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DEMAND SIDE RESPONSE PROGRAM FOR MORE SUSTAINABLE ELECTRICITY MARKET: A CASE STUDY OF TÜRKİYE

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Abstract. This study aims to examine Demand Side Response (DSR) programs, where the consumer side actively participates, to determine the most competitive, transparent, flexible, and suitable program for the structure of the Türkiye electricity market. The objective is to select one of the Demand Side Response (DSR) programs, using mathematical methods, that can provide the most effective response to Türkiye's increasing energy demand and present a market-specific proposal. The limited energy resources, losses in transmission, and environmental problems collectively drive the direction toward more efficient and economical energy use on the demand side (Benek Arslan, 2021). Therefore, various pricing programs and tariff strategies are implemented to regulate and balance demand (Özpınar, 2021). One of these pricing and tariff programs is the Demand Side Response (DSR) program, where consumption is reduced against fluctuations in energy prices in the electricity market or in case of system constraints and security (Hasanova & Varbak, 2021). The main objective of DSR programs is to offer energy to consumers at more affordable prices while ensuring an uninterrupted and sustainable energy supply. These programs promote energy efficiency among consumers, encouraging energy conservation and contributing to more sustainable energy consumption (Acar, Yule Bennett, & Scott, 2021). In this study, firstly, general information about demand side response (DSR) implemented in electricity markets is presented. The method section includes the analysis of DSR programs. The study aims to minimize the high prices in the market, system security, and transmission constraints by selecting one of the DSR programs and to encourage conscious consumption by managing energy consumption on the consumer side.

Keywords: Electricity market; Türkiye; demand side response; demand side response programs; multi-criteria decision making; sustainability; energy pricing; economic development

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1. Introduction

Electricity markets are a control mechanism that ensures electricity reaches consumers at the most favourable prices, economically and efficiently, by balancing supply and demand (Silva-Rodriguez, Sanjab, Fumagalli, Virag, & Gibescu, 2022). In this structure, producers constitute the supply side and consumers the demand side, while pricing is shaped according to supply (Çatak, 2022). Increasing electricity consumption, supply constraints, and environmental problems lead to high electricity prices in the market (Guan, Yan, Shan, Zhou, & Hang, 2023). In this case, the demand side should take an active role in the market by going beyond consumer habits with specific measures and systems. In international markets, the demand side is included in the market within the framework of specific mechanisms and rules and plays an active role in price formation (Tör, Oğuz, Kısakürek, Kurşuncu, & Köksal, 2021). In Türkiye's electricity markets, which have evolved with liberalization, prices are shaped by optimizing supply and demand, while energy trade is generally conducted between producers and wholesalers (Gözen, 2020). However, this creates constraints for consumers to react to price changes and provide market flexibility, leading to an inefficient market problem.

DSR programs in electricity markets allow consumers to restrict their consumption in the short, medium, and long terms as they wish. Therefore, it will be decided which program to integrate into which market, when, and under which conditions. This study selected the most suitable DSR program for the Türkiye electricity market through a mathematical approach. This approach will determine the DSR program that can quickly and easily integrate the consumer side into the currently traded markets. Our research has examined DSR programs that alter and manage consumer consumption habits in response to the increasing changes in electricity prices.

DSR programs regulate consumers' electricity usage habits by adjusting the amount and timing of consumption by shifting electricity consumption from peak to off-peak periods (Sarker, ve diğerleri, 2021). These programs are categorized into two headings (Vinoth Kumar, Sivakumar, & Rajan Singaravel, 2021).

1.1. Price-Based Demand Response

In these programs, consumers who voluntarily participate are billed with more favorable pricing by reducing their electricity consumption according to price signals in the market (Kansal & Rajive, 2023). In price-based demand response, there are three different pricing programs: Time-of-use pricing, Critical peak pricing, and Real-time pricing (Kholerdi & Ghasemi-Marzbali, 2021).

- **Time-of-Use Pricing:** A program that allows consumers to adjust their energy consumption using a mechanism during periods of high demand and high prices. Through this program, consumers can use energy at a more economical price by distributing their energy consumption demands in a more balanced manner. (Wesseh Jr. & Lin, 2022)
- **Critical Peak Pricing:** A pricing program designed to encourage consumers to reduce energy usage during critical hours, such as when unexpected system conditions occur or when distribution companies face high prices in wholesale electricity purchases. Consumers in this program receive price reductions for electricity usage during periods without critical peak pricing.
- **Real-Time Pricing:** A program that aims to reduce a consumer's energy consumption by adjusting it to real-time prices, which are usually announced one day in advance, one hour in advance, or 15 minutes in advance. To implement this program, a two-way communication infrastructure must ensure continuous communication between energy providers and consumers. This communication infrastructure informs consumers instantaneously when and at what levels energy prices are. Thus, consumers can shift their energy consumption to low-cost hours or adjust their energy use in line with their needs. (Li, Wan, & He, 2020)

1.2. Incentive-Based Demand Response

It is a mechanism where financial incentives are offered if the consumer reduces energy consumption in response to demand reduction calls by the system operator. Participation in this mechanism is voluntary; however, sanctions may be imposed on consumers who do not reduce their energy consumption or fulfil their contractual commitments after joining. Incentive-based demand response can be implemented in five ways: Direct Load Control, Interruptible Programs, Demand Bidding/Buyback Programs, Emergency Programs, Capacity Market, and Ancillary Services Market. (Dewangan, ve diğerleri, 2023)

- **Direct Load Control:** A program aimed at ensuring the security of the energy system by remotely switching on/off electric devices of residential and small commercial consumers by the system operator. Consumers participating in this program often receive discounts on their electricity bills.
- **Interruptible/Curtailable Programs:** A program that offers tariff reductions to usually large industrial (or commercial) consumers who agree to reduce their energy consumption in response to issues or limitations in electric systems. Consumers who refuse to reduce their consumption may face penalties such as higher electricity prices or be excluded from the program.
- **Demand Bidding/Buyback Programs:** Programs encouraging large industrial (or commercial) consumers or their representatives to actively participate in wholesale electricity markets by offering commitments to reduce consumption at a specified price. Additionally, it is a program where bids made to meet consumption in the market are retrieved through consumption reduction. Consumers accepting bids in this program face penalties if they fail to reduce consumption.
- **Emergency Markets:** A program that incentivizes consumers to reduce their usage in situations related to system security. Consumers participating in this program might face penalties if they do not reduce their consumption.
- **Capacity Markets:** Programs providing incentive payments to consumers committing to reduce their loads in case of unexpected events in the system. These programs often impose severe penalties for consumers failing to respond when load reduction is requested.
- **Ancillary Services Market:** Programs that provide incentive payments to consumers offered by the system operator in exchange for their commitment to reduce their load. This commitment allows them to stand ready as an operating reserve. If the system operator requests load reductions, consumers are usually paid based on spot market prices.

While DSR programs offer consumers the flexibility to respond to price changes, they also enable more efficient use of the electricity grid (Yu, Ho Hong, Ding, & Ye, 2019). This allows consumers to manage their consumption in the face of increasing electricity prices, thereby saving on their bills (Bucher et al., 2023). As a system operator, balancing energy demand at all times ensures more effective utilization of energy resources. Additionally, it enhances system security by reducing the risks of interruptions due to system overload.
Many studies have shown that in terms of energy efficiency, decarbonization, and system flexibility, the DSR focuses on systems or policies to be implemented in electricity markets in Türkiye (Acar, Yule Bennett, & Scott, 2021). In this context, SWARA and TOPSIS, which are multi-criteria decision-making (MCDM) methods, and which of the DSR models can be integrated into the Türkiye electricity market structure quickly and easily have been studied.

In the literature studies we examined, Şanlı and Alanyalı, in their 2013 study, emphasized the advantages of DSR in Türkiye's energy market (Şanlı & Alanyalı, 2013). Beşli and Dağtekin, in their 2020 study, compared the price advantages brought by Real-Time Pricing, one of the DSR programs, and the low energy prices it provides to consumers (Beşli & Dağtekin, 2020). In the study conducted by Çakmak and Altaş in 2020, consumers attitudes towards the DSR program based on load shifting in smart grid technologies were examined (Çakmak & Altaş, 2020). In a study conducted by Hasanova and Varbak Neşe in 2021, energy consumption in residential buildings was addressed with demand-side management strategies through smart building technologies (Hasanova & Varbak, 2021). In the study conducted by Benek et al. in 2021, the importance of DSR in ensuring energy efficiency and savings was investigated and current practices were evaluated (Benek Arslan, 2021).

2. Methods

In this study, to determine the most appropriate DSR program for the Türkiye electricity market, DSR programs will be analyzed using SWARA and TOPSIS, two of the MCDM methods.

2.1. Multi-Criteria Decision Making (MCDM)

Decision-making is the process of selecting one or more alternatives that provide a solution according to certain criteria. While the decision-making process is simple when there is a single solution to the problem encountered,

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the increase in criteria or conflicting criteria makes it difficult to choose between alternatives. (Więckowski, Kizielewicz, Shekhovtsov, & Sałabun, 2023) In this context, the Multi-Criteria Decision Making (MCDM) method facilitates the decision-making process by comparing the criteria with each other and choosing the most suitable alternative for the purpose of the problem. It helps the decision-maker to make a choice between conflicting criteria.

The general approach to the decision-making process with MCDM methods is as follows (Yalçın, Kılıç, & Delen, 2022)

- The problem is defined.
- Criteria are identified to evaluate alternatives that provide a solution to the problem.
- Alternatives are identified.
- Alternatives are evaluated according to the criteria.
- The best alternative is found.

While Multiple Criteria Decision Making (MCDM) methods are utilized in various fields such as engineering, project management, environmental studies, energy, and more, some of the commonly used MCDM methods include AHP, ANP, SWARA, SAW, PROMETHEE, ELECTRE, and VIKOR methods (Taherdoost & Madanchian, 2023).

In our study, the criteria for the DSR program to be implemented in the Türkiye electricity market are initially weighted using the SWARA method. Subsequently, the TOU programs are ranked based on the weighted criteria using the TOPSIS method to select the most suitable program.

2.2. SWARA Method

The SWARA method, initially used by Keršuliene, Zavadskas, and Turskis (2010), is referred to as 'Step-Wise Weight Assessment Ratio Analysis' (Jafarzadeh Ghoushchi, Garg, Rahnamay Bonab, & Rahimi, 2023). A notable feature of this method is its capability to evaluate experts' opinions regarding the prioritization of criteria (Rahmati, Mahdavi, Ghoushchi, Tomaskova, & Haseli, 2022). According to expert opinions, the most critical criterion is placed at the top, while the least critical criterion is placed at the bottom, prioritizing and evaluating the criteria (Alinezhad, & Khalili, 2019). The procedural steps of the method are as follows:

- Criteria are determined to be independent of each other.
- The decision-maker assesses the importance of each criterion starting from the second criterion. For this, it compares criterion j with criterion j-1 (1).
  $k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases}$ is determined by the coefficient factor (k_j). (1)
  Where:
  k_j = Coefficient factor; j = Criterion; s_j = Comparative importance of average value
- $* q_j = \begin{cases} 1 & j = 0 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases}$ is determined by the variable (q_j). (2)
  Where:
  $* q_j$ = Recalculated weight; j = Criterion; q_j = Variable; k_j = Coefficient factor
- $w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}$ represents the relative value of the weights of criteria determined by each expert (3).
  Where:
  w_j = Importance weight; q_j = Recalculated weight

In our study, in line with the opinions of experts, the evaluation criteria to be used to select the most appropriate DSR program for Türkiye's electricity market structure were determined in Table 1.

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Table 1. Criteria and Definitions for the DSR Program

	CRITERIA	DEFINITION
C_1	**Transparency**	A transparent and fair market environment should be established. Trade secrets should be guaranteed for all market participants and market processes should be openly shared.
C_2	**Competitive**	It should encourage competition. It is important that different participants enter the market and provide demand at competitive prices. This way, the market works efficiently, and consumers are better served.
C_3	**Flexibility**	Market participants should be offered flexibility. Mechanisms enabling participants to handle various forms of demand and capacity should be in place, thereby enhancing the ability to meet energy market demands more effectively.
C_4	**Technology Integration**	Encourage the use of advanced technologies. By integrating smart meters, automated demand management systems, and other advanced technologies, DSR users can be managed more effectively and improve market functioning.
C_5	**Consumer Protection**	Protect the rights of consumers. Consumers should be informed and educated about the DSR. In addition, necessary measures should be taken regarding the privacy and security of consumer data.
C_6	**Regulatory compliance**	It should comply with the energy legislation in Türkiye. It needs to be in line with regulations and policies governing energy markets and should be integrated into the existing legal framework.

To determine the importance of the criteria, 32 market experts ranked each criterion from most important to least important, as shown in Table 2,3,4 below.

Table 2. Assessment of Criteria by Market Experts

	Criteria	DM_1	DM_2	DM_3	DM_4	DM_5	DM_6	DM_7	DM_8	DM_9	DM_{10}	DM_{11}	DM_{12}	DM_{13}
1	C_6	0,19	0,15	0,17	0,23	0,13	0,13	0,12	0,30	0,05	0,19	0,21	0,19	0,14
2	C_1	0,17	0,17	0,15	0,16	0,20	0,14	0,13	0,28	0,25	0,23	0,19	0,18	0,16
4	C_5	0,16	0,19	0,18	0,18	0,18	0,12	0,26	0,21	0,42	0,10	0,14	0,16	0,21
3	C_4	0,18	0,16	0,20	0,13	0,17	0,30	0,21	0,06	0,03	0,10	0,16	0,15	0,15
5	C_2	0,15	0,18	0,12	0,15	0,17	0,17	0,18	0,11	0,16	0,27	0,17	0,17	0,16
6	C_3	0,14	0,15	0,19	0,15	0,15	0,13	0,11	0,04	0,09	0,12	0,13	0,15	0,18

Table 3. Assessment of Criteria by Market Experts-Continued

	Criteria	DM_{14}	DM_{15}	DM_{16}	DM_{17}	DM_{18}	DM_{19}	DM_{20}	DM_{21}	DM_{22}	DM_{23}	DM_{24}	DM_{25}	DM_{26}
1	C_6	0,23	0,51	0,15	0,12	0,13	0,19	0,25	0,16	0,15	0,27	0,23	0,24	0,20
2	C_1	0,17	0,03	0,21	0,10	0,22	0,27	0,15	0,11	0,20	0,21	0,16	0,20	0,22
4	C_5	0,13	0,02	0,19	0,11	0,12	0,17	0,21	0,12	0,15	0,11	0,00	0,19	0,12
3	C_4	0,27	0,25	0,17	0,23	0,13	0,13	0,12	0,20	0,19	0,12	0,33	0,12	0,13
5	C_2	0,11	0,06	0,13	0,16	0,21	0,11	0,17	0,13	0,18	0,16	0,27	0,15	0,19
6	C_3	0,09	0,13	0,14	0,28	0,20	0,12	0,10	0,28	0,13	0,14	0,00	0,11	0,14

Table 4. Assessment of Criteria by Market Experts-Continued

	Criteria	DM_{27}	DM_{28}	DM_{29}	DM_{30}	DM_{31}	DM_{32}	Average
1	C_6	0,42	0,14	0,27	0,11	0,12	0,06	0,1920
2	C_1	0,16	0,17	0,12	0,08	0,19	0,08	0,1702
4	C_5	0,24	0,19	0,14	0,10	0,15	0,47	0,1697
3	C_4	0,09	0,19	0,20	0,07	0,18	0,23	0,1677
5	C_2	0,04	0,16	0,11	0,21	0,13	0,09	0,1548
6	C_3	0,06	0,15	0,16	0,43	0,23	0,06	0,1454

For each criterion, the final weights were obtained by taking the arithmetic average of the values determined by the market experts and ranked from most important to least important. The final weighting of the criteria is shown in Table 5 below.

Table 5. Weighting of Criteria

	1	2	3	4	5	6
Criteria	Regulatory compliance	Transparency	Consumer Protection	Technology Integration	Competitive	Flexibility
Importance degrees	0,1920	0,1702	0,1697	0,1677	0,1548	0,1454

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Following the criteria weights determined using the SWARA method, the DSR program will be evaluated using the TOPSIS method.

2.3. TOPSIS Method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), first introduced by Hwang and Yoon (1981), is a method for evaluating a limited number of alternatives against multiple criteria. (Tian et al., 2023) This method determines the most suitable alternative by comparing how close each alternative is to the ideal solution and how far it is from the negative-ideal solution. (Triantaphyllou, 2000) The procedural steps of the method are as follows:

- The alternatives to be evaluated are determined (4).
- With the participation of k decision-makers assessing n criteria, a decision matrix is obtained for each decision-maker (5).

$$A_{ij}^{k} = \begin{bmatrix} a_{11}^{k} & a_{12}^{k} & \cdots & a_{1n}^{k} \\ a_{21}^{k} & a_{22}^{k} & \cdots & a_{2n}^{k} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1}^{k} & a_{m2}^{k} & \cdots & a_{mn}^{k} \end{bmatrix}$$

Where:
k = Decision-makers; n = Criteria; A_{ij} = Decision matrix

- Calculating the group value using the values obtained from k decision-makers and creating the group decision matrix.

$$a_{ij} = \left(\prod_{k=1}^{k} a_{ij}^{k} \right)$$

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

Where:
a_{ij} = Decision matrix; k = Decision-makers

- By normalizing the decision matrix, a normalized decision matrix is obtained (6).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}}$$

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

Where:
r_{ij}=Normalized decision matrix; a_{ij}= Decision matrix

- The weighted decision matrix is obtained by weighting the normalized decision matrix (7).

$$v_{ij} = w_{ij} \times r_{ij}$$

$$V_{ij} = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}$$

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Where:
r_{ij}=Normalized decision matrix; w_{ij}= Criteria importance weights; v_{ij} = Weighted normalized decision matrix

- (A^*) The positive ideal solution set is obtained (8).

$$A^* = \left\{ \left(\underset{i}{maks} \quad vij \middle| \, j \in J \right), \left(\underset{i}{min} \quad vij \middle| \, j \in J \right) \right\}$$

$$A^* = \{ v_1^*, v_2^*, \ldots\ldots, v_n^* \}$$

Where:
A^*= Positive ideal solution; v_{ij} = Weighted normalized decision matrix

- (A^-) A negative ideal solution set is obtained (9)

$$A^- = \left\{ \left(\underset{i}{min} \quad vij \middle| \, j \in J \right), \left(\underset{i}{maks} \quad vij \middle| \, j \in J \right) \right\}$$

$$A^- = \{ v_1^*, v_2^*, \ldots\ldots, v_n^* \}$$

Where:
A^-= Negative ideal solution; v_{ij} = Weighted normalized decision matrix

- The distances of the alternatives to the positive ideal solution are calculated (10).

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^* \right)^2}$$

Where:
S_i^* = Positive ideal solution point; v_{ij} = Weighted normalized decision matrix; v_j^*= Positive ideal solution

- The distances of the alternatives to the positive ideal solution are calculated (11).

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2}$$

Where:
S_i^- = Negative ideal solution point; v_{ij} = Weighted normalized decision matrix; v_j^- = Negative ideal solution

- Calculating the relative closeness values of alternatives to the ideal solution. (12)

$$C_i = \frac{S_i^-}{S_i^- + S_i^*}; \; 0 \leq C_i \leq 1$$

Where:
C_i = Closeness Coefficient; S_i^- = Distance from the negative ideal solution; S_i^* = Distance from the positive ideal solution

In our study, the DSR programs that can be applied to the Türkiye electricity markets are shown in Table 6 below. These programs constitute the alternatives that we will consider in the TOPSIS method.

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Table 6. Alternatives of DSR Programs

Alternatives	
A_1	Time-of-Use Pricing
A_2	Critical Peak Pricing
A_3	Real-Time Pricing
A_4	Direct Load Control
A_5	Interruptible/Curtailable Programs
A_6	Demand Bidding/Buyback Programs
A_7	Emergency Markets
A_8	Capacity Markets
A_9	Ancillary Services Market

Each alternative was evaluated on a scale of 1-5 according to the criteria and a decision matrix was created (Table 7).

Table 7. Evaluation of Alternatives According to Criteria

	C_1	C_2	C_3	C_4	C_5	C_6
A_1	5	3	3	2	4	5
A_2	2	3	1	4	1	4
A_3	2	1	1	1	1	2
A_4	2	1	3	3	3	1
A_5	2	1	3	3	3	3
A_6	3	1	1	1	1	4
A_7	2	1	1	1	1	2
A_8	2	2	1	1	1	3
A_9	3	5	3	5	5	5

The decision matrix is normalized by equation (6). See Table 8.

Table 8. Normalized Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6
A_1	0,841317	0,316619	0,496186	0,122686	0,494242	0,565125
A_2	0,134611	0,316619	0,055132	0,490742	0,03089	0,36168
A_3	0,134611	0,03518	0,055132	0,030671	0,03089	0,09042
A_4	0,134611	0,03518	0,496186	0,276042	0,278011	0,022605
A_5	0,134611	0,03518	0,496186	0,276042	0,278011	0,203445
A_6	0,302874	0,03518	0,055132	0,030671	0,03089	0,36168
A_7	0,134611	0,03518	0,055132	0,030671	0,03089	0,09042
A_8	0,134611	0,14072	0,055132	0,030671	0,03089	0,203445
A_9	0,302874	0,879497	0,496186	0,766785	0,772253	0,565125

The normalized decision matrix is weighted by equation (7). See Table 9.

Table 9. Weighted Normalized Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6
A_1	0,143192	0,049013	0,072145	0,02082	0,082884	0,108504
A_2	0,022911	0,049013	0,008016	0,083279	0,00518	0,069443
A_3	0,022911	0,005446	0,008016	0,005205	0,00518	0,017361
A_4	0,022911	0,005446	0,072145	0,046844	0,046622	0,00434
A_5	0,022911	0,005446	0,072145	0,046844	0,046622	0,039061
A_6	0,051549	0,005446	0,008016	0,005205	0,00518	0,069443
A_7	0,022911	0,005446	0,008016	0,005205	0,00518	0,017361
A_8	0,022911	0,021783	0,008016	0,005205	0,00518	0,039061
A_9	0,051549	0,136146	0,072145	0,130123	0,129507	0,108504

The weighted normalized decision matrix yields ideal and negative ideal solution values through equations (8) and (9). See Table 10.

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Table 10. Positive Ideal Solution and Negative Ideal Solution Values

A+	0,108504	0,143192	0,130123	0,129507	0,136146	0,072145
A-	0,00434	0,022911	0,005205	0,00518	0,005446	0,008016

Equations (10) and (11) are used to obtain the distance values to the ideal and non-ideal points. See Table 11.

Table 11. Distance from ideal and non-ideal points

	S+	**S-**
A_1	0,147354	0,193933
A_2	0,212955	0,110598
A_3	0,273919	0,01302
A_4	0,237077	0,08697
A_5	0,224004	0,093645
A_6	0,249361	0,071123
A_7	0,273919	0,01302
A_8	0,25989	0,038373
A_9	0,091643	0,252838

Equation (12) was used to calculate the closeness coefficient of the alternatives to the ideal solution. See Table 12.

Table 12. Closeness Coefficient of Alternatives

	C	**Prioritization**
A_1	0,568241	2
A_2	0,341824	3
A_3	0,045377	8
A_4	0,268388	5
A_5	0,294807	4
A_6	0,221924	6
A_7	0,045377	8
A_8	0,128655	7
A_9	0,733968	1

When these values are sorted from largest to smallest, it is concluded that the best alternative is A_9. The obtained closeness values and rankings are presented in Table 13 below.

able 13. Ranking of Alternatives

Ranking	**Alternatives**
1	Ancillary Services Market
2	Time-of-Use Pricing
3	Critical Peak Pricing
4	Interruptible/Curtailable Programs
5	Direct Load Control
6	Demand Bidding/Buyback Programs
7	Capacity Markets
8	Real-Time Pricing and Emergency Markets

According to Table 13, it has been observed that the most suitable DSR program capable of adapting to Türkiye's electricity market structure is the Ancillary Services Market. Compared to other TCC programs, the main reason for this selection is that the Ancillary Services Market is directly connected to the transmission level of the organizations that can reduce consumption, so that demand decreases can be monitored and measured more easily and operational processes can be carried out without the need for advanced technological tools (smart meters, etc.).

3. Results

As a result of the evaluation using SWARA and TOPSIS methods, it was determined that the most suitable program for Türkiye's electricity market structure is the Ancillary Services Market. In the Ancillary Services Market operated by TEİAŞ incorporated in Türkiye, tenders are organized under the name of "Demand Side Reserve Service". The conditions for participation in these tenders are that the enterprises must consume at least 10,000 MWh of electricity annually, be voluntary, and be directly connected to the transmission level. As the operator of the Türkiye electricity system, TEİAŞ will ensure the security of supply in the transmission system by making demand load reduction calls to consumers participating in the tenders. However, since market participants do not participate in the auctions, demand response cannot be implemented. The reason for this is

- Insufficient knowledge of demand response on the part of market participants
- Low prices in terms of profitability in the tenders made
- Since the tenders cover large-scale industrial consumers, these enterprises do not pay the necessary attention to energy costs.

In this context, by selecting the Ancillary Services Market program with mathematical methods, our study proves that demand response is the right choice from a market perspective.

In the articles we have reviewed, authors have generally considered demand response in conjunction with concepts such as energy efficiency, energy conservation, and security of supply. In this study, we go beyond these concepts and focus on why and how demand response should be implemented in a sustainable electricity market. At the same time, a DSR program that is suitable for Türkiye's energy sector dynamics is evaluated and selected based on the identified market criteria.

4. Discussion

In our study, which aims to provide a recommendation for the market by mathematically selecting one of the DSR programs suitable for the structure of the Türkiye electricity market, the Ancillary Services Market Program was found. However, the lack of expected participation in the implementation of the program may indicate that the Türkiye electricity market is not ready for these programs. In this context, before the programs can be implemented, new approaches are needed to change and guide consumption habits by providing necessary information and guidance on the demand side. In addition, incentives provided by market regulators may increase participation in DSR programs.

Looking at the other alternatives evaluated, the reasons for preferring other programs to the ancillary services market program are primarily the lack of legislative infrastructure. However, factors such as the lack of technological infrastructure (smart meters, smart grids, etc.), the lack of mechanisms and tools to manage energy demand, and the inability to measure and price electricity that is not consumed stand out.

Furthermore, to enable the demand side to compete on an equal footing with the supply side, a fair, transparent, competitive, and flexible market environment can be created by offering demand-side participants the opportunity to participate in energy markets.

References

Acar, A., Yule Bennett, S., & Scott, D. (2021 August). Türkiye Elektrik Piyasasında Talep Tarafı Katılımının Etkinleştirilmesi. *SHURA Enerji Dönüşümü Merkezi*. https://shura.org.tr/turkiye-elektrik-piyasasinda-talep-tarafi-katiliminin-etkinlestirilmesi/

Alinezhad, A., & Khalili, J. (2019). SWARA Method. *New Methods and Applications in Multiple Attribute Decision Making (MADM)*, 1-7. https://link.springer.com/book/10.1007/978-3-030-15009-9

Benek Arslan, T. & Baykal, Ş., Terciyanlı, A. & Çam, E. (2021). Enerji Verimliliği ve Tasarrufunda Tüketici Algı Yönetimi Yöntemlerinin Değerlendirilmesi. *Avrupa Bilim ve Teknoloji Dergisi,* (27), 710-717. https://doi.org/10.31590/ejosat.932265

Beşli, N., & Dağtekin, Y. (2020). Demand Response: A Way to Balance Production and Consumption of Energy for Turkey. *Department of Electrical and Electronics Engineering.* https://doi.org/10.1109/ELECO.2015.7394583

Bucher, D., Düblein, J., Corey, O., Ivan, A., Wimmer, B., Ghosh, K., Cortiana G., Linnhoff-Popien, C. (2023). Dynamic Price Incentivization for Carbon Emission Reduction using Quantum Optimization. https://doi.org/10.48550/arXiv.2309.05502

Çakmak, R., & Altaş, İ. H. (2020). Türkiye'deki Müşterilerin Akıllı Şebekelerde Yük Kaydırmaya Dayalı Talep Tarafı Yönetimine Tepkileri. *Karadeniz Fen Bilimleri Dergisi,* 10(2), 395-416. https://doi.org/10.31466/kfbd.818410

Çatak, Ç. (2022). Energy Derivatives- an Analysis of the Turkish Electricity Market. *Uluslararası İktisadi ve İdari İncelemeler Dergisi*, 35, 17-30. https://doi.org/10.18092/ulikidince.930399

Dewangan, C. L., Vijayan, V., Shukla, D., Chakrabarti, S., Singh, S., Sharma, A., & Hossain, A. M. (2023 December). An improved decentralized scheme for incentive-based demand response from residential customers. *Energy*, 1-14 https://doi.org/10.1016/j.energy.2023.128568

Gözen, M. (2020). Comments on Main Factors Affecting Electricity Price Risk in Turkish Electricity Market. *Anemon Journal of Social Sciences of Mus Alparslan University*, 189-204. http://dx.doi.org/10.18506/anemon.622870

Guan, Y., Yan, J., Shan, Y., Zhou, Y., & Hang, Y. (2023 February). Burden of the global energy price crisis. *Nature energy*, 304-316. https://doi.org/10.1038/s41560-023-01209-8

Hasanova, N., & Varbak, N. S. (2021). Demand-Side Energy Management in Smart Buildings. European Journal Of Technıque, Vol.11, No.2. https://doi.org/10.36222/ejt.969881

Jafarzadeh Ghoushchi, S., Garg, H., Rahnamay Bonab, S., & Rahimi, A. (2023). An integrated SWARA-CODAS decision-making algorithm with spherical fuzzy information for clean energy barriers evaluation. *Expert Systems With Applications*, 1-14. https://doi.org/10.1016/j.eswa.2023.119884

Kansal, G., & Rajive, T. (2023). A Comprehensive and Preferential Analysis of Demand Response Programs. *2023 IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies (GlobConHT).* https://doi.org/10.1109/GlobConHT56829.2023.10087476

Kholerdi, S. S., & Ghasemi-Marzbali, A. (2021). Interactive Time-of-use Demand Response for Industrial Electricity. *Elsevier*, 1-12. https://doi.org/10.1016/j.jup.2021.101192

Li, H., Wan, Z., & He, H. (2020 March). Real-Time Residential Demand Response. *IEEE Transactions on Smart Grid*, 4144 - 4154. https://doi.org/10.1109/TSG.2020.2978061

Özpinar, A. (2021). Dinamik Tüketici Talep Yönetimi Yapabilen Blokzincir/Kripto Para Tabanlı Elektrik Piyasası İşletme Modeli.Avrupa Bilim ve Teknoloji Dergisi, (Special Issue), 63-69. https://doi.org/10.31590/ejosat.1115892

Rahmati, S., Mahdavi, M.H., Ghoushchi, S.J., Tomaskova, H., Haseli, G. (2022 January). Assessment and Prioritize Risk Factors of Financial Measurement of Management Control System for Production Companies Using a Hybrid Z-SWARA and Z-WASPAS with FMEA Method: A Meta-Analysis. *Mathematics*, 10, 253. https://doi.org/10.3390/math10020253

Sarker, E., Halder, P., Seyedmahmoudian, M., Jamei, E., Horan, B., Mekhilef, S., & Stojcevski, A. (2020 May). Progress On The Demand Side Management In Smart Grid and Optimization Grid Approaches. *International Journal of Energy Research Wiley*, 37. https://doi.org/10.1002/er.5631

Silva-Rodriguez, L., Sanjab, A., Fumagalli, E., Virag, A., & Gibescu, M. (2022 February). Short term wholesale electricity market designs: A review of identified challenges and promising solutions. *Renewable and Sustainable Energy Reviews, 1-13.* https://doi.org/10.1016/j.rser.2022.112228

Şanlı, B., & Alanyalı, M. (2013 December). Türkiye Elektrik Piyasasında Talep Katılımının Tasarımı. Retrieved 08 December 2023 from https://www.barissanli.com/calismalar/2013/bsanli-malanyali-talepyonetimi-aralik2013.pdf

Taherdoost, H., & Madanchian, M. (2023). Multi-Criteria Decision Making (MCDM) Methods. *Encyclopedia*, 3(1), 77-87. https://doi.org/10.3390/encyclopedia3010006

Tian, G., Zhang, X., Zhan, M., A. Dulebenets, M., Aleksandrov, A., Fathollahi-Fard, A., & Ivanov, M. (2023 April). A survey of multi-criteria decision-making techniques for green logistics and low-carbon transportation systems. *Environmental Science and Pollution Research* 30:57279–57301. https://doi.org/10.1007/s11356-023-26577-2

Tör, O. B., Oğuz, H., Kısakürek, S. M., Kurşuncu, E. N., & Köksal, A. O. (2021). Talep Birleştiricilerin Rol Aldığı Elektrik Piyasa Mekanizmaları ve Türkiye'deki Mevcut Durum Analizi. *Sosyoekonomi* (49), 307-322. https://doi.org/10.17233/sosyoekonomi.2021.03.16

Triantaphyllou, E. (2000). *Multi-criteria Decision Making Methods: A Comparative Study. Sprınger-Scıence+Busıness Medıa B.V.*

Vinoth Kumar, B., Sivakumar, P., Rajan Singaravel, M.M,. (2021). Intelligent Paradigms for Smart Grid and Renewable Energy Systems. *Springer.* https://doi.org/10.1007/978-981-15-9968-2

Wesseh Jr., P., & Lin, B. (2022 November). A time-of-use pricing model of the electricity market considering system flexibility. *Energy Reports*, 1457-1470. https://doi.org/10.1016/j.egyr.2021.12.027

J. Więckowski, B. Kizielewicz, A. Shekhovtsov, and W. Sałabun (2023 August). How do the criteria affect sustainable supplier evaluation? - A case study using multi-criteria decision analysis methods in a fuzzy environment. *J. Eng. Manag. Syst. Eng*., 2(1), 37-52. https://doi.org/10.56578/jemse020102

Yalçın, A., Kılıç, H., & Delen, D. (2022). The use of multi-criteria decision-making methods in business analytics: A comprehensive literature review. *Technological Forecasting & Social Change*, 1-35. https://doi.org/10.1016/j.techfore.2021.121193

Yu, M., Ho Hong, S., Ding, Y., & Ye, X. (2019 February). An Incentive-Based Demand Response (DR) Model Considering Composited DR Resources. *Ieee Transactions On Industrial Electronics*, 1488-1498. https://doi.org/10.1109/TIE.2018.2826454

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