earlier in this study, it is very difficult to develop a selection criterion that can precisely describe the preference of one location over another. Many precision-based methods for undesirable location selection have been investigated. Most of these methods have been developed, based on the concepts of accurate measurements. However, most of the selection parameters cannot be given precisely and the evaluation data of undesirable facility locations suitability for various subjective criteria is usually expressed by using the decision maker's (DM) judgments. For example, most of the cost-related criteria like the construction cost of a facility can be measured or estimated accurately. On the other hand, when such social and