Classification on SWARA method and an application with SMAA-2

SWARA yönteminde sınıflandırma ve SMAA-2 yöntemi ile uygulama

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Highlights

- ❖ *Categorization of the SWARA Method according to its implementations*
- ❖ *The effects of different application methods*
- ❖ *Renewable energy application*

Grafik Özet (Graphical Abstract)

In this study, different utilizations of the SWARA Method were applied to the same problem and the changes in the criterion weight values and their effects on the results were evaluated.

	1		2		3		4
	w_j		w_j		w_j		w_j
C-1	0,180	C1	0,344	C1	0,351	C1	0,249
C-2	0,164	C2	0,212	C2	0,216	C2	0,203
C-4	0,147	C4	0,143	C4	0,144	C5	0,135
C-5	0,119	C5	0,105	C5	0,104	C4	0,132
C-3	0,108	C3	0,070	C3	0,068	C3	0,115
C-8	0,097	C6	0,054	C6	0,052	C6	0,069
C-6	0,096	C8	0,040	C8	0,038	C8	0,050
C-7	0,088	C7	0,031	C7	0,027	C7	0,047

Table 11. Main Results

Aim

Bu çalışmanın amacı, SWARA Metodunun farklı uygulama yöntemlerinin kriter ağırlıkları ve alternatif seçimleri üzerindeki etkilerini ortaya çıkarmaktır. / The aim of this study is to reveal the effects of different application methods of the SWARA Method on criterion weights and alternative selection.

Design & Methodology

SWARA Metodunun değişik kullanım şekilleri literatürden alınarak aynı probleme uygulanmıştır. SMAA-2 Yöntemi ile sonuçlara etkisi değerlendirilmiştir. / Various applications of the SWARA Method were obtained from the literature and applied to the same problem. The changes in the results were determined with the SMAA-2 Method.

Originality

Deterministik bir yöntem olan SWARA Metodu, stokastik bir yöntem olan SMAA-2 ile birlikte kullanılmış ve SWARA Yönteminin uygulama şeklinin sonuca etkisi değerlendirilmiştir. / SWARA which is a deterministic method, implemented with a stochastic method SMAA-2 and the effect of the application form of the SWARA Method on the result was evaluated.

Findings

Yöntemlerin uygulamasındaki değişimin sonuçları değiştirdiği gözlemlenmiştir. / It was observed that the changes in the application of the methods affected the results.

Sonuç (Conclusion)

Önerilmiş bir yönteme değişik işlemler/adımlar/uygulamalar yapılacaksa, bu konu çalışmada açıkça belirtilmelidir. / If a different process/step/application will be added to the proposed methods from the original, this issue should be clearly stated together with the reasons in the study.

Etik Standartların Beyanı (*Declaration of Ethical Standards*)

Bu makalenin yazar(lar)ı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler. / The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Classification on SWARA Method and an Application with SMAA-2

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ABSTRACT

Multi criteria decision making methods are decision support systems guiding decision makers in real life problems. The SWARA Method is one of the multi criteria decision making methods proposed in the literature. Many changes, additional steps or mathematical operations have been added to proposed multi criteria decision methods. SWARA Method is also one of the methods that have changed in various ways. However, many studies have not provided any information on these changes. In this study, the changes/variations implemented in the steps of the method were evaluated and an application was practised with another multi criteria decision making method, SMAA-2. As a result of the application, it was observed that the criterion weights and alternative choices have changed.

Keywords: SWARA, SMAA-2, decision support, renewable energy.

SWARA Yönteminde Sınıflandırma ve SMAA-2 Yöntemi ile Uygulama

ÖZ

Çok kriterli karar verme yöntemleri karar vericilere gerçek hayat problemlerinde rehberlik eden karar destek sistemleridir. SWARA Metodu da bir çok kriterli karar verme yöntemi olarak önerilmiştir. Önerilen çok kriterli karar yöntemlerine birçok değişiklik, ek adım veya matematiksel işlem ilave edilmiştir. SWARA Metodu da değişikliğe uğrayan yöntemlerdendir. Ancak birçok çalışmada yapılan değişikliklerle ilgili herhangi bir bilgi verilmemiştir. Bu çalışmada; SWARA Yöntemin adımlarında yapılan değişiklikler değerlendirilmiş ve başka bir çok kriterli karar verme yöntemi olan SMAA-2 ile bir uygulama yapılmıştır. Uygulama sonucunda kriter ağırlıklarının ve alternatif seçimlerin değiştiği görülmüştür.

Anahtar Kelimeler: SWARA, SMAA-2, karar destek, yenilenebilir enerji.

1. INTRODUCTION

Multi criteria decision making (MCDM) methods are decision support systems including decision makers, alternatives and criteria. These methods provide decision support to managers in many real-life problems with series of some mathematical operations. In multi criteria decision making process, decision makers are mostly selected from experts and managers related to the problem area and there is also an analyst managing the study. After defining the problem, the decision making group, alternatives and criteria are determined. Usually, alternatives and criteria are determined from the literature review or/with according to the preferences of the decision making group. After these determinations, the analysts or decision makers decide the method to handle/solve or implement the problem. At this point, many methods, including multi criteria decision making process, are encountered. Here, decision makers / analysts are faced with determining the method choice.

Generally, if it is not an academic study, they prefer the clearest and the simplest method.

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There are many MCDM methods proposed in the literature. These methods have undergone changes over time, such as extending by adding/reducing some operations or implementations with fuzzy logic. As a result, their original form changes.

SWARA (Step wise weight assessment ratio analysis) Method is one of the MCDM methods that have been modified from its original form. The reason why the changes/variations in the SWARA Method subject to criticism is that the reason for the change/variation is not stated in any way and the information about the change/variation is not expressed anywhere in the studies.

In this study, instead of examining the SWARA Method, an evaluation was made to see how extensions have changed the results with an application. In order to provide the determined innovations / additions and different usage patterns in a clear and understandable way, a simple application has been made on the selection of a renewable energy source. SWARA Method was used in weighting criteria and the SMAA-2 Method was used to evaluate the alternatives in order to see the results.

The study was organized as literature review in the second part, steps of the SWARA Method including determined innovations / additions and different usage patterns in the third part, brief information about SMAA-2 in the fourth part and finally an application in the fifth part.

2. LITERATURE REVIEW

The SWARA Method was introduced for the selection of the rational dispute resolution model in 2010 [1]. After this study, this method has been widely used in many subjects. The SWARA Method is used for architect selection [2], machine tool selection [3], evaluating sustainability indicators of the energy system [4], evaluating the design of products with both internal and external perspectives [5], facility location problem (Shopping Mall Location) [6], evaluating the exterior wall modernization of residential buildings [7], evaluating the prominent criteria in high tech industry investment prioritization [8], evaluating the criteria for regions of Iran for solar projects [9], personnel selection problem (Mining Industry) [10], project selection in Iran [11], for assessment of regional landslides [12] and 3 PL provider selection problem [13]. The different forms of the SWARA Method, which is the subject of this study, are given below.

In the general literature review, it has been determined that the SWARA Method is used in four different forms (Except fuzzy logic and extended forms). These forms are considered only in the context of steps of the SWARA Method. The next part of the literature review has been continued in this context.

The authors used the SWARA Method with different mathematical operations in the step where pair wise comparisons were evaluated in their studies. In the first article where the SWARA Method was proposed, the authors asked the participants to rank the criteria of the problem in order of importance rather than making pair wise comparison and then they determined a criterion importance rating starting with the one which is the highest number of votes [1]. In some articles, different from the first application, the authors applied the SWARA Method by determining the average of the rankings of the participants or the average of the values given by the participants [14, 15]. All three studies [1, 14, 15] switched to "Comparative importance of average value (sj)" step without any pair wise comparisons. This situation has been accepted as the first implementation approach in this study.

The second implementation approach starts by asking all participants to rank the criteria. And after determining individual criteria importance orders, a new criterion importance order is obtained by the average of individual evaluations. Following this process, all SWARA steps were applied according to the new criteria order of evaluations for each participant and finally, the weight values of the participants were averaged to obtain the final weights [2, 16-20].

The third implementation approach starts with a consensus about importance order of the criteria by the participants. After that, according to this new order of criteria, the participants were asked to make pair wise comparisons then the average of these values (sj) was taken, and SWARA's steps were applied [3-13, 15, 21-26].

In the fourth implementation approach, each participant was asked to rank the criteria independently and the average of the criteria weights were determined by applying the steps of the SWARA Method separately for each participant [27-31].

As a result of the literature review, it has been determined that the SWARA Method has been performed with different mathematical operations, including the first proposal article. These differences are at the stage of determining the order of importance of the criteria and making pair wise comparisons.

In this study, the application for the selection of renewable energy sources will be presented. For this reason, studies on this subject with other MCDM methods are presented briefly.

Haralambopoulos and Polatidis, Tsoutsos et al., Mohamadabadi et al., Cavallaro, Lerche et al., used PROMETHEE, PROMETHEE I and PROMETHEE II for evaluating renewable energy sources [32-36]. Kahraman et al., Heo et al., Shen et al., Reza et al., Davoudpour et al., Pons and Aguado, Saraçoğlu, Haddad, B. et al. carried out their studies for selecting renewable energy sources with AHP and Fuzzy AHP Methods [37-44]. Doukas et al., Cavallaro, Lozano-Minguez et al., Perera et al., Şengül et al., Papapostolou et al. used TOPSIS and Fuzzy TOPSIS Methods for selecting renewable energy source and energy investment plans [44-50]. Shiue and Lin, Kabak and Dağdeviren, Cannemi et al. evaluated renewable energy alternatives with the ANP Method [51-53]. Aydın used the OWA Method [54], San Cristóbal and Vučijak et al. used the VIKOR Method [55-56], Balezentiene et al. used the Fuzzy Multi MOORA Method [57], Sánchez- Lozano et al. used the ELECTRE III Method for selecting renewable energy alternatives [58].

Besides these MCDM Models, some hybrid models are proposed for selecting renewable energy sources in the literature. Kabak et al. integrated SWOT-FANP [59], Ertay et al. used MACBETH-FUZZY AHP [60], Al-Yahyai et al. used AHP-OWA [61], Yeh and Huang used Fuzzy DEMATEL-ANP [62], Vafaeipour et al. used SWARA and WASPAS Methods [63], Georgiou et al. used PROMETHEE and AHP [64], Çelikbilek and Tüysüz used Gray ANP, DEMATEL and Gray VIKOR Methods [65] for selecting renewable energy sources and renewable energy policies.

3. SWARA METHOD

The steps of the SWARA Method are given below [1].

Phase 1: Drawing a list of attributes (Criteria)

The attributes (criteria) are determined by literature review and/or expert opinions according to the problem in the phase.

Phase 2: Respondent (Expert/Decision maker) survey

At this stage, experts/decision makers are asked to rank the determined list of criteria/attributes. Usually, the criteria with relatively low importance are eliminated in this phase. Thus the relatively most important criteria remain the final list. The final list of criteria is listed from the most important to the least important.

Phase 3: Determining the comparative importance of the average value (s_j)

Beginning with the second criterion, experts evaluate the criteria by pair wise comparisons to determine the importance of the jth criterion compared to the previous criterion $(j-1)^{th}$.

Phase 4: Calculating the coefficient values (k_j)

The coefficient value is calculated as follows:

$$k_j = \begin{cases} 1 & j=1 \\ s_j + 1 & j>1 \end{cases} \quad (1)$$

Phase 5: Determining the recalculated weight (q_j)

q_j is calculated as follows:

$$q_j = \frac{k_{j-1}}{k_j} \quad (2)$$

Phase 6: Calculating the relative weights (w_j)

The relative weights of the criteria are calculated as follows:

$$w_j = \frac{q_i}{\sum_{j=1}^{n} q_j} \quad (3)$$

3.1. Different Approaches

The main subject of this study (different application methods) is explained in this subsection. Without any justification or explanation by the authors, some changes were made in the aforementioned phases. Different usages occur in the second and third phases of the original method, in which the order of importance of the criteria is determined and pairwise comparisons are made. Varied publications are given in the literature review section. Common use with modification is presented below.

The first usage is the one suggested in the original SWARA article. The authors determined the amount of preference for criteria from a questionnaire related to the problem and eliminated ineffective ones. Then, they arranged the preferred criteria in the order of importance according to the result they obtained in the same questionnaire. And they applied the method taking the preference values as the comparative importance of the average value (s_j) by mathematically subtracting from each other.

The second usage is the one that all participants rank criteria on their opinion, then a new (final) ranking is obtained by averaging the criteria rankings, which is shown in Table 1. Final criteria order is evaluated by decision makers again and the SWARA Method is applied for each evaluation. Then the obtained weights are averaged. When Table 1 is examined, 4 criteria are ranked according to the opinion of each decision maker. The final ranking list is obtained taking the average of the rankings. After that, decision makers make pair wise comparisons of this new list.

The third usage is similar to the second usage. Again, the criteria importance order was obtained as in the second usage form, decision makers made their own pair wise comparisons, but instead of taking the average of the weight values at the end of the SWARA Method, the process was continued by taking the average of the pairwise comparisons (s_j). An example process is presented in Table 2. For a better understanding, a study accepted and published in the literature is repeated [26] and given in Table 3. When the results in Table 3 are compared, it is seen that the order of importance did not change but the weights did. A meaningful rate for this change could not be determined. If an alternative is selected by another method after criterion weighting, it is considered that changing weight values may affect the results.

Table 1. Example 1

	Exp. 1	Exp. 2	Exp. 3	Average	Final Criteria Order	Exp. 1	Exp. 2	Exp. 3	Final w_j
C-1	1	2	3	2,000	C-3				0,389
C-2	2	1	2	1,667	C-1	0,55	0,20	0,75	0,262
C-3	4	3	4	3,667	C-4	0,15	0,35	0,60	0,194
C-4	3	4	1	2,667	C-2	0,10	0,55	0,15	0,155

Table 2. Example 2

	Exp. 1	Exp. 2	Exp. 3	Average	Final Criteria Order	Exp. 1	Exp. 2	Exp. 3	Average s_j	w_j
C-1	1	2	3	2,000	C-3					0,394
C-2	2	1	2	1,667	C-1	0,55	0,20	0,75	0,500	0,263
C-3	4	3	4	3,667	C-4	0,15	0,35	0,60	0,367	0,192
C-4	3	4	1	2,667	C-2	0,10	0,55	0,15	0,267	0,152

In the last usage form; each expert declares his / her own criteria importance order and own pair wise comparison. Then, the SWARA Method is applied separately for each expert's evaluation. The results are averaged to obtain the final weights. The SWARA Method and different application methods in the literature are briefly explained with examples. It has been determined with the examples that different application methods change the weight. In the next part of the study, how much the change in criterion weights affects the choice of alternative will be determined by an application. In the application, criterion weighting was structured with the SWARA Method and alternative selection was implemented by the SMAA-2 Method. The SMAA-2 Method gives decision makers the opportunity to proportionally determine the preferred alternatives according to their evaluations. That is why the SMAA-2 Method was preferred in this study. The SMAA-2 Method is briefly explained in the next section.

Table 3. Zavadskas et al. (2017)'s study [26]

Expert		Pairwise comparison of criteria relative importance						
	X_1	X_{1-2}	X_{2-3}	X_{3-4}	X_{4-5}	X_{5-6}	X_{6-7}	X_{7-8}
1		0.10	0.85	0.20	0.60	0.20	0.80	0.00
2		0.05	0.70	0.10	0.80	0.05	0.70	0.20
3		0.80	0.20	0.70	0.50	0.10	0.70	0.00
4		0.60	0.05	0.80	0.30	0.05	0.00	0.10
5		0.50	0.40	0.60	0.70	0.30	0.65	0.10
6		0.10	0.20	0.00	0.00	0.80	0.00	0.85
7		0.70	0.30	0.60	0.40	0.00	0.50	0.10
8		0.00	0.50	0.10	0.20	0.70	0.00	0.75
9		0.70	0.10	0.05	0.05	0.80	0.00	0.00
10		0.00	0.60	0.10	0.30	0.50	0.20	0.80
Results (q_j) Second Usage	0.2758	0.2081	0.1506	0.1175	0.0891	0.0654	0.0522	0.0412
Results (q_j) Third Usage	0.2895	0.2137	0.1537	0.1160	0.0838	0.0620	0.0458	0.0355

4. SMAA-2 METHOD

Stochastic Multi Criteria Acceptability Analysis (SMAA) is a multi-criteria decision making method that can provide decision support with incomplete, incorrect or missing information and it was first proposed in 1998 [66]. After the proposal, in order to improve the method, the utility function was added to determine the best alternative (SMAA) and to rank the alternatives according to decision makers' preferences (SMAA-2) [67]. SMAA-2 Method provides decision support with multi-dimensional integral calculations in the appropriate solution space. The method relies on simulation to obtain descriptive indices. Although these indices are calculated with multi-dimensional integrals in practice, they are actually determined by Monte Carlo Simulation. Thus, a JSMAA software is presented [68]. The main results (indices) are Rank Acceptability Indices, Confidence Factors and Central Weight Vectors. Confidence factors define the preference possibility of an alternative and the central weight vectors define the expected center of weight.

Since the main subject of this study is the use of the SWARA Method, the SMAA-2 Method has been kept short. For detailed information on SMAA Methods, researchers should refer to the references section [66-72]. In this study, JSMAA v1.0.3 software was used for all calculations regarding the SMAA-2 Method.

5. APPLICATION IN RENEWABLE ENERGY

In this part of the study, a decision support system is presented for the selection of potential renewable energy sources in Turkey. In this study, 8 criteria were selected from the literature to determine the weights by the SWARA Method. Four different uses of the SWARA Method which is described in the literature review section and is the main subject of the study, were applied with 10 experts. The selection of alternatives was evaluated using the SMAA-2 Method with the weight information obtained from the SWARA Method. Background information of the experts is given in Table 4. The set of alternatives is determined according to the renewable energy potential characteristics of Turkey: Wind Energy (A1); Solar Energy (A2); Hydro Power

Energy (A3); Biomass Energy (A4); Geothermal Energy (A5).

The criteria set is determined from both literature review and expert views: Efficiency (C-1) measures the most useful energy that can be obtained from a renewable energy resource (The actual amount that can be obtained from total energy potential); Investment Costs (C-2) measure the initial investment expenditures; Operational and Maintenance Cost (C-3) measures the plant running cost, systems and equipment maintenance costs, and personnel expenses after the construction; Payback Period (C-4) represents the time of the net cash inflows to be provided by the investment to cover the investment costs; Political Aspects (C-5) indicate the national policies; Social Acceptability (C-6) represents the people's approval and opinion on renewable energy plants; Employment (C-7) indicates direct and indirect employment chances of the local people living in the place where the plant will be established (employees working at the power plant and working in the production/assembly of equipment); Impact on Ecosystem (C-8) measures the potential risks on the ecosystem such as climate change, impacts on aircraft, impacts on agricultural land, etc. Information is given for a 1 MW power plant in Appendix-A.

Table 4. Information of Experts

Organization	Position	Participant Number	Education	Experience
Government	Manager	2	Ph.D./Master	>10 Years
	Engineer	1	Bachelor	9 Years
	Facility Manager	1	Master	4 Years
Academic	Faculty Member	1	Ph.D.	>8 Years
Private Sector	Manager	2	Master	>8 Years
	Engineer	3	Master/Bachelor	1-15 Years

5.1. Determination of Criterion Importance

5.1.1. First implementation approach
10 experts were asked to rank 8 criteria according to their own opinions and evaluated the criteria by pair wise comparisons. Calculating the average of wise comparisons, the new criterion importance order is obtained. After obtaining the new order, the weights were determined implementing the operations of the study conducted by Keršuliene et al., (2010) [1]. Expert views and operations are shown in Table 5 and Table 6.

Table 5. Expert Views

Cr.	Exp. 1	Cr.	Exp. 2	Cr.	Exp. 3	Cr.	Exp. 4	Cr.	Exp. 5	Cr.	Exp. 6	Cr.	Exp. 7	Cr.	Exp. 8	Cr.	Exp. 9	Cr.	Exp. 10
1	1,00	2	1,00	4	1,00	2	1,00	5	1,00	1	1,00	1	1,00	2	1,00	1	1,00	1	1,00
2	0,75	1	0,50	2	0,80	4	0,20	1	0,90	5	0,30	2	0,85	1	0,85	2	0,50	5	0,90
4	0,25	3	0,80	1	0,75	3	0,20	2	0,55	4	0,90	3	0,20	4	0,50	3	0,30	2	0,40
5	0,55	6	0,40	3	0,20	5	0,10	3	0,10	3	0,25	4	0,85	3	0,20	6	0,20	4	0,50
3	0,80	4	0,85	6	0,10	1	0,80	4	0,75	2	0,95	6	0,10	5	0,10	4	0,90	3	0,20
6	0,50	5	0,30	5	0,30	8	0,15	6	0,20	7	0,10	5	0,30	8	0,10	5	0,50	8	0,05
8	0,20	8	0,60	8	0,35	7	0,20	8	0,25	8	0,15	7	0,05	7	0,10	7	0,10	7	0,10
7	0,10	7	0,25	7	0,10	6	0,20	7	0,10	6	0,15	8	0,15	6	0,05	8	0,15	6	0,20

Table 6. First implementation approach

New Criteria Importance Order (Average Value of expert views)		s_j	k_j	q_j	Final w_j
C-1	0,880		1,000	1,000	0,180
C-2	0,780	0,100	1,100	0,909	0,164
C-4	0,670	0,110	1,110	0,819	0,147
C-5	0,435	0,235	1,235	0,663	0,119
C-3	0,325	0,110	1,110	0,597	0,108
C-8	0,215	0,110	1,110	0,538	0,097
C-6	0,210	0,005	1,005	0,536	0,096
C-7	0,120	0,090	1,090	0,491	0,088

5.1.2. Second implementation approach

10 experts were asked to rank 8 criteria according to their own opinions and a new criteria importance order was determined by calculating the geometric mean of these rankings. The new ranking was evaluated by pairwise comparisons by decision makers and then 10 sets of criteria weights were obtained by applying the steps of the SWARA Method. The final weights were found by averaging these weights. The calculations are shown in Table 7; expert views and calculations are presented in Appendix-B.

Table 7. Second implementation approach

	Expert views										Geometric Mean	New Criteria Importance Order	Final w_j
	1	2	3	4	5	6	7	8	9	10			
C-1	1	2	3	5	2	1	1	2	1	1	1,614	C-1	0,344
C-2	2	1	2	1	3	5	2	1	2	3	1,931	C-2	0,212
C-3	5	3	4	3	4	4	3	4	3	5	3,728	C-4	0,143
C-4	3	5	1	2	5	3	4	3	5	4	3,187	C-5	0,105
C-5	4	6	6	4	1	2	6	5	6	2	3,646	C-3	0,070
C-6	6	4	5	8	6	8	5	8	4	8	5,985	C-6	0,054
C-7	8	8	8	7	8	6	7	7	7	7	7,271	C-8	0,040
C-8	7	7	7	6	7	7	8	6	8	6	6,865	C-7	0,031

5.1.3. Third implementation approach

10 experts were asked to rank 8 criteria according to their own opinions and a new criteria importance order was determined by calculating the geometric mean of these rankings [2, 10, 17-20], which was shown in Table 7. The new ranking was evaluated by pairwise comparisons by decision makers, which was presented in Appendix-B. By applying the SWARA Method, the weights were calculated. The weights are shown in Table 8.

Table 8. Third implementation approach

	The average of experts' pairwise comparisons (s_j)	k_j	q_j	Final w_j
C-1	-	1,000	1,000	0,351
C-2	0,625	1,625	0,615	0,216
C-4	0,495	1,495	0,412	0,144
C-5	0,395	1,395	0,295	0,104
C-3	0,530	1,530	0,193	0,068
C-6	0,300	1,300	0,148	0,052
C-8	0,370	1,370	0,108	0,038
C-7	0,390	1,390	0,078	0,027

5.1.4. Fourth implementation approach

Each decision maker was asked to rank the criteria independently and then the average of the criteria weights was determined by applying the steps of the SWARA Method separately for each decision makers' evaluation.

The weight sets of 10 decision makers are shown in Table 9 and final results are shown in Table 10. Decision makers' evaluations and the calculations are presented in Appendix-C.

Table 9. Weight sets of 10 decision makers

	Expert 1		Expert 2		Expert 3		Expert 4		Expert 5		Expert 6		Expert 7		Expert 8		Expert 9		Expert 10
1	0,361	2	0,373	4	0,354	2	0,234	5	0,367	1	0,327	1	0,341	2	0,316	1	0,309	1	0,346
2	0,206	1	0,249	2	0,197	4	0,195	1	0,193	5	0,251	2	0,185	1	0,171	2	0,206	5	0,182
4	0,165	3	0,138	1	0,112	3	0,162	2	0,125	4	0,132	3	0,154	4	0,114	3	0,158	2	0,130
5	0,106	6	0,099	3	0,094	5	0,147	3	0,113	3	0,106	4	0,083	3	0,095	6	0,132	4	0,087
3	0,059	4	0,053	6	0,085	1	0,082	4	0,065	2	0,054	6	0,076	5	0,086	4	0,069	3	0,072
6	0,039	5	0,041	5	0,065	8	0,071	6	0,054	7	0,049	5	0,058	8	0,078	5	0,046	8	0,069
8	0,033	8	0,026	8	0,049	7	0,059	8	0,043	8	0,043	7	0,055	7	0,071	7	0,042	7	0,063
7	0,030	7	0,021	7	0,044	6	0,049	7	0,039	6	0,037	8	0,048	6	0,068	8	0,037	6	0,052

Table 10. Results

	Final w_j
C-1	0,249
C-2	0,203
C-3	0,115
C-4	0,132
C-5	0,135
C-6	0,069
C-7	0,047
C-8	0,050

As a result of the operations, four different approaches, the criteria weights and rankings are presented in Table 11. As can be seen, it is clear that the rankings and criterion weights have changed. SMAA-2 Method was used to see how the differences effect the alternative choices determined in four different approaches.

Table 11. Main Results

	1 w_j		2 w_j		3 w_j		4 w_j
C-1	0,180	C1	0,344	C1	0,351	C1	0,249
C-2	0,164	C2	0,212	C2	0,216	C2	0,203
C-4	0,147	C4	0,143	C4	0,144	C5	0,135
C-5	0,119	C5	0,105	C5	0,104	C4	0,132
C-3	0,108	C3	0,070	C3	0,068	C3	0,115
C-8	0,097	C6	0,054	C6	0,052	C6	0,069
C-6	0,096	C8	0,040	C8	0,038	C8	0,050
C-7	0,088	C7	0,031	C7	0,027	C7	0,047

5.2. SMAA-2 Results

SMAA-2, which is a very effective MCDM method, can be used in real life problems. SMAA Method calculations can be implemented on a java-based software (JSMAA). It has been previously stated that the outputs of this method are rank acceptability indices, confidence factors and central weight vectors. The rank acceptability indices should be evaluated as the probability of choosing an alternative. Therefore, the criteria weights belonging to four different approaches, may not change the ranks but may change the acceptance rates.

The information given in Appendix-A has been entered into the JSMAA Software together with the weight information which were obtained by SWARA approaches. The obtained results are presented in Table 12.

When Table 12 is examined, it is seen that the A-1 alternative is preferred in the first place in each approach. In the first and fourth approaches, it is seen that the probability of choosing the A-1 alternative in the first place is 100 % and the confidence factor is 100 %, but in the second and third approaches, it is seen that the probability of choosing the A-1 alternative in the first place is 98 % and the confidence factors are 98 % and 97 % .

When the second and third rows are examined, it is seen that the places of the alternatives have also changed. This is an indication that the criterion weight values may affect alternative preferences.

Table 12. SMAA-2 Results

	1			2			3			4	
Rank	%	CF	Rank	%	CF	Rank	%	CF	Rank	%	CF
A1	1,00	1	A1	0,98	0,98	A1	0,98	0,97	A1	1,00	1
A2	0,90	1	A3	0,61	0,02	A3	0,60	0,00	A2	0,68	1
A3	0,48	1	A2	0,63	0,00	A2	0,62	0,03	A3	0,63	1
A4	0,56	1	A4	0,98	1	A4	0,98	1	A4	0,95	1
A5	1,00	1	A5	1,00	1	A5	1,00	1	A5	1,00	1

6. CONCLUSION

Many multi criteria decision making methods are proposed as decision support systems to choose the best alternatives. These methods never remained as suggested. Many changes, additional steps or mathematical operations such as fuzzy logic were added to these methods in order to provide more precise and clear solutions. SWARA Method emerges as a method in which the decision makers/experts can express themselves more easily. It is known that the number of pair wise comparisons and the mathematical operations are relatively low. At the same time, the accuracy of the solution depends on the decision makers/experts' predictions.

In this study, the changes/variations (except fuzzy logic and extensions) which were applied in the SWARA Method were evaluated. As a result, with the same evaluations and the same problem area, it was determined that the weights, the order of importance and values of the criteria changed and affected the alternative choices. It has been also determined that the authors/researchers used different forms/steps of the SWARA Method without any justification or explanation. The main subject of this study was the effect/outcome of changes in the SWARA Method. If a different process/step/application from the original one is to be added to the proposed methods, this issue should be stated together with the reasons in the study.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Özer EROĞLU: Performed the design and implementation of the research, wrote the manuscript.

Cevriye GENCER: Analysed the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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Appendix A

	Criteria		Alternatives	Measurement	Definition
C-1	Efficiency	A1	Wind Energy	30-40	The percentage of technical potential that can be technically transformed into electrical energy.
		A2	Solar Energy	30-35	
		A3	Hydro Power Energy	70-80	
		A4	Biomass Energy	45-50	
		A5	Geothermal Energy	25-30	
C-2	Investment Costs	A1	Wind Energy	1 300 000 ($)	The investment costs of 1 MW power plant
		A2	Solar Energy	1 200 000 ($)	
		A3	Hydro Power Energy	4 000 000 ($)	
		A4	Biomass Energy	2 500 000 ($)	
		A5	Geothermal Energy	3 500 000 ($)	
C-3	Operation and Maintenance Costs	A1	Wind Energy	1 200 ($)	The cost of 1 MW/h of electricity that can be produced
		A2	Solar Energy	1 400 ($)	
		A3	Hydro Power Energy	203 ($)	
		A4	Biomass Energy	1 300 ($)	
		A5	Geothermal Energy	1 500 ($)	
C-4	Payback period	A1	Wind Energy	3-4 years	Varies according to the size of the investment project.
		A2	Solar Energy	4-5 years	
		A3	Hydro Power Energy	6-9 years	
		A4	Biomass Energy	6-8 years	
		A5	Geothermal Energy	5-8 years	
C-5	Political Aspects	A1	Wind Energy	1	Decision makers ranked the state support policy in an order of 1-5. (1 the most supported, 5 the least supported). This ranking was obtained as a result of the decision makers' consensus.
		A2	Solar Energy	2	
		A3	Hydro Power Energy	5	
		A4	Biomass Energy	3	
		A5	Geothermal Energy	4	
C-6	Social Acceptability	A1	Wind Energy	1	Decision makers ranked the social acceptability in an order of 1-5. (1 the most accepted, 5 the least accepted). This ranking was obtained as a result of the decision makers' consensus.
		A2	Solar Energy	2	
		A3	Hydro Power Energy	5	
		A4	Biomass Energy	3	
		A5	Geothermal Energy	4	
C-7	Employment	A1	Wind Energy	0.40-0.55	Employment range of per MW.
		A2	Solar Energy	0.15-0.32	
		A3	Hydro Power Energy	0.16-1.66	
		A4	Biomass Energy	1.79-2.92	
		A5	Geothermal Energy	0.44-1.27	
C-8	Impact on Ecosystem	A1	Wind Energy	1	Decision makers ranked the impacts in order of 1-5. (1 the most impacts, 5 the least impacts). This ranking was obtained as a result of the decision makers' consensus
		A2	Solar Energy	2	
		A3	Hydro Power Energy	5	
		A4	Biomass Energy	4	

Appendix B

Exp. 1	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,361
C-2	0,75	1,75	0,571	0,206
C-4	0,25	1,25	0,457	0,165
C-5	0,55	1,55	0,295	0,106
C-3	0,80	1,80	0,164	0,059
C-6	0,50	1,50	0,109	0,039
C-8	0,20	1,20	0,091	0,033
C-7	0,10	1,10	0,083	0,030
			2,770	

Exp. 2	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,406
C-2	0,75	1,75	0,571	0,232
C-4	0,85	1,85	0,309	0,125
C-5	0,30	1,30	0,238	0,097
C-3	0,80	1,80	0,132	0,054
C-6	0,40	1,40	0,094	0,038
C-8	0,45	1,45	0,065	0,026
C-7	0,25	1,25	0,052	0,021
			2,461	

Exp. 3	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,259
C-2	0,40	1,40	0,714	0,185
C-4	0,35	1,35	0,529	0,137
C-5	0,20	1,20	0,441	0,114
C-3	0,20	1,20	0,367	0,095
C-6	0,10	1,10	0,334	0,087
C-8	0,35	1,35	0,247	0,064
C-7	0,10	1,10	0,225	0,058
			3,858	

Exp. 4	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,325
C-2	0,75	1,75	0,571	0,186
C-4	0,20	1,20	0,476	0,155
C-5	0,20	1,20	0,397	0,129
C-3	0,80	1,80	0,220	0,072
C-6	0,40	1,40	0,157	0,051
C8	0,15	1,15	0,137	0,045
C-7	0,20	1,20	0,114	0,037
			3,073	

Exp. 5	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,329
C-2	0,55	1,55	0,645	0,212
C-4	0,50	1,50	0,430	0,141
C-5	0,60	1,60	0,269	0,088
C-3	0,20	1,20	0,224	0,074
C-6	0,20	1,20	0,187	0,061
C-8	0,25	1,25	0,149	0,049
C-7	0,10	1,10	0,136	0,045
			3,040	

Exp. 6	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,378
C-2	0,80	1,80	0,556	0,210
C-4	0,70	1,70	0,327	0,124
C-5	0,10	1,10	0,297	0,112
C-3	0,50	1,50	0,198	0,075
C-6	0,40	1,40	0,141	0,054
C-8	0,75	1,75	0,081	0,031
C-7	0,85	1,85	0,044	0,017
			2,644	

Exp. 7	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,390
C-2	0,85	1,85	0,541	0,211
C-4	0,70	1,70	0,318	0,124
C-5	0,30	1,30	0,245	0,095
C-3	0,45	1,45	0,169	0,066
C-6	0,20	1,20	0,141	0,055
C-8	0,50	1,50	0,094	0,037
C-7	0,65	1,65	0,057	0,022
			2,563	

Exp. 8	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,276
C-2	0,25	1,25	0,800	0,221
C-4	0,30	1,30	0,615	0,170
C-5	0,20	1,20	0,513	0,141
C-3	0,80	1,80	0,285	0,079
C-6	0,40	1,40	0,204	0,056
C-8	0,50	1,50	0,136	0,037
C-7	0,80	1,80	0,075	0,021
			3,628	

Exp. 9	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,362
C-2	0,50	1,50	0,667	0,242
C-4	0,60	1,60	0,417	0,151
C-5	0,90	1,90	0,219	0,079
C-3	0,30	1,30	0,169	0,061
C-6	0,20	1,20	0,141	0,051
C-8	0,50	1,50	0,094	0,034
C-7	0,75	1,75	0,054	0,019
			2,759	

Exp. 10	s_j	k_j	q_j	w_j
C-1		1,00	1,000	0,351
C-2	0,65	1,65	0,606	0,213
C-4	0,50	1,50	0,404	0,142
C-5	0,60	1,60	0,253	0,089
C-3	0,45	1,45	0,174	0,061
C-6	0,20	1,20	0,145	0,051
C-8	0,05	1,05	0,138	0,049
C-7	0,10	1,10	0,126	0,044
			2,846	

Appendix C

Exp. 1	s_j	k_j	q_j	w_j
C-1	0,00	1,00	1,000	0,361
C-2	0,75	1,75	0,571	0,206
C-4	0,25	1,25	0,457	0,165
C-5	0,55	1,55	0,295	0,106
C-3	0,80	1,80	0,164	0,059
C-6	0,50	1,50	0,109	0,039
C-8	0,20	1,20	0,091	0,033
C-7	0,10	1,10	0,083	0,030
			2,770	

Exp. 2	s_j	k_j	q_j	w_j
C-2	0,00	1,00	1,000	0,373
C-1	0,50	1,50	0,667	0,249
C-3	0,80	1,80	0,370	0,138
C-6	0,40	1,40	0,265	0,099
C-4	0,85	1,85	0,143	0,053
C-5	0,30	1,30	0,110	0,041
C-8	0,60	1,60	0,069	0,026
C-7	0,25	1,25	0,055	0,021
			2,678	

Exp. 3	s_j	k_j	q_j	w_j
C-4	0,00	1,00	1,000	0,354
C-2	0,80	1,80	0,556	0,197
C-1	0,75	1,75	0,317	0,112
C-3	0,20	1,20	0,265	0,094
C-6	0,10	1,10	0,241	0,085
C-5	0,30	1,30	0,185	0,065
C-8	0,35	1,35	0,137	0,049
C-7	0,10	1,10	0,125	0,044
			2,825	

Exp. 4	s_j	k_j	q_j	w_j
C-2	0,00	1,00	1,000	0,234
C-4	0,20	1,20	0,833	0,195
C-3	0,20	1,20	0,694	0,162
C-5	0,10	1,10	0,631	0,147
C-1	0,80	1,80	0,351	0,082
C-8	0,15	1,15	0,305	0,071
C-7	0,20	1,20	0,254	0,059
C-6	0,20	1,20	0,212	0,049
			4,281	

Exp. 5	s_j	k_j	q_j	w_j
C-5	0,00	1,00	1,000	0,367
C-1	0,90	1,90	0,526	0,193
C-2	0,55	1,55	0,340	0,125
C-3	0,10	1,10	0,309	0,113
C-4	0,75	1,75	0,176	0,065
C-6	0,20	1,20	0,147	0,054
C-8	0,25	1,25	0,118	0,043
C-7	0,10	1,10	0,107	0,039
			2,722	

Exp. 6	s_j	k_j	q_j	w_j
C-1	0,00	1,00	1,000	0,327
C-5	0,30	1,30	0,769	0,251
C-4	0,90	1,90	0,405	0,132
C-3	0,25	1,25	0,324	0,106
C-2	0,95	1,95	0,166	0,054
C-7	0,10	1,10	0,151	0,049
C-8	0,15	1,15	0,131	0,043
C-6	0,15	1,15	0,114	0,037
			3,061	

Exp. 7	s_j	k_j	q_j	w_j
C-1	0,00	1,00	1,000	0,341
C-2	0,85	1,85	0,541	0,185
C-3	0,20	1,20	0,450	0,154
C-4	0,85	1,85	0,243	0,083
C-6	0,10	1,10	0,221	0,076
C-5	0,30	1,30	0,170	0,058
C-7	0,05	1,05	0,162	0,055
C-8	0,15	1,15	0,141	0,048
			2,929	

Exp. 8	s_j	k_j	q_j	w_j
C-2	0,00	1,00	1,000	0,316
C-1	0,85	1,85	0,541	0,171
C-4	0,50	1,50	0,360	0,114
C-3	0,20	1,20	0,300	0,095
C-5	0,10	1,10	0,273	0,086
C-8	0,10	1,10	0,248	0,078
C-7	0,10	1,10	0,226	0,071
C-6	0,05	1,05	0,215	0,068
			3,163	

Exp. 9	s_j	k_j	q_j	w_j
C-1	0,00	1,00	1,000	0,309
C-2	0,50	1,50	0,667	0,206
C-3	0,30	1,30	0,513	0,158
C-6	0,20	1,20	0,427	0,132
C-4	0,90	1,90	0,225	0,069
C-5	0,50	1,50	0,150	0,046
C-7	0,10	1,10	0,136	0,042
C-8	0,15	1,15	0,119	0,037
			3,237	

Exp. 10	s_j	k_j	q_j	w_j
C-1	0,00	1,00	1,000	0,346
C-5	0,90	1,90	0,526	0,182
C-2	0,40	1,40	0,376	0,130
C-4	0,50	1,50	0,251	0,087
C-3	0,20	1,20	0,209	0,072
C-8	0,05	1,05	0,199	0,069
C-7	0,10	1,10	0,181	0,063
C-6	0,20	1,20	0,151	0,052
			2,892	