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M. Kemal Korucu & Aykan Karademir

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TECHNICAL PAPER

Siting a municipal solid waste disposal facility, Part II: The effects of external criteria on the final decision

M. Kemal Korucu,* and Aykan Karademir
University of Kocaeli, Department of Environmental Engineering, Kocaeli, Turkey
Please address correspondence to: M. Kemal Korucu, University of Kocaeli, Department of Environmental Engineering, 41380 Kocaeli, Turkey; e-mail: kemal.korucu@kocaeli.edu.tr

The procedure of a multi-criteria decision analysis supported by the geographic information systems was applied to the site selection process of a planning municipal solid waste management practice based on twelve different scenarios. The scenarios included two different decision tree modes and two different weighting models for three different area requirements. The suitability rankings of the suitable sites obtained from the application of the decision procedure for the scenarios were assessed by a factorial experimental design concerning the effect of some external criteria on the final decision of the site selection process. The external criteria used in the factorial experimental design were defined as "Risk perception and approval of stakeholders" and "Visibility". The effects of the presence of these criteria in the decision trees were evaluated in detail. For a quantitative expression of the differentiations observed in the suitability rankings, the ranking data were subjected to ANOVA test after a normalization process. Then the results of these tests were evaluated by Tukey test to measure the effects of external criteria on the final decision. The results of Tukey tests indicated that the involvement of the external criteria into the decision trees produced statistically meaningful differentiations in the suitability rankings. Since the external criteria could cause considerable external costs during the operation of the disposal facilities, the presence of these criteria in the decision tree in addition to the other criteria related to environmental and legislative requisites could prevent subsequent external costs in the first place.

Implications: An experimental design was applied to a siting process based on different scenarios. The suitability rankings of suitable sites were obtained for each scenario. The external criteria used in the design were defined as perception and visibility. The presence of the external criteria produced meaningful differentiations. Two widespread persuasions about site selection were disproved using the results.

Introduction

Total social cost of an economic activity, which can be defined as the sum of all the costs associated with the activity, includes the private and external costs of the activity (Dijkgraaf and Vollebergh, 2004). External costs (externalities), on the other hand, could be defined as the sum of the costs (negative externalities) and the benefits (positive externalities) realized when an economic activity of one group has an impact on another (Eshet et al., 2006).

Each of the waste disposal methods has some externalities in different forms and levels. These externalities are affected by a number of variables, including waste composition, type of the disposal method, the location of disposal site, legal limitations, and so on. The main factors that generate the negative externalities arising generally from collection and transportation of the wastes and operation of the disposal facilities may be classified as (1) emissions to air, soil, and water bodies, and (2) disamenities (Eshet et al., 2007a).

It is widely accepted that externalities can be conceptually split into fixed and variable costs and benefits. In waste management, the term "fixed externality" refers to the externalities that arise from the mere existence of a disposal process. Such fixed costs should be calculated for each site and should relate to the existing distribution of households around a site. In the context of landfills, such costs should therefore be independent of the size of the landfill (area or stock capacity), the amount of waste it receives (flow volume), and possibly the type of waste it receives (inert, biodegradable, or hazardous). The term "variable externality," on the other hand, refers to the externalities that depend on the type and amount of waste going to a landfill. Most waste externalities such as emissions to air, water, and soil bodies are variable external costs, but the disamenities are mostly fixed externalities (Defra, 2003).

The nature of the negative externalities caused by the disamenities related to incinerators and landfills shows similarities to a great extent, although there are some basic differences between them. Jamasb and Nepal (2010) state that the role of the externalities resulting from disamenities in the total social cost is about 10% for incineration and 25% for landfilling. The amount of this externality is generally affected by factors

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including odor, fly ash, litter, noise, traffic, visibility, and so on (Eshet et al., 2007a). The disamenities and related externalities vary depending on the level of risk perception in the public, which is closely related to being visible for settlers (Eshet et al., 2007b; Jamasb and Nepal, 2010). Therefore, the risk perception and the factors leading to this perception, such as visibility (Kontos et al., 2005), determine levels of the externalities that will be caused by the disposal facility in the future. In this context, it can be said that the externalities arising from disamenities are directly related to the site selection procedure of the disposal facilities. Hence the methods to prevent the externalities in the first step, that is, site selection, should be preferred to paying compensatory funds (Chiueh et al., 2008) to overcome the oppressions related to the negative perceptions emerging after the facility is constructed and starts to operate.

In recent years, selection of a suitable site for a disposal facility is generally performed by simultaneous use of geographic information systems (GIS) and multicriteria decision analysis (MCDA) methods (Al-Yaqout et al., 2002; Vaillancourt and Waaub, 2002; Na et al., 2007; Chang et al., 2008; Sharifi et al., 2009; Wang et al., 2009; Aragonés-Beltrán et al., 2010; De Feo and De Gisi, 2010; Moeinaddini et al., 2010; Gorsevski et al., 2012). However, only a few of these studies considered the factors leading to externalities such as negative risk perception (Al-Yaqout et al., 2002; Vaillancourt and Waaub, 2002; Na et al., 2007; Chang et al., 2008; Cheng et al., 2002) and visibility (Kontos et al., 2003; Kontos et al., 2005; Aragonés-Beltrán et al., 2010; Geneletti, 2010; Moeinaddini et al., 2010; Tavares et al., 2011; Zelenovic Vasiljevic et al., 2012). The externalities that could arise from unsuitable site selection were generally omitted in most of the studies, and there is also no investigation in the literature that clarifies how the final decision of the site selection procedure is effected by external criteria. Therefore, probable effects of the omission of the externalities on the final decision of the site selection procedure should be investigated in details with respect to the whole waste management practice.

In this study, the effects of some external criteria on the final decision are investigated by a factorial experimental design. The external criteria considered in the study were selected as "risk perception and approval of stakeholders" and "visibility" due to the possibility that they could create some external costs after the disposal facility is built and started to operate. The suitability rankings produced by the default decision tree (i.e., the structure without external criteria) and those produced by the structure with external criteria were compared by the statistical methods of analysis of variance (ANOVA) and Tukey tests, and the extent of the differentiations is discussed in detail.

Material and Methods

A real-life study was conducted to assess the effects of the external criteria on the final decision of a site selection process (i.e., suitability ranking). The results of area requirements obtained by Korucu et al. (2013b) for a real municipal solid waste disposal problem, which includes the determination of types of the disposal facilities and corresponding area requirements, were used as the reference data. The details of the decision tree with three phases (i.e., "Phase_1," "Phase_2," and "Phase_3") used for the determination of suitable sites for disposal facilities were given in Korucu and Erdagi (2012), while the details of the site selection procedure with GIS were given in Korucu et al. (2013a).

Area requirements and site selection procedure

A cost optimization study was conducted by Korucu et al. (2013b) to determine the disposal methods to be used for the disposal of municipal solid wastes produced within the period of 2015–2040 in Kocaeli, Turkey. The study showed that a management model including one incinerator and two landfills would be the optimum solution for handling the municipal solid wastes of Kocaeli. The minimum area requirements for these facilities were determined as 15 acres for incinerator, and 250 and 500 acres for the landfills. Therefore, all the assessments presented in this study are made based on these three different area requirements.

In this study, the first phase of the site selection procedure ("Phase_1") proposed by Korucu and Erdagi (2012) was applied to two different buffering modes of the decision tree: "Legislation" mode, which satisfies the buffering conditions obliged only by the Turkish environmental regulations, and "Proposed" mode, which satisfies new additional conditions proposed by Korucu and Erdagi (2012). The counts and the locations of suitable areas were determined by the processes of buffering and the elimination of unsuitable areas with GIS for each mode separately. These applications were called "Section_1" in this study.

The suitable areas obtained for "Section 1" were put in a suitability ranking by the application of "Phase_2" with GIS. "Phase_2" application was performed for two different criteria weights: the weights determined by a decision-making team, which were called the "Table," and the weights taken as equal for all criteria, which were called "Equal." As a consequence of these applications performed for each area requirement (i.e., 15, 250, and 500 acres), 12 different scenarios results were obtained in total (15_Legislation_Equal, 15_Legislation_Table, 15_Proposed_Equal, 15_Proposed_Table, 250_Legislation_Equal, 250_Legislation_Table, 250_Proposed_Equal, 250_Proposed_Table, 500_Legislation_Equal, 500_Legislation_Table, 500_Proposed_Equal, 500_Proposed_Table). These applications were called "Section_2" in this study.

Factorial experimental design

This study includes the utilization of aforementioned two sections ("Section_1" and "Section_2") to observe possible effects of the external criteria on the final decision for 12 different scenarios. For this purpose, the whole of "Section_2" was separately structured by a factorial experimental design for the all scenarios, and differentiations in the suitability rankings caused by the external criteria were tested.

In the application of the factorial experimental design, the criteria with the highest weight value in each main criteria group (i.e., public health and safety criteria group, economical criteria group and social criteria group) were defined as "main factors." These main factors are "distance from residential areas" (in

public health and safety criteria group), "proximity to customers" (in economical criteria group), and "risk perception and approval of stakeholders" (in social criteria group), according to Korucu et al. (2013a). Among them, the criterion of "risk perception and approval of stakeholders" could directly cause externalities in the management process. However, since mapping of this criterion is determined by the subjective conditions of the residents (Lober, 1995), it could show significant differences with time and the changes in the administrative conditions. Therefore, an additional criterion, "visibility," which can also be assessed as an external criterion, was added to the structure to be used in the factorial experimental design. The maps showing the site selection layers formed for the four criteria that were determined as the "main factors" in the factorial experimental design are given in Figures 1 to 4. The details related to these criteria are given next:

Distance from residential areas. This is the layer obtained from the weighting of the distances from the large public places, urban study areas, nonresidential study areas, auxiliary business centers, central business areas, existing urban and rural residential areas together with the parks and gardens, and the residential areas with different densities (i.e., very low, low, medium and high) that are planned to be built in the near future (the most



Figure 1. Map of the criterion of "distance from residential areas."

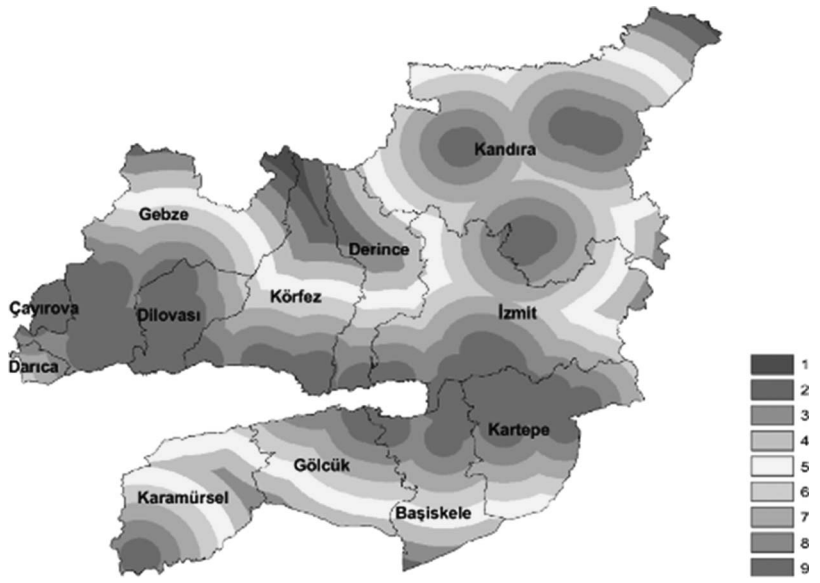


Figure 2. Map of the criterion of "proximity to customers."

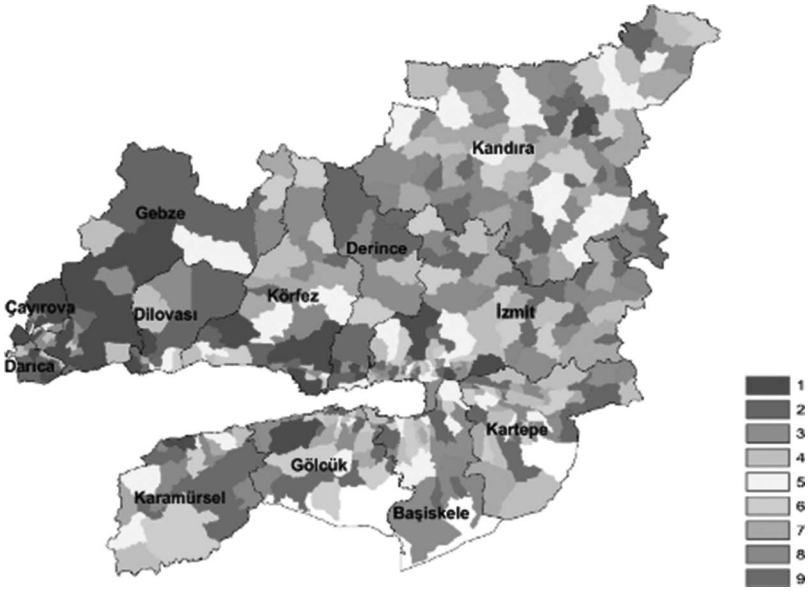


Figure 3. Map of the criterion of "risk perception and approval of stakeholders."

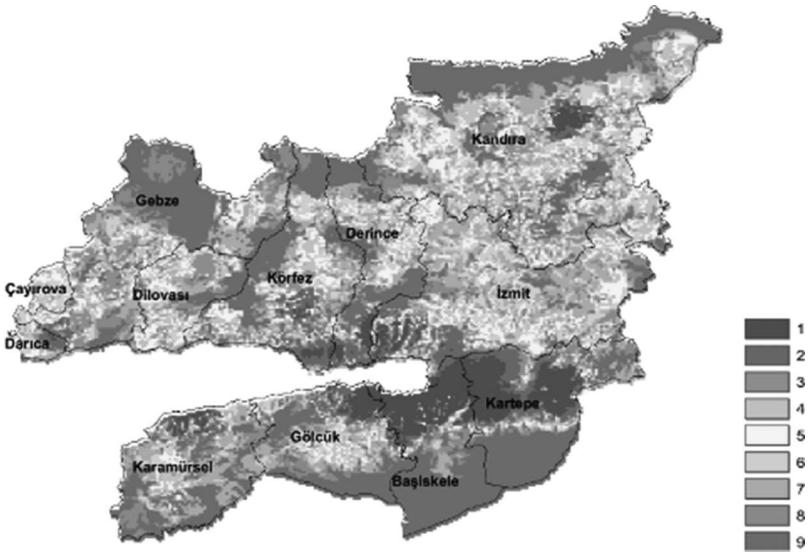


Figure 4. Map of the criterion of "visibility."

distant grids were weighted as 9, and the nearest grids were weighted as 1).

Proximity to customers. This is the layer obtained from the weighting of the proximity to the sites where customers and/or suppliers for the valuable materials recycled from the solid wastes are present, including storage areas, industrial areas in different scales, free zones, technology development areas, wastewater treatment plants and solid waste collection centers, and so on (the nearest grids were weighted as 9, and the most distant grids were weighted as 1).

Risk perception and approval of stakeholders. This is the layer obtained from the weighting of distances from the areas with a high population density, based on the hypothesis that risk perception would be highly negative in the areas with high population (the nearest grids to the most crowded areas were weighted as 1, and the nearest grids to the least crowded areas were weighted as 9).

Visibility. This is the layer obtained from the weighting of the visibility of the disposal sites at a distance up to 3 km from the residential areas (it was defined as the visibility of a 5-m-high waste dump by a person standing on a 30-m-high building as the person turns around his or her own axis by 360 degrees with a visual angle between +45 and –45 degrees from the person's eye level) (the grids that could not be seen from any residential area were weighted as 9, and the grids that could be seen easily from the most of the residential areas were weighted as 1).

Since the number of factors to be used in the factorial experimental design is 4 ("Distance from residential areas," "Risk perception and approval of stakeholders," "Proximity to customers" and "Visibility"), there should be a design including 4^2 experiments (or structure) when it is formed in two different levels of use (+) and nonuse (–) of these factors in the GIS-supported site selection process. The structures and the interaction types of these experiments are given in Table 1.

The structure "A" in Table 1 is the structure where all main factors were used in the site selection procedure, and it was the only structure used by Korucu et al. (2013a). In this study, the experiments were additionally performed by using all the structures given in Table 1 for 12 different scenarios separately. A random code was given to each parcel of the "suitable areas" obtained from the "Section_1" applications before these experiments. These areas were divided into the grids with a resolution of 10 × 10 m. A suitability value was obtained for each suitable area by application of "Section_2." Then the suitability values were organized in descending order. An example of the rankings based on the suitability values is given in Table 2.

Statistical analysis of suitability rankings

Based on the results of the experiments performed for each scenario, a statistical analysis was conducted to observe how the main factors change the suitability rankings. In order to assess the degree of changes observed in the experiments separately in relation to each other, the structure "P" in Table 1, where none of the main factors is included in the site selection procedure, was taken as reference. The data related to the rankings given in Table 2 were normalized to make a statistical comparison based on "P" reference structure. In this application, parcel code was marked as "1" (which means that no change was observed) if it was the same as the corresponding parcel code in the "P" structure. It was marked as "0" (which means that a little change was observed) if it was the same as any parcel code in the "P" structure other than the corresponding parcel code. It was marked as "–1" (which means that a significant change was observed) if it was not the same as any parcel code in the "P" structure. This procedure was applied to all the structures from "A" to "P," which constitutes an experimental design set, and all the values in the reference "P" structure were assigned certainly as "1." Table 3 shows the result of this normalization procedure applied to Table 2.

Tables of the suitability rankings produced for 12 different scenarios just like Table 2 were reorganized separately based on the aforementioned normalization procedure to obtain a table similar to Table 3 for each scenario. A variance analysis (one-way ANOVA) on Excel was used to determine the experimental design sets with meaningful differentiations. All of the experimental design sets were determined as significant because their F values were higher than the F-critical value (1.74).

Since ANOVA could not order the experiments according to the level of differentiations, the Tukey test was applied to assess the level of differentiations as a post hoc test. The test was applied to all the experiment design sets by an open-source XL Toolbox application that could be performed in Excel. The q values obtained for the reliability level of 95% in Tukey tests were ordered and all the experiments with a q value higher than q-critical were accepted as the experiments causing a meaningful differentiation in the experiment set. In this regard, the experiment with the highest q value should necessarily be the experiment causing the highest differentiation. As an example, the results obtained by the application of this procedure to the minimum area requirement of 250 acres are presented in Table 4. As shown in Table 4, for the "250_Legislation_Equal" scenario, structure "A" showed the highest differentiation in the suitability ranking with respect to that of the reference structure "P," while

Table 1. The main factors, interactions, and the configuration of factorial experimental design used in the study

Structure	Distance from residential areas	Proximity to customers	Risk perception and approval of stakeholders	Visibility
A (quadruple interaction)	+	+	+	+
B (triple interaction)	−	+	+	+
C (triple interaction)	+	−	+	+
D (dual interaction)	−	−	+	+
E (triple interaction)	+	+	−	+
F (dual interaction)	−	+	−	+
G (dual interaction)	+	−	−	+
H (main factor)	−	−	−	+
I (triple interaction)	+	+	+	−
J (dual interaction)	−	+	+	−
K (dual interaction)	+	−	+	−
L (main factor)	−	−	+	−
M (dual interaction)	+	+	−	−
N (main factor)	−	+	−	−
O (main factor)	+	−	−	−
P (reference structure)	−	−	−	−

Notes: + = The main factor was used in the structure for "Section_2" application; − = the main factor was not used in the structure for "Section_2" application.

Table 2. Suitability rank of the parcel codes produced by 16 different experimental designs for the scenario of "250_Legislation_Table"

	Suitability rank of the parcel codes									
Structure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
A	130	51	41	38	39	40	43	45	46	48
B	51	38	39	40	41	43	45	46	48	49
C	130	51	22	38	39	41	43	45	48	49
D	51	130	38	39	41	43	45	48	49	50
E	130	52	22	39	41	49	50	51	83	45
F	52	130	22	39	41	49	50	51	83	45
G	130	52	22	51	20	39	41	49	50	129
H	130	52	51	20	22	39	41	49	50	83
I	130	38	39	40	41	43	45	46	47	48
J	38	39	41	43	45	46	48	50	51	52
K	130	22	38	39	41	43	45	46	48	49
L	38	39	41	43	45	48	50	51	52	83
M	130	20	22	39	41	52	50	99	83	51
N	39	41	52	50	99	130	83	51	20	48
O	130	52	20	22	39	41	49	50	51	99
P	20	39	41	50	52	130	22	48	51	129

Table 3. Normalized values of "250_Legislation_Table" scenario

	Suitability rank of the parcel codes in terms of normalized values									
Structure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
A	0	0	1	−1	0	−1	−1	−1	−1	0
B	0	−1	0	−1	0	−1	−1	−1	0	−1
C	0	0	0	−1	0	0	−1	−1	0	−1
D	0	0	−1	0	0	−1	−1	1	−1	0
E	0	0	0	0	0	−1	0	0	−1	−1
F	0	0	0	0	0	−1	0	0	−1	−1
G	0	0	0	0	0	0	0	−1	0	1
H	0	0	0	0	0	0	0	−1	0	−1
I	0	−1	0	−1	0	−1	−1	−1	−1	0
J	−1	1	1	−1	−1	−1	0	0	1	0
K	0	0	−1	0	0	−1	−1	−1	0	−1
L	−1	1	1	−1	−1	0	0	0	0	−1
M	0	0	0	0	0	0	0	−1	−1	0
N	0	0	0	1	−1	1	−1	0	0	0
O	0	0	0	0	0	0	−1	0	1	−1
P	1	1	1	1	1	1	1	1	1	1

structure "L" showed the lowest differentiation. On the other hand, the differentiations caused by the structures "H," "E," and "N" were not found to be statistically significant.

In the studies of the factorial experimental design, the main factors were represented by the structures "O" (distance from residential areas), "N" (proximity to customers), "L" (risk perception and approval of stakeholders), and "H" (visibility) in the experimental design set. Additionally, the structures "D," "F," "G," "J," "K," and "M" represent the dual interactions of these four main factors in the experimental design. Similarly, the structures "B," "C," "E," and "I" represent the triple interactions, and the structure "A" represents the quadruple interaction (see Table 1). Since it requires a detailed statistical analysis to determine which main factor, and to what extent, causes the

Table 4. Results of one-way ANOVA followed by Tukey test for the area requirement of 250 acres

250_Legislation_Equal				250_ Legislation _Table			250_Proposed_Equal				250_Proposed_Table			
Structure	q	p	Sig.	Structure	q	p	Sig.	Structure	q	p	Sig.	Structure	q	p	Sig.
A	6.24	0.0011	Yes	B	8.86	−4E-05	Yes	A	6.02	0.0022	Yes	B	8.37	−4E-05	Yes
D	6.24	0.0011	Yes	I	8.86	−4E-05	Yes	B	5.55	0.0084	Yes	I	8.37	−4E-05	Yes
K	6.24	0.0011	Yes	K	8.30	−4E-05	Yes	K	5.55	0.0084	Yes	J	8.37	−4E-05	Yes
O	6.24	0.0011	Yes	A	7.75	−3.6E-05	Yes	M	5.55	0.0084	Yes	A	7.81	−3.7E-05	Yes
G	5.79	0.0042	Yes	C	7.75	−3.6E-05	Yes	L	5.55	0.0084	Yes	D	7.81	−3.7E-05	Yes
M	5.79	0.0042	Yes	D	7.20	9.86E-07	Yes	I	5.55	0.0084	Yes	K	7.81	−3.7E-05	Yes
B	5.35	0.0147	Yes	F	7.20	9.86E-07	Yes	O	5.09	0.0279	Yes	L	7.81	−3.7E-05	Yes
I	5.35	0.0147	Yes	E	7.20	9.86E-07	Yes	D	4.63	0.0798	No	C	7.81	−3.7E-05	Yes
J	5.35	0.0147	Yes	H	6.64	0.0003	Yes	N	–	–	No	E	7.25	−6.7E-06	Yes
C	5.35	0.0147	Yes	M	6.64	0.0003	Yes	G	–	–	No	G	6.69	0.0002	Yes
F	4.90	0.0438	Yes	L	6.64	0.0003	Yes	H	–	–	No	H	6.13	0.0015	Yes
L	4.90	0.0438	Yes	J	6.09	0.0018	Yes	E	–	–	No	O	6.13	0.0015	Yes
H	4.46	0.1131	No	O	6.09	0.0018	Yes	F	–	–	No	M	6.13	0.0015	Yes
E	–	–	No	G	5.54	0.0089	Yes	J	–	–	No	F	5.58	0.0079	Yes
N	–	–	No	N	5.54	0.0089	Yes	C	–		No	N	3.35	0.5735	No

Notes: Sig. = significance.

differentiations in each interaction, it was assumed that the differentiations were caused by all the factors in all interactions equally. In this manner, the experimental sets include 15 experimental structures composed of four main factors, six dual interactions, four triple interactions, and one quadruple interaction. Another normalization process was applied to order the differentiation effects of these 15 experimental designs on the results. In order to do this, the *q* values obtained for the experiments were organized in descending order (impact order). Then an impact level value (ILV) of 15 was assigned to the structure with the highest *q* value, and it was decreased correspondingly with the *q* values (14 to the structure with the second highest *q* value, etc.). The sum of the ILVs was defined as the total impact value (TIV) for the corresponding scenario, and a normalized impact value (NIV) of each experiment was assigned in percentage based on TIV.

All in all, the overall methodology used in the study can be summarized as follows:

(1) "Section_1": The counts and the locations of suitable areas for each area requirement (i.e., 15, 250, and 500 acres) were determined by the processes of buffering and the elimination of unsuitable areas using a geographic information system (GIS). A random code was given to each parcel of the "suitable areas." This was performed for "Legislation" and "Proposed" modes separately.
(2) "Section_2": The "suitable areas" obtained from "Section 1" were put in a suitability ranking by a weighted overlay analysis with GIS. This was performed for "Table" and "Equal" criteria weights separately. As a consequence of these applications, 12 different scenario results were obtained in total.
(3) Factorial experimental design applications: "Section_2" was repeated for all the experimental structures given in Table 1.
(4) Statistical analysis: The suitability rankings were normalized to make a statistical comparison. After the normalization, one-way ANOVA and the Tukey test were used to determine the experimental design sets with meaningful differentiations. Finally, it was assumed that the differentiations were caused by all the main factors in all interactions equally, and another normalization process was applied to order the differentiation effects.

Results and Discussion

The counts of suitable areas greater than 15 acres, 250 acres, and 500 acres were determined as 613, 71, and 31 for "Proposed" mode, and 979, 134, and 46 for "Legislation" mode in "Section_1," respectively. The results indicate that "Proposed" mode has a more conservative approach as compared to "Legislation" mode. Furthermore, it is clear that the counts of suitable areas decrease as the area requirement increases. According to this data set, it could be expected that the differentiations in the suitability ranking should be at the lowest level for "500_Proposed" mode, which has the minimum counts of suitable areas and the highest level for "15_Legislation" mode, which has the maximum counts of suitable areas. The results given by Korucu et al., (2013a) for structure "A" agree with this assessment.

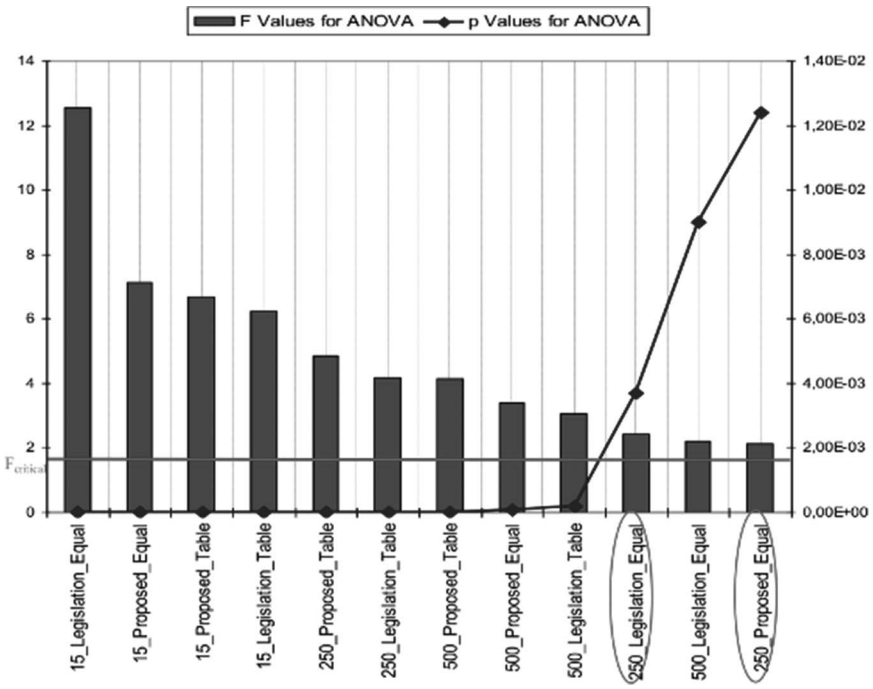


Figure 5. The results of ANOVA tests for 12 different scenarios.

Figure 5 shows the results of ANOVA tests for 12 different scenarios. As expected, the differentiation in the suitability ranking was the highest level for 15-acre modes, which have the highest *F* values and the lowest *P* values. However, the differentiation in the suitability ranking was not at the lowest level for 500-acre modes. Furthermore, the "Proposed" modes showed lower differentiations in the suitability ranking as compared to the corresponding "Legislation" modes in some scenarios. Thus, the expectation that the differentiation level decreases as the counts of suitable areas decrease is not valid for all structures. According to this, it is hard to say that obtaining the most exact decision for site selection is ensured by working on large-scale area requirements.

The results of the statistical analyses related to the experimental structures representing the main factors and all the interactions between them are given in Table 5. In order to clear the differentiations in the suitability ranking caused by the main factors, the impact orders and impact values (NIVs) presented in Table 5 were simplified to display only the main factors. For this, the final impact levels (FILs) of the main factors were determined by adding own NIVs of the factors to the NIVs of the factors in the interactions with the assumption that the contribution of each factor in total differentiations is equal in an interaction. For example, the FIL of "H" structure is the sum of the NIV of the "H" structure, halves of the NIVs of the dual interactions of "H" with the structures "D," "F," and "G," one-third of the NIVs of the triple interactions of "H" with the structures "B," "C," and "E," and one-fourth of the NIV of the quadruple interaction of "H" with the structure "A" (see Table 1). The same procedure was applied to the other main factors, and results are given in Table 6.

As shown in Table 6, the main factor with the lowest FIL was the criterion of "N" (proximity to customers) in seven out of 12 scenarios. The main factor with the highest FIL, on the other hand, varied from one scenario to another to different extents. The main factor with the highest FIL was the criterion of "L" (risk perception and approval of stakeholders) in five out of 12 scenarios and the criterion of "H" (visibility) in two out of 12 scenarios. In the same way, the main factor with the second highest FIL was the criterion of "L" (Risk perception and approval of stakeholders) in six out of 12 scenarios and the criterion of "H" (Visibility) in three out of 12 scenarios. Consequently, it is impossible to say that the differentiations of the suitability ranking caused by external criteria are negligible in the site selection procedure under all circumstances.

Conclusion

In site selection applications, it is generally expected that as the counts of suitable areas decrease, the probability of differentiation in the suitability ranking by any criteria decreases. For this reason, working on larsge-scale area requirements is usually preferred in site selection applications. Besides, the weights of criteria are determined by the subjective conditions of the residents and/or the decision makers, and the external criteria are generally not taken into account in the site selection procedure. What will happen if the decision makers are not right? In this study, it was indicated that some widespread expectations are not valid under all circumstances. In this case, it could be said that the incorrect final decisions made in the past could have caused some avoidable externalities.

The results obtained in this study suggest that the major factor causing differentiations in the suitability rankings may be the location of the suitable areas rather than their counts. On the other hand, since the external criteria are generally not considered in the current site selection procedures, the effects of the

Table 5. Impact orders and NIVs (%) obtained for the main factors and the dual interactions between them

15 acres								250 acres								500 acres							
Legislation_ Equal		Legislation_ Table		Proposed_ Equal		Proposed_ Table		Legislation_ Equal		Legislation_ Table		Proposed_ Equal		Proposed_ Table		Legislation_ Equal		Legislation_ Table		Proposed_ Equal		Proposed_ Table	
H	0.83	I	0.83	C	0.83	N	0.83	H	0.00	N	0.83	D	0.00	N	0.00	F	0.00	E	0.00	H	0.00	K	0.00
N	1.67	B	1.67	A	1.67	I	1.67	E	0.00	G	1.67	N	0.00	F	1.68	K	0.00	G	0.00	N	1.68	H	0.00
F	2.50	F	2.50	B	2.50	K	2.50	N	0.00	O	2.50	G	0.00	M	2.52	M	0.00	N	0.00	F	2.52	F	0.00
B	3.33	N	3.33	D	3.33	F	3.33	L	3.51	J	3.33	H	0.00	O	3.36	E	0.00	O	0.00	D	3.36	O	3.51
M	4.17	M	4.17	E	4.17	M	4.17	F	4.39	L	4.17	E	0.00	H	4.20	J	4.55	F	0.00	B	4.20	M	4.39
L	5.00	L	5.00	F	5.00	O	5.00	C	5.26	M	5.00	F	0.00	G	5.04	I	5.45	H	5.71	J	5.04	G	5.26
E	5.83	K	5.83	G	5.83	H	5.83	J	6.14	H	5.83	J	0.00	E	5.88	L	6.36	C	6.67	E	5.88	N	6.14
J	6.67	J	6.67	H	6.67	C	6.67	I	7.02	E	6.67	C	0.00	C	6.72	O	7.27	D	7.62	C	6.72	D	7.02
A	7.50	H	7.50	I	7.50	L	7.50	B	7.89	F	7.50	O	10.71	L	7.56	H	8.18	M	8.57	I	7.56	I	7.89
D	8.33	E	8.33	J	8.33	J	8.33	M	8.77	D	8.33	I	11.90	K	8.40	B	9.09	I	9.52	L	8.40	C	8.77
I	9.17	D	9.17	K	9.17	D	9.17	G	9.65	C	9.17	L	13.10	D	9.24	G	10.00	B	10.48	M	9.24	A	9.65
O	10.00	O	10.00	L	10.00	G	10.00	O	10.53	A	10.00	M	14.29	A	10.08	N	10.91	K	11.43	O	10.08	E	10.53
K	10.83	C	10.83	M	10.83	B	10.83	K	11.40	K	10.83	K	15.48	J	10.92	C	11.82	A	12.38	K	10.92	L	11.40
G	11.67	A	11.67	N	11.67	A	11.67	D	12.28	I	11.67	B	16.67	I	11.76	A	12.73	L	13.33	G	11.76	B	12.28
C	12.50	G	12.50	O	12.50	E	12.50	A	13.16	B	12.50	A	17.86	B	12.61	D	13.64	J	14.29	A	12.61	J	13.16

Table 6. Impact orders and FILs (%) obtained for the main factors

15 acres								250 acres								500 acres							
Legislation_ Equal		Legislation_ Table		Proposed_ Equal		Proposed_ Table		Legislation_ Equal		Legislation_ Table		Proposed_ Equal		Proposed_ Table		Legislation_ Equal		Legislation_ Table		Proposed_ Equal		Proposed_ Table	
N	16.32	N	16.53	N	18.06	N	20.00	N	17.91	N	21.53	H	10.02	N	20.17	O	21.21	H	18.33	H	17.58	H	19.08
H	21.18	L	23.19	H	23.06	O	23.19	H	20.83	O	22.92	N	21.13	O	21.99	N	21.21	O	18.49	N	19.12	O	19.81
L	28.13	H	29.44	L	28.61	L	26.81	L	28.44	H	26.53	O	34.03	H	23.11	L	27.42	N	21.19	L	27.38	N	27.56
O	34.38	O	30.83	O	30.28	H	30.00	O	32.82	L	29.03	L	34.82	L	34.73	H	30.15	L	41.98	O	35.92	L	33.55

external costs on the total costs are neglected. The minimization of these external costs could be possible by involvement of the external criteria into the decision-making structure of the site selection procedure. The results of this study show that addition of external criteria such as "risk perception and approval of stakeholders" and "visibility" to the decision tree could cause significant differentiations in the final decision. Since visibility could be defined in physical terms, it could be integrated into the GIS-based structure easily. But the integration of risk perception could be possible only by the active participation of all the stakeholders in the site selection procedure.

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About the Authors

M. Kemal Korucu is working as a research assistant in the Graduate School of Natural and Applied Sciences, and is currently a Ph.D. student in the Department of Environmental Technologies at the University of Kocaeli. His current research focuses on method and site selection for disposal of municipal solid wastes.

Aykan Karademir is working as an associate professor in the Department of Environmental Technologies at the University of Kocaeli. His research interests include hazardous wastes, persistent organic compounds, air pollution, and risk assessment.