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A Review on Multiple Criteria Undesirable Facility Location Problems

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ABSTRACT

This paper will review the research conducted on multi criteria location problem for undesirable facilities in two separate groups. First, multi attribute studies to select appropriate site for undesirable facilities such as landfill and treatment center are reviewed. Thereafter, some of the important and common criteria and sub-criteria to select site for landfill from reviewed studies are derived. Second, multi-objective model to locate undesirable facilities are surveyed. Also, different objectives that are considered usually in location undesirable facilities are extracted. This study can help decision makers and researchers to know significant criteria in field of undesirable facilities location problems. Also, it can help to have knowledge about solution methods to tackle multi criteria problem.
KEYWORDS: undesirable facility, location, multi-objective, multi-attribute

1. INTRODUCTION

Facility location can be considered a one-hundred years old science. Even though it is old, we believe that applications of these models are getting more attractive. In general, there are two different groups of facilities. First group is desirable facility that should be close to demand centers and customers such as hospital and fire station. Second group are undesirable facilities, people want these facilities to be located far away from their area such as landfills and treatment centers in waste management system. Undesirable facilities also are divided into noxious and obnoxious facility [1]. Noxious facility have hazard to the health and human life, and obnoxious facilities have bad effect to the human lifestyle and environment.

Decision making plays an important role in management science. Most of the managers encounter conflicting criteria to make decision. Multiple Criteria Decision Making (MCDM) is eminent class of operation research approaches for responding manager needs. MCDM is a tool to model the real world problems with multiple conflicting criteria. In recent years, MCDM has been utilized by researchers in the field of location to select proper sites for undesirable facilities. These methods help decision makers to reduce harmful impacts on environment and human health.

There are two different contexts for MCDM problem: first, Multi Attribute Decision Making (MADM) and second, Multi Objective Decision Making (MODM). However, the basis of MADM problem is a number of alternatives described by various and usually conflicting attributes. Different techniques have been introduced to meet MADM problems such as Elimination and Choice Expressing Reality (ELECTER), Simple Additive Weighting (SAW), Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Idea Solution (TOPSIS), and VIKOR[2]. On the other hand, MODM is a helpful tool for decision makers to deal with number of conflicting objectives, which must reach suitable level of results with regard to the defined constraints. MODM problem have different parts that are common in all of them, these parts are as follow:

a) A group of quantifiable objectives
b) A group of specified constraints
c) A process of exploring the available tradeoffs process

Facility location mathematical model are classified as p-median problem, p-center problem, unlimited facility location problems and exponential allocation problem [3].

Different approaches exist to solve multi objective problems. These approaches are explained in the coming section:

- Scalarization method: to combine multi-objectives problem into single objectives and solving model with new single objective
- Pareto optimal approaches: The numbers of alternatives are reduced to an optimal set (pareto frontier)

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• Complicated problem in first and second group, also can be solved by evolutionary algorithm such as Multi Objective Genetic Algorithm [4], Elitist Non-Dominated Sorting Genetic Algorithm [5]. There are various algorithms to tackle MODM that they mentioned at [2].

In this paper a review from multi criteria problems related to undesirable facility location are surveyed. The remaining of this paper is arranged as follow, in section 2, multi attribute studies to select suitable site for undesirable facilities with Performed methods to solve these problems are presented. Also, a classification is suggested for grouping important criteria and sub-criteria to select site for undesirable facility. In section 3, a survey on multi-objective papers to locate undesirable facilities and routing waste between these facilities are provided. In addition, the objectives that are usually considered for these problems will be concluded. Section 4 is devoted to a conclusion for this study.

2. Multi Attribute to select site

Multi- objective decision making is a valuable tool in management science. Here, a briefing of using this method in previous studies to select a location for undesirable facilities has been presented.

Lahdelma et al.[6] have used 17 criteria for establishing treatment centers which these criteria are chosen through analysts and supervisory group by some public meeting. They considered negative and positive criteria groups such as population, ground water, surface water and business. They proposed the stochastic multi-criteria acceptability analysis with ordinal criteria method (SMAA-O) to locate a treatment facility. SMAA-O has used simulating suitable mapping in ordinal and cardinal scale to achieve ordinal information to cardinal information. Mahler and Sant'Anna de Lima [7] believe, there are numerous aspects that should be considered to select a sanitary landfill site, thus geo-environmental, technical, economic and sociopolitical factors have been utilized with considering 13 related attributes. They proposed using hierarchical fuzzy system model to select landfill area based on qualitative attribute because of uncertainty in relevant attributes to choose this place. Al-Jarrah and Abu-Qdais [8], also proposed a system for locating new landfills, they have taken into account some additional criteria like economy, safety and socio-cultural features. They have suggested using intelligent system for municipal solid waste landfill location. Their method utilized fuzzy inference system to encode opinion of environments experts to rank selected site, one of the important features of this method is flexibility, which means new data about landfill site can inter to the data base. Norese [9] performed a multi criteria analysis to make decision to locate waste disposal site and incinerator site in Italy. In their study, 45 decision makers worked together for 16 months to recognize important criteria, which have effect on locating incinerator and waste disposal site. In this way, they introduced three dimensions include of: 1) local traffic conditions and inherent consequence 2) social equity 3) natural and social environment. They utilized some criteria for each dimension to select disposal site. They also used technical aspects, local development, environmental effects & self-sufficiency and social equity dimension to select incinerator site with considering some criteria for each dimension. ELECTER is utilized by Norese [9] for selecting proper site to locate treatment center and disposal site. This method evaluates chosen criteria for various sites.

Önüt and Soner [10] mentioned in their paper, site selection in waste management is a difficult work due to complexity of site selection subject and conflicting between criteria. Therefore, a MCDM method is appropriate to select transshipment site. They considered four group wastes include of domestic solid waste, construction debris and rubble, medical solid waste and hazardous solid waste. They used five criteria based on interview with authorities. They also believe Solid waste area needs to consider tangible and intangible conflict criteria together. In this way they have utilized a combination of AHP and fuzzy TOPSIS to measure weights of criteria and to locate a transshipment area for solid waste respectively. Tuzkaya et al.[11] also believe sitting undesirable facilities is complicated. Hence, they have taken into account qualitative and quantitative criteria together. In addition, they answered these questions by interviewing experts that criteria should be included and what is the suitable weight for these criteria. Khadivi and FatemiGhomi [12] believe to select criteria for illustrating priority of a location to another one has complexity; therefore quantitative factors are considered in their proposed method. They proposed using Analytical Network Process (ANP), which can integrate quantitative factors with subjective data, and also a Data Envelopment Analysis (DEA) to transform managerial information into a suitable quantitative input for decision making tools.

Wang et al. [13] have used qualitative as well as quantitative factors; their proposed method has been used in geographical information system (GIS) to select an appropriate disposal site based on spatial data with environmental and economic criteria. Each criterion has been graded between 1 to 5, the best choice can take grade five and the worst is considered one. AHP method has also been utilized by them to calculate criteria weights to find a suitable landfill site on the basis of evaluating weighted criteria. They also used geographical information system to display spatial data too. Using multi-criteria decision method based on geographical information system(GIS) also presented by Gorsevski et al.[14].They proposed using environmental criteria with 9 sub criteria and also, economic

criteria with 3 sub criteria with fuzzy standardization membership function to transform trends of linear and nonlinear criteria. They utilized GIS based on multi criteria decision analysis procedure to use AHP for elicitation attribute weights. They performed Ordered Weights Average (OWA) method to produced various decision option to respond multiple center interaction uncertainty. Economic and environmental factors, also, have been considered by Cheng et al. [15]. They used these criteria with some sub-criteria to landfill selection site in Canada. They compared five techniques together including: ELECTER, TOPSIS, Cooperative Game Theory (CGT), weighted product method (WP) and Simple Weighted Addition method (SAW) to select landfill location. At the end, they derived various method solution are incompatible, hence using more than one technique has been proposed. Yesilnacar and Cetin [16] applied various methods to locate hazardous waste landfills site. They used sit screen study for this problem and considered some factors such as geology, soil, transportation and climate to sit hazardous waste landfills site.

Erkut and Moran [17] believed qualitative, quantitative economic and engineering criteria are important to locate a municipal landfill. They considered environmental, social and economic criteria with their sub criteria to find suitable area for landfill. This decision making model is solved by AHP and applied in Canada.

The presenting (Table1) conclusion can be drawn from reviewed papers to collect common and significant attributes in selection of landfill site areas. All criteria are classified in four main groups, 1) environmental and critical 2) economic 3) social and political 4) infrastructure and foundation. We also specify some sub-criteria for each criterion. Most of these criteria are common between different centers in waste management such as landfill and treatment centers. The inquired criteria can be chosen by decision makers for various facilities in different condition.

Tab 1.Significant criteria to select proper site for landfill area

criteria	Sub-criteria	criteria	Sub-criteria
Environmental and critical	Geology	Economic	Land cost
	Topography		New job opportunity
	Hydrology		Extensibility
	Hydrogeology		Land value drop
	Landfill life time		
	Natural deposit of soil for daily cover	Social and political	
	Climate		Legislation
	Land slope		Impact on local traffic
	Soil hydraulic conductivity		Total opposition
	Land altitude		
	Distance from urban and rural area	Infrastructure and foundation	
	Distance from tourist and recreation area		Infrastructure like energy and telephone
	Distance from military area		Proximity to motorway and railway
	Distance from historic and religious area		Distance from airport
	Distance from water supply resources		

3. Multi-objective for location and location-routing waste

In order to review MCDM papers, we have attempted to reconsider MODM studies related to waste facility location or undesirable facility in this section. Erkut and Neuman [18] presented a multi-objective mixed integer model for location undesirable facilities .This model, has three objectives: minimize of total cost, minimize of total opposition and minimum of maximum disutility to any person, an enumeration algorithm has been proposed to find set of efficient solution. Wyman and Kuby [19] developed a mixed integer model with three objectives: cost minimization, risk minimization and also minimize of maximum inequity for toxic facility. Melachrinoudis et al.[20] presented a dynamic location model to sit landfills site. Their model has four objectives including operation cost minimization, minimize of total risk on human population, minimize of total risk on nonhuman population and minimize of disequity. They used a weighting method to generate efficient solution by HYPER-LINDO. Rakas et al.[21] proposed a deterministic multi-objective model for undesirable facility location. They utilized two objectives including minimizing total cost by taking into account transportation and investment cost and minimizing of population opposition. They also proposed an extension to their model by considering fuzzy parameter for amount of produced waste per person. They also used, sum weighted method to combine two objectives into one objective to solve model. Alçada-Almeida et al. [22] used mixed integer programing with Cost and risk objectives to locate incinerators. They utilized GIS to analyze facilities site by spatial maps and Interactive Decision Support System (IDSS) to select suitable area for incinerator. Srivastava and Nema [23] developed a comprehensive fuzzy

parametric programing with two objectives including minimizing environmental risk and cost. They considered multi period system to locate solid waste facilities such as transportation station, recycle center, compost plants, incinerators and landfills. Some parameters are uncertain in their model, including amount of waste and operation capacity of each facility. Krarup et al.[24] believed, some location facility models only consider pull objective, location facility close to demand points, and in some models only use push objectives, location facility far away from population center. Therefore, they developed a set of push-pull models to locate facilities with semi-obnoxious features. They utilized the enumerative methods to solve problems because their models are NP-hard. Melachrinoudis and Xanthopulo [25] developed a nonlinear bi-objective model to locate a new semi-obnoxious facility in bounded region. First objective is to maximize minimum of Euclidean distance from all demand points. Second objective is to minimalize total transportation cost. They use an algorithm to convert two objectives to a single objective parametric nonlinear program. Plastria and Carrizosa [26] proposed a model with two criteria to locate undesirable facility. First criterion is to maximize radius of influence risk. It is a distance from undesirable facility that has harm effect on population. Second criterion is to minimize covered population by undesirable facility. Semi-obnoxious facility is kind of undesirable facility that has special undesirable effect on their environment. In this way, Melachrinoudis [27] developed a bi-objective model to locate a new semi-obnoxious facility between existing facilities. The author, used maximin and minisum objectives. Maximin objective is to maximize the minimum distance between two facilities and minisum objective is to minimize total transportation cost.Karaskal and Nadirler [28] applied a bi-objective model to locate semi-desirable facility. Two objectives of their model are to minimize weighted distance from facility and demand center as well as to minimize cost of service for all facilities. They also suggested an interactive geometrical branch and bound algorithm to solve model. Heydariand Melachrinoudis [29] proposed a location model for a single semi-obnoxious facility. They considered two objectives: to minimize total transportation cost; to minimize undesirable of new semi-obnoxious facility. Coutinho-Rodrigues et al. [30] also developed a bi-objective model to locate semi-obnoxious facilities. Total investment cost and dissatisfaction minimization are objectives for their study. They applied pull and push factors in dissatisfaction objective. They proposed, using a constraint method to solve model and generating non-dominated supported and unsupported solutions.

There is also a large volume of papers using MODM for location- routing simultaneously in the field of waste management and locating undesirable facility. Giannikos [31] developed a multi-objective model for hazardous waste transportation and sitting treatment facilities. They considered four objectives for this model; to minimize total operating cost; to minimize total perceived risk; equitable distribution of risk among population centers; equitable distribution of the disutility caused by the operation of the treatment facilities. They proposed, a goal programming to solve model. Alumur and Kara [32] presented a new locating-routing mathematical model for hazardous waste. Minimization of total cost and transportation risk are objectives of their model. They considered treatment centers and disposal centers location and also routing different type of hazardous waste to compatible treatment centers and disposal centers in their proposed framework. They devoted percentage of recyclable hazardous waste, at both of generation nodes and after passing treatment centers. To solve model, they combined two objectives to one objective with scalarization approach due to different unit of cost and risk objective. Alumur and Kara [32] model has been developed by Samanlioglu [33] with three objectives , minimization of total cost include transportation and operating cost, minimize of transportation risk and minimize of site risk for location-routing industrial hazardous waste. In addition, he located recycle centers and amount of transported hazardous waste between recycle centers and disposal centers. The author has developed a lexicographic weighted Tchebycheff and used Cplex software to solve model. Jacobs and Warmerdam [34] presented a multi objective model with cost and risk objectives. This model can be applied for routing hazardous waste and locating related facility. The formulation of this model considered transport, storage and disposal hazardous waste. Xie et al.[35] proposed a multi-objective integer program with cost and risk objectives in different way. In their study, location of transfer yards and transportation routes are optimized. They also considered multiple modes in routing plans including highway and railway. Their model is nonlinear and difficult to solve. Therefore, some constraints are introduced to convert the model to a linear model. Mousavi et al. [36] developed a fuzzy multi-objective model to locate undesirable facilities with minimization of cost and risk objective. Cost objective consists of transportation cost and fixed cost. Risk objective is about minimizing risk of site location impact. Two parameters are considered uncertain in this model, including produced hazardous material per each center and also related risk to locate a facility to a special site. In this field, Zhao [37] developed a location-routing model with cost and risk objectives and a goal programming method is used to optimize problem.

The following objectives can be concluded from MODM papers:

1) Minimize of total cost include of transportation cost, operation cost, initial investment cost

2) Minimize of site risk
3) Minimize of transportation risk
4) Minimize of opposition
5) Minimize of maximum disutility on any individual
6) Minimize of maximum disequity/maximize of equity
7) Minimize of dissatisfaction

4. CONCLUSION

This paper has given a review of widespread use of MCDM method included of MADM and MODM in waste management system to select and locate appropriate sites to meet conflicting criteria and objectives. In addition, some common criteria from previous papers to select landfill site was illustrated. Also, some important objectives from reviewed papers for MODM problem were presented.

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