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GIS-based multi-criteria decision analysis for parking site selection

Derya Ozturk[1], Fatmagul Kilic-Gul[2]*

[1] Dept. of Geomatics Engineering, Ondokuz Mayis University, Samsun, 55139, Turkey

[2] Dept. of Geomatics Engineering, Yildiz Technical University, Istanbul, 34220, Turkey

**Corresponding author: dozturk@omu.edu.tr*

Abstract

Site selection is one of the strategic decisions in spatial planning and requires the consideration of many factors. Integration of Geographic Information Systems (GIS) and Multi-criteria Decision Analysis (MCDA) are useful for solving complex spatial decision problems such as site selection. In this study, integration of GIS and the Ordered Weighted Averaging (OWA) method, which is one of the most widely used MCDA methods in spatial decision problems, were used to analyze a "parking site selection" problem in Atakum (Samsun, Turkey). A GIS-OWA tool was developed in ArcGIS 9.2 via ArcObjects/Visual Basic for Applications (VBA), and a decision analysis for parking site selection was performed. Because the OWA method is based on parameters with mainly fuzzy quantifiers, by changing these parameters, a broad decision strategy set could be formed. Different scenarios provided a flexible approach for problem solution and the result obtained for δ=1 was compared with the present and planned parking sites. A comparison of the results showed that present and planned parking sites in the urban plan do not meet parking needs in Atakum (Samsun, Turkey).

Keywords: Geographic information system; GIS-OWA; multi-criteria decision analysis; ordered weighted averaging; parking site selection.

1. Introduction

Population growth has increase and resources are being coming more limited. Optimally meeting these growing land-use demands and regulations has pushed the decision-making process to a critical point (Mosadeghi *et al*., 2015; Boggia *et al*., 2018; Wang *et al*., 2018). Due to the scarcity of natural resources, the formation of land use policies that balance protection and use are vitally important in today's world (Shi *et al*., 2012; Ozturk, 2015). To use these natural resources effectively and to enable social and economic development by managing environmental policies, it is a critical to develop sound decision-making strategies. Thus, the utmost attention must be applied to solve planning and site selection problems (Wang *et al*., 2012; Dorning, 2015).

Cities can be characterized by their land use and transportation structures. The transportation systems constitute the most significant components of an urban infrastructure (Russo & Comi, 2012; Rodrigue *et al*., 2017). Because transportation systems connect all urban use areas, problems that occur in transportation negatively affect other urban activities. Kaiser *et al*., (1995) and Obot *et al*., (2009) explain that parking sites (lots or structures) are components of transportation systems. Therefore, an inadequate amount of parking areas in terms of quality and/or quantity can cause transportation system to fail. Parking on streets blocks traffic. When street parking is lessened, traffic flows more smoothly. In fact, optimal site selection for parking areas enables a smoother passage of traffic (Farzanmanesh *et al*., 2010; Jelokhani-Niaraki & Malczewski, 2015a).

Spatial decision problems (e.g., site selection) on account of their characteristics, generally have a complex nature. To develop appropriate decision-making strategies, any problems must be clearly identified, and all causative factors must be included in the analysis (Jelokhani-Niaraki & Malczewski, 2015b). Therefore, providing solutions based on one or several factors, which is the case in classical approaches, is no longer valid in modern practices (Mosadeghi *et al*., 2015). However, an increase in the number of factors in complex decision problems (coupled with issues involving solving problems with a wide range of alternatives) makes the solution of these problems even more difficult (Moghtadernejad *et al* ., 2018).

Although Geographic Information Systems (GIS) provides a great deal of flexibility in spatial analysis, spatial querying and visualization issues (Butt, 2017) has a limited capacity to actually solve complex decision problems. For this reason, GIS-based Multi-criteria Decision Analysis (MCDA) is becoming more often used for solving complex spatial decision problems (Jelokhani-Niaraki & Malczewski, 2015a; Stojanovic *et al*., 2015). The GIS-based MCDA (spatial MCDA) process is based on making a selection from a variety of spatial alternatives with respect to criteria that is in line with the objective of the problem (Malczewski, 1999; Massei *et al*., 2014).

Decision making is a process that begins with identifying the problem, and it ends when a final decision is made with more than one alternative (Wehmeyer & Shogren, 2017). However, the solution of complex decision problems includes numerous alternatives and requires the decision maker to evaluate multiple factors, meanwhile mankind's memory and data-processing capacity are not sufficient to solve such problems (Drobne & Lisec, 2009). Therefore, a variety of MCDA algorithms and methods have been integrated with GIS to solve complex decision problems (Malczewski, 1999; Malczewski & Rinner, 2015). Because site selection problems play a vital role in forming land use policies, the most common issue in GIS-based MCDA is site selection (De Feo & De Gisi, 2014; Latinopoulos & Kechagia, 2015). However, the number of studies addressing the problem of parking site location is rather limited (Farzanmanesh *et al*., 2010; Jelokhani-Niaraki & Malczewski, 2015a).

Parking lots and structures are extremely significant components of any transportation system. Selecting sites for them depends on many factors. In order to solve problems with site selection, the MCDA approach can be used (Yu *et al*., 2011).

In this study, the integration of GIS and the Ordered Weighted Averaging (OWA) method, which is one of the most popular MCDA methods, were taken into consideration. In this context, the locations where parking sites are needed in Atakum (Samsun, Turkey) were determined. The study area was chosen because it is experiencing serious parking problems as a result of rapid population growth. Atakum has an average annual population growth rate of approximately 6.5%, and is the most rapidly growing district in the city of Samsun, Turkey (Ozturk, 2015). Depending on the population increase, the number of vehicles in Atakum increases by approximately of 2.5% per year (Turkish Statistical Institute, 2020). For analysis, the GIS-OWA tool was developed via ArcObjects/Visual Basic for Applications (VBA) in the ArcGIS 9.2 Software, and then the OWA method was applied to determine suitable parking sites.

2. Materials and methods

2.1 OWA method

The OWA method was fundamentally developed in the context of the fuzzy set theory by Yager (1988). It provides flexible aggregation ranges from the minimum and the maximum (Amina & Emrouznejad, 2011). OWA is the weighted sum of the ordered evaluation criteria. For this reason, order weights are also used in addition to the criteria weights assigned to the evaluation criteria (Malczewski, 1999). A criterion weight is assigned to a criterion based on a decision maker's preferences and indicates the relative importance of the criterion for all locations. For order weights, the criteria values are arranged in descending order at each location, and order weights are assigned on a location-by-location basis (Drobne & Lisec, 2009; Feizizadeh *et al*., 2015). In the OWA method, parameters specified using fuzzy (linguistic) quantifiers are employed, allowing for a wide range of decision strategy scenarios to be constituted by changing the parameters (Malczewski, 2006a). The order weights allow the decision maker to directly control the levels of trade-off among the criteria (Malczewski, 1999).

The OWA decision rule for each alternative is presented in Equation 1 (Malczewski, 2006b):

$$A_{OWA} = \sum_{j=1}^{n} \left(\frac{w_j ow_{ij}}{\sum_{j=1}^{n} w_j ow_{ij}} \right) a_{ij} \, , \; i = 1,2,3,...,m \quad , \qquad (1)$$

where aij is the standardized score of the ith alternative for the jth criterion, wj is the weight of the jth criterion, and owij is the order weight of the ith alternative for the jth criterion (Malczewski, 2006b).

As the criteria may occur in different evaluation intervals, the criteria layers must be standardized (value scaling) before aggregation (Malczewski & Rinner, 2015). A linear scale transformation is the deterministic method that is most frequently used to transform data layers into the same scale range (Malczewski, 1999; Chakhar & Mousseau, 2008). There are many linear scale transformation approaches. The two procedures that are most often used are the maximum score procedure and the score range procedure (Malczewski, 1999; Young *et al*., 2010).

Criteria weights can be defined as a value of relative importance. As the weight value increases, the criterion's importance increases. The weights are generally normalized to obtain a sum of 1. For weighting, a number of procedures have been proposed. Some of the most popular procedures are ranking, rating, and pairwise comparison (Malczewski & Rinner, 2015). The ranking method is the simplest technique used to determine weights. In this method, the evaluation criteria are ranked according to the decision maker's preferences. The rating method is based on scoring the criteria at a predetermined specific scale (Malczewski, 1999). The pairwise comparison method involves the comparison of each criterion with the other criteria in pairs (Zardari *et al*., 2015). To determine how important a criterion is relative to the other criterion, the preference scale of (1-9) is utilized (Murphy, 2014). The most important advantage of this method is that the consistency of the pairwise comparison judgments can be measured (Malczewski, 1999). This measure is referred to as the consistency ratio (CR). If CR < 0.10, it is concluded that the judgments are consistent. If CR ≥ 0.10, there is inconsistency in judgments and in these cases, the decision maker should reconsider and revise the values used in the pairwise comparison matrix (Malczewski & Rinner, 2015; Malczewski, 2018).

Order weights are expressed by a polynomial function (Equation 2).

$$ow_{ij} = \left(\frac{k}{n}\right)^{\delta} - \left(\frac{k-1}{n}\right)^{\delta}, \; k=1,2,3,..,n \quad , \tag{2}$$

where k is the order of criterion, n is the number of criteria and δ is the degree of the function (Tesfamariam & Sadiq, 2008).

Order weights are the basis of the OWA combination procedures. These weights are related to the degree of ANDness, ORness, and Trade-off (Drobne & Lisec, 2009). The ANDness, ORness, and Trade-off characteristics of order weights can be calculated using Equations 3, 4, and 5 (Malczewski, 1999):

$$ANDness = (1/(n-1))\sum_{j=1}^{n}((n-i)ow_{ij}) \tag{3}$$

$$ORness = 1 - ANDness \tag{4}$$

$$TRADEOFF = 1 - \sqrt{\frac{n\sum(ow_{ij} - 1/n)^2}{n-1}} \tag{5}$$

Table 1 shows a selected set of order weights and ANDness, ORness, and Trade-off values for three criteria. Figure 1 shows a graphical representation of all possible distributions of order weights (Mysiak, 2010). From Figure. 1, one can see how different decision analysis results can be obtained by changing the order weights by controlling the levels of trade-off and risk (Drobne & Lisec, 2009). Trade-off is a measure of the compensation of criteria. This value indicates how much a poor performance of a criterion can be compensated for by a good performance from the other criteria under consideration. This then indicates the degree of criterion substitutability (Malczewski & Rinner, 2015). The trade-off measure takes values in the range [0-1] (Table 1 and Figure 1). A value of 0 means there is no trade-off among the criteria. If the value is 1, then there is a full trade-off among the criteria. The trade-off measure can be interpreted as the degree of dispersion in the OWA weights and can be controlled by changing the order weights (Malczewski, 2006a; Drobne & Lisec, 2009).

Table 1. Characteristics of selected sets of order weights for three criteria

	Order Weights					
	ow_1	ow_2	ow_3	ANDness	ORness	Trade-off
MIN	1	0	0	1	0.00	0
	0.9	0.1	0	0.95	0.05	0.15
	0.8	0.2	0	0.90	0.10	0.28
	0.5	0.5	0	0.75	0.25	0.50
	0.5	0.3	0.2	0.65	0.35	0.74
	0	1	0	0.50	0.50	0.00
	0	0.8	0.2	0.40	0.60	0.28
MAX	0	0	1	0.00	1	0.00
Average	0.33	0.33	0.33	0.50	0.50	1

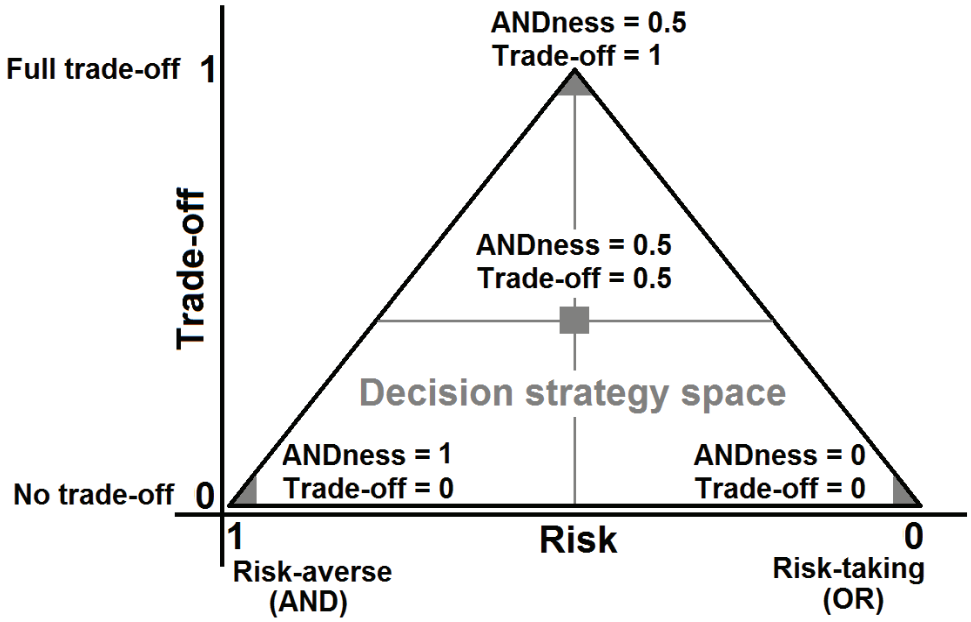

Fig. 1. Triangular decision-strategy space used in OWA method and defined by dimension of trade-off and risk.

In the OWA method, order weights can be determined according to the allowed trade-off degree. The use of order weights allows for flexible aggregation solutions at different risk levels between AND and OR. Order weights differ from criteria weights and are not applied on a criterion basis. Instead, these weights are based on the ordering of all criteria at each position and are applied on a pixel-by-pixel basis (Drobne & Lisec, 2009; Amiri *et al*., 2013).

The OWA method is quite flexible and allows different decision strategies to be achieved using a fuzzy quantifier (Cabrerizo *et al*., 2010). Decision uncertainty (risk) in an OWA application can be interpreted. Using the logical operator AND, a risk aversion decision rule (a pessimistic solution) is obtained. Whereas using the logical operator OR, the risk acceptance decision rule (an optimistic solution) is obtained. Any intermediate solution allows for a trade-off among the criteria (Malczewski, 1999).

This method offers a flexible perspective for a problem-solving process because it takes into account both the weights (indicate the relative importance of the criteria) and the order weights. Therefore, by offering a broad range of decision making strategies, OWA enables the users to simulate different scenarios (Malczewski, 2006a).

2.2. GIS-OWA tool

GIS-OWA was written with VBA using ArcObjects. To employ the data processing and analysis functions of the ArcGIS software, the tool was designed as a program dependent on ArcGIS 9.2. The GIS-OWA tool performs analyses using raster data, and the desired quantity of criteria layers can be included into analysis. To perform the decision analysis, the criteria layers are first prepared in the ArcGIS environment, and then, when the analysis is performed via GIS-OWA, a result analysis layer is added to the ArcMap screen. This tool was designed in a format that can be used in any type of GIS-based decision problem. There are no limitations to the nature and quantity of criteria that can be employed. The main structure and components of the GIS-OWA tool are shown in Figure 2.

To perform decision analysis via OWA, it is essential to know the relative importance of the criteria with respect to one another. In GIS-OWA, to detect the weights, ranking, rating and pairwise comparison methods can be used, and the computed weights are saved as a *.txt file. It is also possible to enter the weights manually.

To collectively analyze data in the GIS-OWA tool, criteria layers in a raster format with quantitative values are prepared in ArcGIS. Next, to scale the criteria layers within the same value range in GIS-OWA, standardization using the linear scale transformation method can be applied. GIS-OWA has two options as the maximum score and score range procedures for a linear scale transformation.

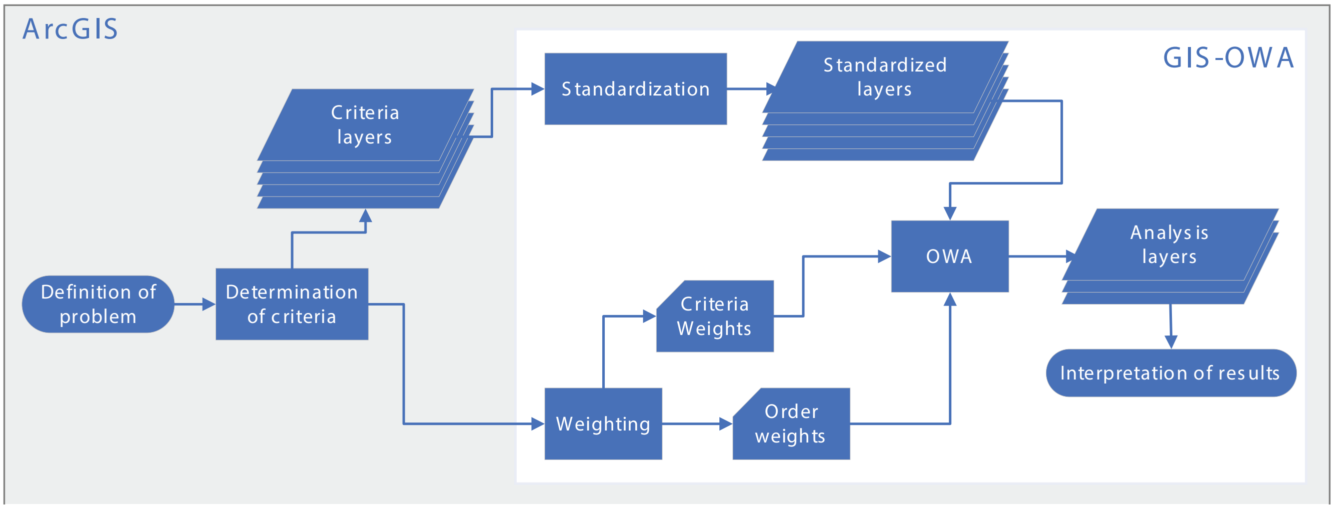

Fig. 2. General structure of GIS-OWA tool combining criterion weights and order weights.

After the criteria weights and standardized layers are defined, a δ value is entered so that the order weights can be automatically accessed and added to the decision analysis process using the OWA method. Using the GIS-OWA tool, the order weights, criteria weights and standardized criteria layers are combined according to the OWA decision rule, and the value of every pixel in the output layer is computed according to the OWA algorithm. The output layer reflects the decision strategy that was obtained with respect to the selected δ value. By changing the δ value, a user can create the desired quantity of alternatives. These decision strategies fall in a wide range, reaching from the most pessimistic to the most optimistic decision strategy.

3. Case study: Parking site selection in Atakum (Samsun, Turkey)

In this study, an application was performed by applying the OWA method to select a parking site in Atakum (Samsun, Turkey) (Figure 3).

There has recently been an increase in the number of cars in Atakum, corresponding to the recent growth in population. Traffic loads are becoming heavier every day, and the current major roads are inadequate to meet this rising traffic demand. Additionally, the quality and quantity of parking areas is insufficient and often triggers a rise in the number of cars parking along roadsides, which adversely affects traffic flow. To procure sites for new parking lots and structures, a decision analysis was performed using the OWA method. We first determined what criteria should be considered in the decision analysis. For this purpose, we evaluated regional trends and held a number of meetings with administrators and city planners in the Atakum Municipality. Eventually, the primary issues were defined as (1) proximity to commercial and shopping centers; (2) proximity to entertainment venues and recreation areas; (3) proximity to hospitals; (4) proximity to official centers; (5) proximity to major roads; and, (6) proximity to tram stations. In this study, land cost was not considered because an assessment was made based on only physical requirements. Next, the criteria layers were prepared using the GIS software. Finally, by applying the OWA method via the GIS-OWA tool, the analysis layers were generated.

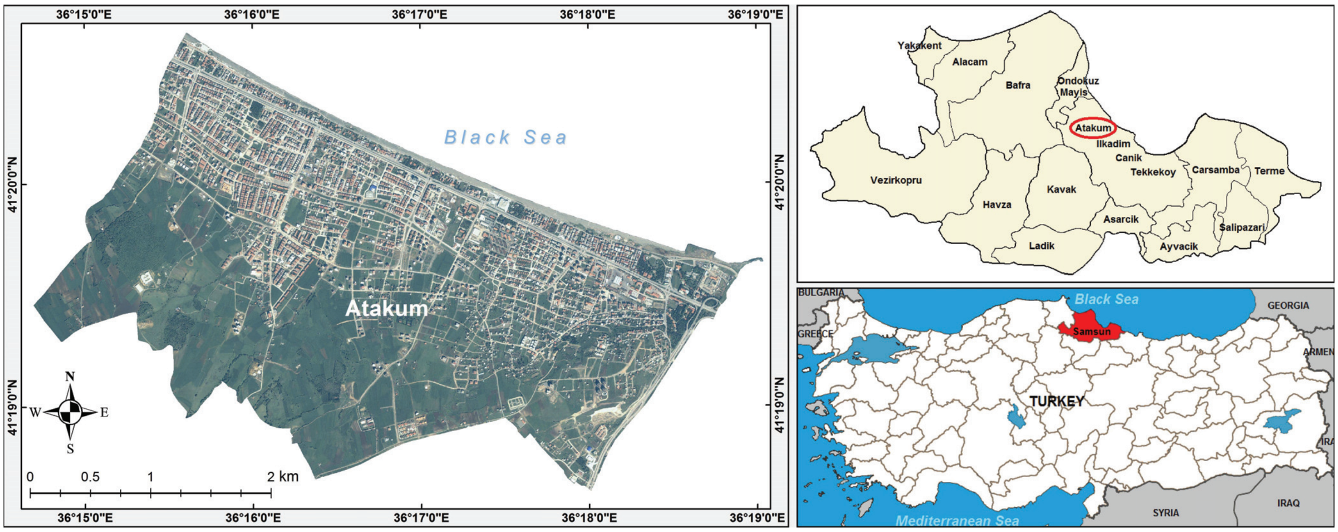

Fig. 3. Study area (11.3 km^2) of Atakum (Samsun, Turkey).

3.1. Data preparation

To prepare the criteria layers with GIS, 1/1000-scale base maps and urban plans were used. A rating method was used for each criterion layer. For each evaluation criterion, the criterion values were based on scores that varied between 0 and 10 (Table 2). High scores indicated sites that were more suitable for parking areas, and low scores indicated sites that were unsuitable. Criteria layers were formed using the "straight line distance" tool in the ArcGIS 9.2 software. They were transformed into raster data with 10-meter pixel size. Then the layers were reclassified using the scores in Table 2 (see Figure 4 as well). Because the criteria layers were all graded in the same value range, no standardization was required for this study.

Table 2. Evaluation criteria by distance and scores

Proximity to commercial and shopping centers	Score	Proximity to entertainment venues and recreation areas	Score	Proximity to hospitals	Score
0-100 m	10	0-100 m	10	0-100 m	10
100-200 m	9	100-200 m	9	100-200 m	9
200-300 m	8	200-300 m	8	200-300 m	8
300-400 m	7	300-400 m	7	300-400 m	7
400-500 m	6	400-500 m	6	400-500 m	6
500-600 m	5	500-600 m	5	500-600 m	5
600-800 m	4	600-800 m	4	600-800 m	4
800-1000 m	3	800-1000 m	3	800-1000 m	3
> 1000 m	2	> 1000 m	2	> 1000 m	2

Proximity to official centers	Score	Proximity to major roads	Score	Proximity to tram stations	Score
0-100 m	10	0-100 m	10	0-100 m	10
100-200 m	8	100-200 m	8	100-200 m	9
200-300 m	6	200-300 m	6	200-300 m	8
300-400 m	5	300-400 m	4	300-400 m	6
400-500 m	4	400-500 m	3	400-500 m	4
>500 m	1	>500 m	1	>500 m	1

3.2. Detecting criteria weights

Using the GIS-OWA tool, criteria weights were computed via the pairwise comparison method, and the consistency ratio of the pairwise comparisons was computed. A pairwise comparison matrix, computed weights and consistency ratio are shown in Table 3. The criteria weights are (1) proximity to commercial and shopping centers (0.293); (2) proximity to entertainment venues and recreation areas (0.293); (3) proximity to hospitals (0.177); (4) proximity to official centers (0.108); (5) proximity to major roads (0.065); and (6) proximity to tram stations (0.065). The computed consistency ratio was 0.007. This value is smaller than 0.10, which proves that the pairwise comparisons are consistent.

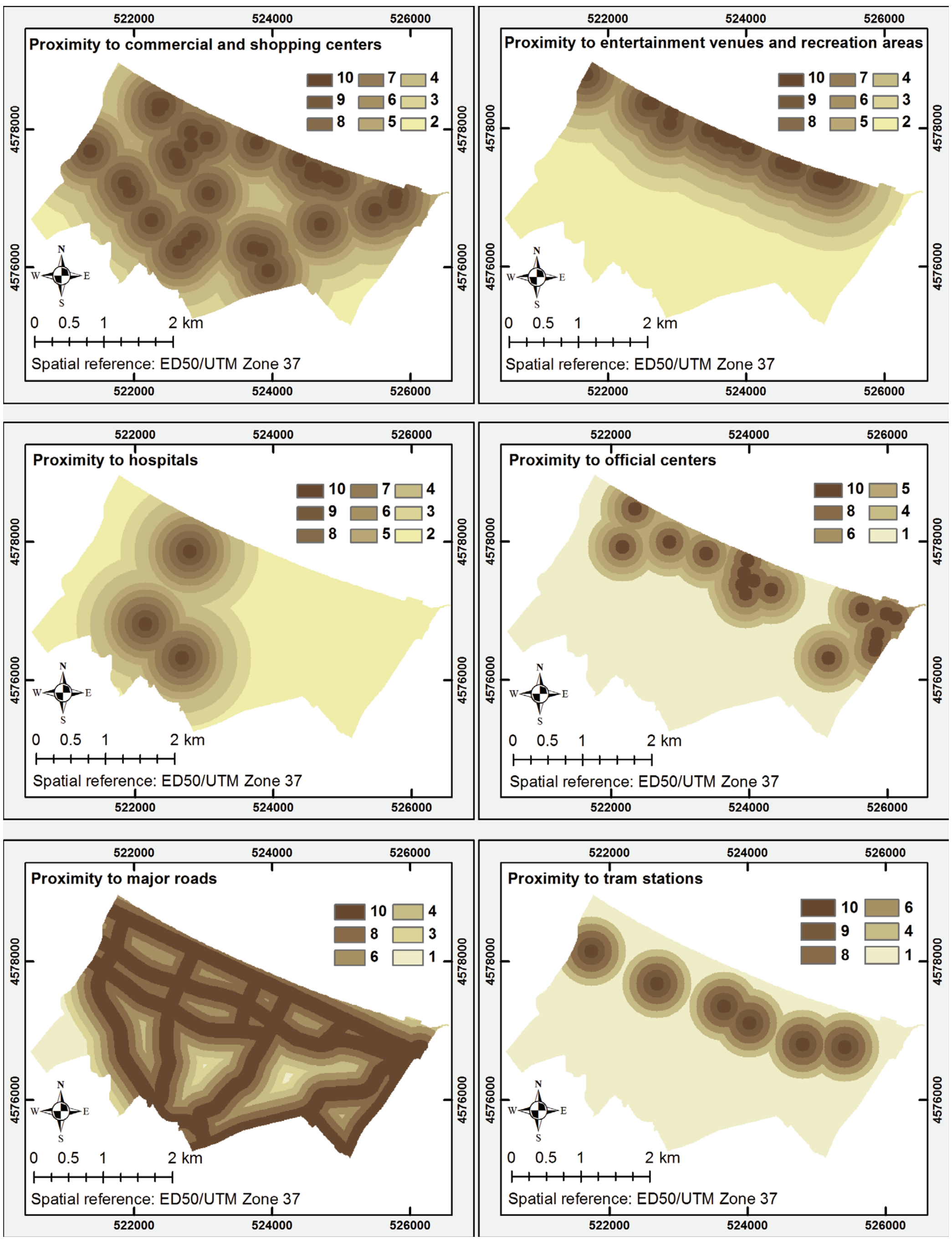

Fig. 4. Criterion layers for each evaluation criterion. Grading to form the criteria values was based on scores that varied between 1 to 10. Higher values indicate higher suitability of parking site.

3.3. Decision analysis

Using different values of δ via GIS-OWA, order weights were computed (Table 4). To identify the most suitable areas for parking sites, decision analyses were performed via the OWA method by using criteria layers, criteria weights, and order weights. High scores in this study indicate which sites are more suitable for parking sites, and low scores indicate which sites are unsuitable. For better interpretation of the analysis results, a classification was performed. To classify the pixel values within groups in ArcGIS 9.2, the "equal interval classification" method was used, and suitability was evaluated under five categories as very high, high, medium, low, and very low (Figure 5). The ANDness, ORness and Trade-off values of the order weights for the selected δ values are given in Table 5.

Table 3. Determination of criterion weights by pairwise comparison

Criterion	C1	C2	C3	C4	C5	C6	Weight
C1	1	1	2	3	4	4	0.293
C2	1	1	2	3	4	4	0.293
C3	0.500	0.500	1	2	3	3	0.177
C4	0.333	0.333	0.500	1	2	2	0.108
C5	0.250	0.250	0.333	0.500	1	1	0.065
C6	0.250	0.250	0.333	0.500	1	1	0.065
						CR=0.007	Σ=1.001≈1

C1: proximity to commercial and shopping centers; C2: proximity to entertainment venues and recreation areas; C3: proximity to hospitals; C4: proximity to official centers; C5: proximity to major roads; C6: proximity to tram stations

Table 4. Order weights for selected δ values

I	II	III	IV	Average	VI	VII	VIII	IX
δ→ 0	δ=0.2	δ=0.5	δ=0.7	δ=1	δ=1.5	δ=2	δ=3	δ→ + ∞
1	0.70	0.41	0.29	**0.17**	0.07	0.03	0.01	**0**
0	0.10	0.17	0.18	**0.17**	0.12	0.08	0.03	**0**
0	0.07	0.13	0.15	**0.17**	0.16	0.14	0.09	**0**
0	0.05	0.11	0.14	**0.17**	0.19	0.19	0.17	**0**
0	0.04	0.10	0.13	**0.17**	0.22	0.25	0.28	**0**
0	0.04	0.09	0.12	**0.17**	0.24	0.31	0.42	**1**

Table 5. ANDness, ORness and Trade-off values of order weights for selected δ values

	I	II	III	IV	Average	VI	VII	VIII	IX
	δ → 0	δ=0.2	δ=0.5	δ=0.7	δ=1	δ=1.5	δ=2	δ=3	δ → + ∞
ANDness	1	0.85	0.69	0.61	0.50	0.38	0.30	0.21	0
ORness	0	0.15	0.31	0.39	0.50	0.62	0.70	0.79	1
Trade-off	0	0.36	0.70	0.85	1	0.84	0.74	0.61	0

4. Results and discussion

In Figure 5, nine units in the alternative land suitability layer for the parking site are displayed. Each resulting layer is associated with a selected δ value, and thus, it is also associated with a trade-off measure. The decision strategy obtained with the $\delta \rightarrow 0$ value provided the best scenario, whereas the most pessimistic result was obtained with the $\delta \rightarrow +\infty$ value. As the δ value decreased from $+\infty$ to 0, the number of suitable areas for parking sites increased.

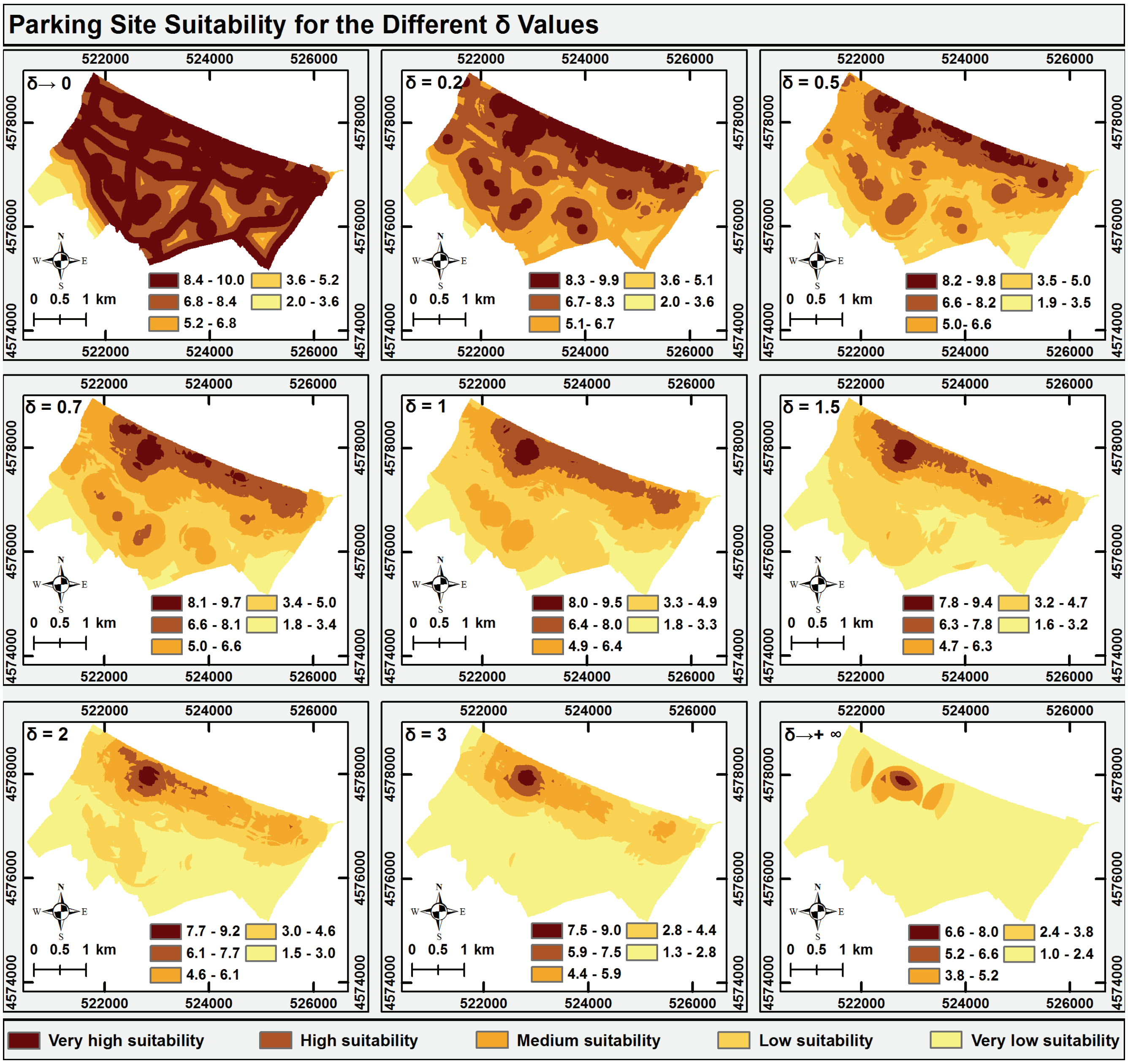

Fig. 5. Selecting the most suitable parking site in Atakum: Alternative decision strategies obtained via OWA method for selected δ values. Higher value represents higher suitability of the areas for parking sites.

δ=1 represents the strategy corresponding to a conventional weighted linear combination. This strategy is characterized by ORness=0.5 and a full trade-off (Malczewski, 2006a). A rise in the δ value above 0 corresponded with increases in the ORness value and decreases in the ANDness value. As the δ value approaches from 1 to 0 and + ∞, the trade-off between the criteria decreased.

In this section, the main objective was not to offer a final solution for the parking site selection problem but to show that by applying the OWA method to spatial decision problems on a wide scale with different risk and trade-off levels, city planners and administrators could compile a variety of decision strategies and scenarios.

Figure 5 demonstrates that for the particular problem that was investigated, it is possible to obtain multiple potential solutions by employing the OWA method. Different solutions offer viable ideas that allow city administrators and planners to compare and discuss alternative solutions. Parking sites that are currently allotted or included in urban plans are overlapped with the analysis layers that were obtained for a selected δ value and can be compared with analysis results in the GIS environment. Thus, during urban planning, decision makers can determine whether parking sites are located in the most suitable areas. Instead of considering a single result, the collective evaluation of different solutions adds flexibility to the problem-solving process, and it provides decision makers with a variety of alternative solutions. In this study, the analysis results obtained for the δ=1 were overlapped with the present and planned parking sites (Figure 6). According to the OWA analysis results for the δ=1 value, the planned parking sites do not meet the parking needs and need to be revised.

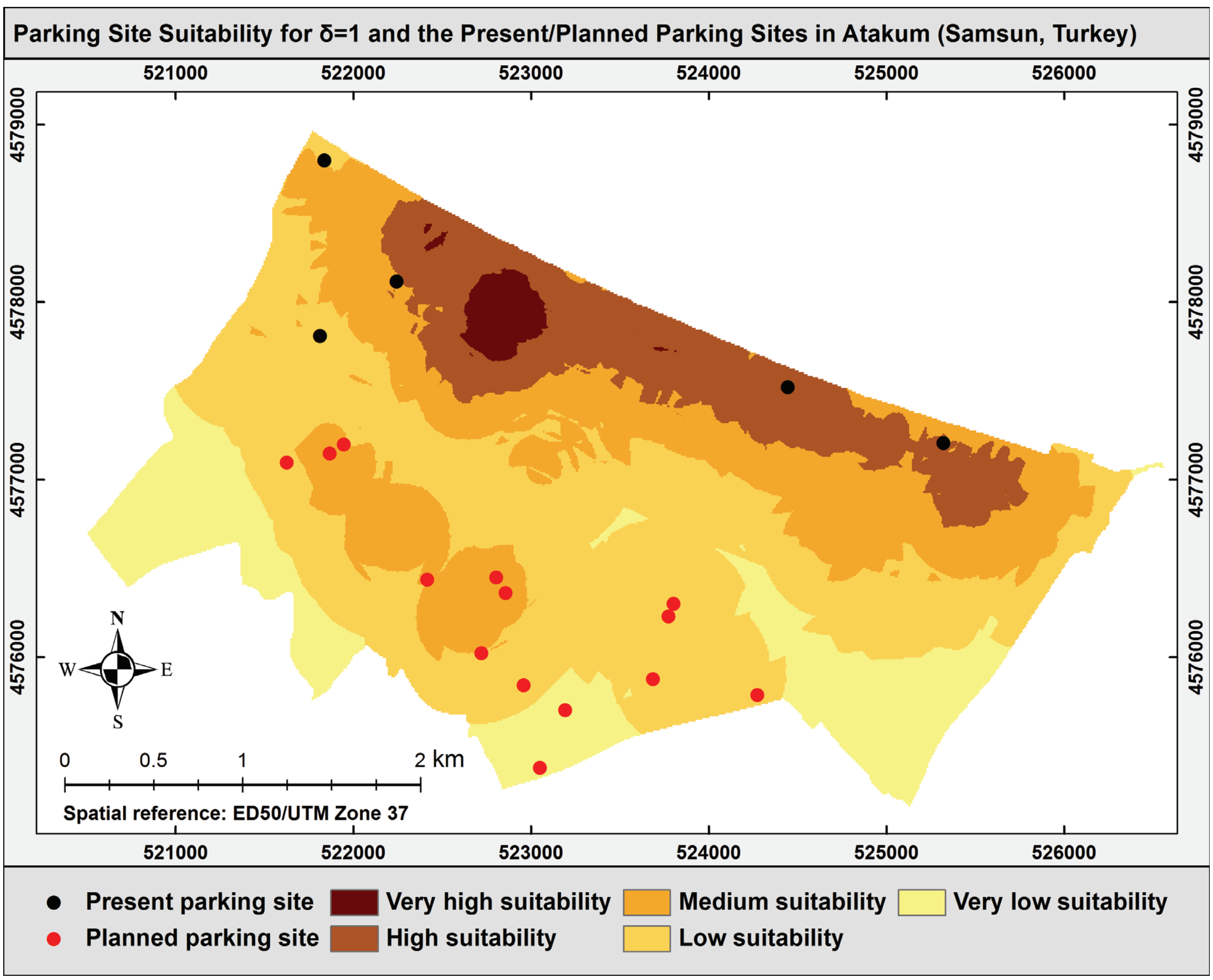

Fig. 6. Comparison between present/planned parking sites and OWA analysis results for the δ=1 value in Atakum (Samsun, Turkey). Planned parking sites are not in agreement with the needs identified by the analysis.

5. Conclusion

This study focused on the integration of OWA method and GIS for selection parking site in Atakum (Samsun, Turkey). A GIS-OWA tool developed via ArcObjects/VBA to integrate GIS and the OWA method using the ArcGIS 9.2 software was used to obtain decision strategies. In the OWA method, changeable order weights provided the different decision strategies. When the analysis result for $\delta=1$ was compared with the present and planned parking sites, it was understood that present and planned parking sites in the urban plan do not meet the parking needs. It can be concluded that the situation in Atakum must be solved by revising urban plans. However, the objective of this study was to show what the OWA method offers in the utilization of a spatial decision problem. Hence, a problem can be evaluated within a broader context by increasing the number of criteria in different fields.

Integrating GIS and the OWA method can provide faster and more effective solutions in a variety of decision making problems and particularly in site selection and planning. Because GIS-based OWA allows a user to prepare different scenarios, it also provides a flexible approach towards problem solutions and different perspectives for city planners and administrators to solve spatial problems. Thus, we believe that the current study will contribute to further studies related to spatial decision-making problems.

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تحليل القرار المتعدد المعايير المعتمد علي نظم المعلومات الجغرافية GIS لاختيار مواقع الانتظار

[1]دريا اوزتورك، [2]فاطمة جول كيليك جول
[1]قسم هندسة الجيوماتكس، جامعة Ondokuz Mayis، سامسون -تركيا
[2]قسم هندسة الجيوماتكس- جامعة يلدز التقنية، إسطنبول- تركيا

ملخص

يشير هذا البحث إلى أن اختيار الموقع هو أحد القرارات الاستراتيجية الخاصة بالتخطيط المكاني ومن ثم فهو يتطلب وضع عدد من العوامل في الاعتبار. ويعتبر دمج نظم المعلومات الجغرافية (GIS) وتحليل القرار متعدد المعايير(MCDA) في غاية الأهمية لحل المشكلات المعقدة المتعلقة بالقرار المكاني من قبيل اختيار الموقع. اعتمد هذا البحث علي دمج نظم المعلومات الجغرافية وتقنية متوسط أوزان الرتب (OWA)، والتي تعتبر أكثر طرق تحليل القرار المتعدد المعايير(MCDA)استخداما في حل مشكلات القرار المكاني، لتحليل مشكلة 'اختيار موقع وقوف السيارات' في منطقة أتاكوم Atakum (في مقاطعة سامسون في تركيا). ولقد تم تطوير جهاز GIS-OWA في برنامج السوفت وير المسمي ArcGIS9.2 من خلال تطبيقات من (ArcObjects /Visual Basic (VBA، كما تم تنفيذ تحليل القرار لاختيار موقع وقوف السيارات. وبما أن طريقة متوسط أوزان الرتب OWA تعتمد علي باراميترات المحددات المُضببة بصفة رئيسية، فعن طريق تغيير هذه المُحددات يمكن إرساء أسس واضحة لاستراتيجية القرار. ولقد قدمت السيناريوهات المختلفة مُقاربة مرنة لحل المشكلة وتمت مقارنة النتيجة التي تم التوصل إليها وهي $\delta = 1$ بمواقع الوقوف الحالية والمواقف المُخطط لها، حيث أظهرت نتائج المقارنة أن مواقع الانتظار الحالية والمواقع التي تم التخطيط لها في الخطة العمرانية لا تلبي احتياجات مواقف الانتظار.