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Application of MCDM Method in Selecting Renewable Energy

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ABSTRACT

This paper aims to explore the application of the Multiple Criteria Decision Making (MCDM) method in the selection of renewable energy sources. The growing concern for environmental sustainability and the need to shift towards renewable energy have led to an increased interest in finding the most suitable renewable energy option. The MCDM method provides a systematic approach for evaluating and comparing various criteria related to renewable energy sources. Through a comprehensive literature review and numerical analysis, this paper examines the effectiveness of the MCDM method in supporting decision-making processes in renewable energy selection. The findings highlight the advantages, limitations, and potential areas of improvement for using MCDM techniques in the selection of renewable energy sources for different contexts.

1. Introduction

The rapid depletion of fossil fuel resources and the environmental consequences associated with their usage have necessitated a shift towards renewable energy sources. The selection of an appropriate renewable energy option requires the consideration of multiple criteria, such as cost, environmental impact, availability, and technical feasibility. The MCDM method offers a structured and systematic approach to evaluate and compare these criteria, enabling decision-makers to identify the most suitable renewable energy alternatives. This section provides an overview of the research objectives, methodology, and organization of the paper [1].

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There are several types of renewable energy sources that are being increasingly utilized to generate clean and sustainable energy. Here are some of the main types:

1. Solar Energy: Solar energy involves harnessing the power of sunlight to generate electricity or heat. Photovoltaic (PV) systems convert sunlight directly into electricity, while solar thermal systems use sunlight to heat water or other fluids for various applications.

2. Wind Energy: Wind energy utilizes the power of wind to drive turbines and generate electricity. Wind farms, often located in windy areas or at sea, consist of multiple turbines connected to an electricity grid.

3. Hydropower: Hydropower involves harnessing the energy of moving or falling water to generate electricity. It can be obtained from rivers, dams, or ocean tides. Hydropower plants use water to drive turbines and produce renewable electricity.

4. Biomass Energy: Biomass energy utilizes organic matter derived from plants and animals. It can be obtained from various sources such as agricultural residues, wood pellets, dedicated energy crops, and organic waste. Biomass can be burned to produce heat or converted into biogas or biofuels [2].

5. Geothermal Energy: Geothermal energy utilizes heat from the Earth's interior to generate electricity or provide heating and cooling. It involves extracting heat from underground reservoirs of hot water or steam. Geothermal power plants and geothermal heat pumps are examples of geothermal energy applications.

6. Tidal Energy: Tidal energy harnesses the power of ocean tides and currents to generate electricity. It involves the use of underwater turbines that rotate as the tides flow in and out, converting kinetic energy into electrical energy.

7. Wave Energy: Wave energy captures the energy from ocean waves to generate electricity. Devices such as wave buoys or oscillating water columns convert the up-and-down motion of waves into mechanical energy, which is further transformed into electrical power [3-4].

Each type of renewable energy has its advantages, limitations, and suitability for different geographic locations and energy demands. The combination and integration of multiple renewable energy sources are often employed to ensure a more reliable and consistent supply of clean energy (Figure 1) [5].

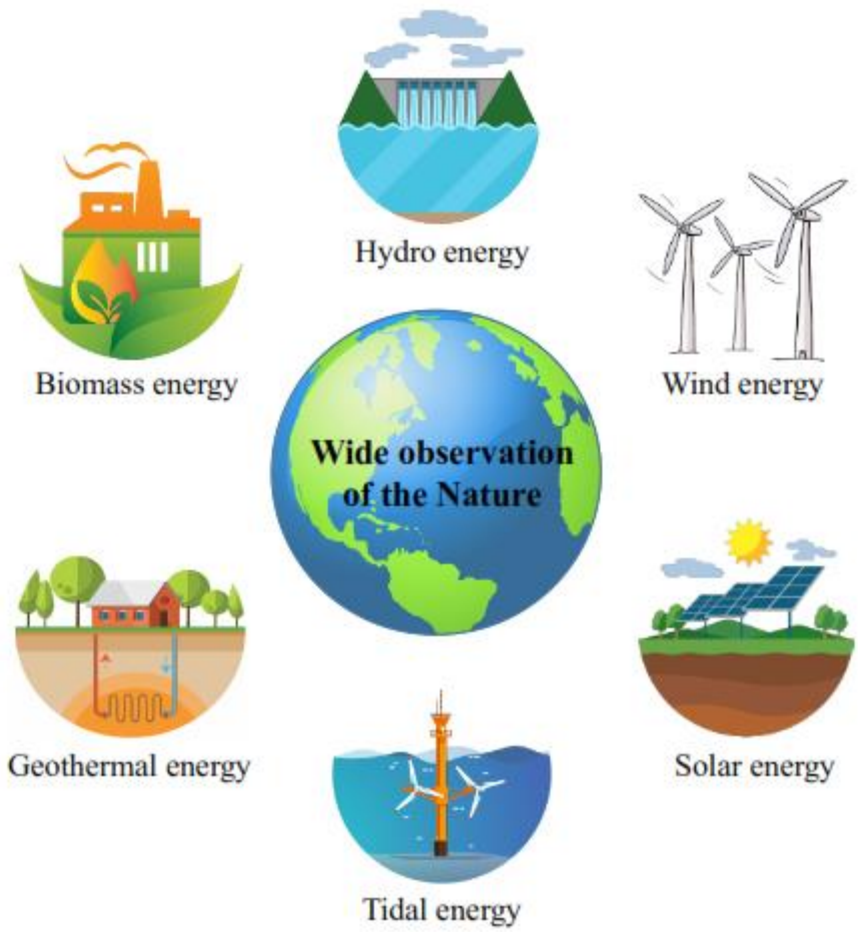

Figure 1: Renewable energy types.

One important issue in the application of MCDM methods for selecting suitable renewable energy options is the challenge of defining and quantifying the criteria [6-7]. Since MCDM methods rely on quantitative or qualitative assessments of criteria, it's crucial to have clear and measurable metrics for evaluation. Here are some key considerations related to this issue:

1. Defining Relevant Criteria: Identifying the right criteria that appropriately represent the goals and requirements of the renewable energy project is essential. It requires careful consideration of various aspects such as economic, environmental, social, and technical factors. Inadequate or inappropriate criteria may lead to biased or incomplete evaluations.

2. Assigning Weights to Criteria: Assigning weights to criteria reflects their relative importance in the decision-making process. Determining these weights is often subjective

and depends on stakeholders' perspectives. Ensuring a well-balanced and consensus-based approach in assigning weights is crucial to maintain fairness and credibility in the assessment.

3. Data Availability and Reliability: MCDM methods heavily rely on data for evaluating alternatives against criteria. The availability and reliability of data, especially in the context of different renewable energy sources, can pose challenges. Incomplete or inaccurate data may impact the accuracy and validity of the analysis.
4. Handling Uncertainty and Subjectivity: MCDM methods typically assume certainty and rely on precise measurements. However, in the renewable energy domain, there are inherent uncertainties and subjective judgments involved. It's important to incorporate approaches that address uncertainty, such as sensitivity analysis or using probabilistic methods to account for variability in data and judgments.
5. Transparency and Stakeholder Involvement: Transparency in the decision-making process is crucial for building trust and consensus among stakeholders. Involving relevant stakeholders, such as energy experts, policymakers, local communities, and environmental organizations, promotes a holistic evaluation and considers diverse perspectives. Including stakeholder input in defining criteria and weights can enhance the legitimacy and acceptance of the MCDM process [8-9].

Addressing these issues requires careful planning, robust methodologies, and an inclusive approach. It's important to regularly update and refine the assessment as new data and knowledge become available. Applying the MCDM method with openness, flexibility, and continuous improvement can lead to more informed decisions in selecting suitable renewable energy options [3].

This research is arranged into five sections. Section 2 defines the literature review and recent studies in area of forecasting renewable energy generation in Iran and tries to show the gap in research. Section 3 suggests methodology for calculation. Section 4 proposes the results of this research. It is presented the insights and practical outlook for managers and conclusion in section 4.

2. Literature review

The recent work about application of MCDM method in selecting renewable energy are defined and try to determine research gaps. Although the researchers cover gap research and suggest contributions to this issue, when new concepts come, they can apply and combine with this study that is not defined previously.

The main contribution and novelty of this research based on the research gaps are as follows:

- Forecasting renewable energy generation in Iran by data science method.

In this section, we present a comprehensive review of the existing literature on the application of the MCDM method in renewable energy selection. The review covers the fundamental concepts of MCDM, its various techniques (such as Analytic Hierarchy Process, TOPSIS, and ELECTRE), and previous studies that have applied MCDM in renewable energy decision-making. The literature review identifies the strengths and weaknesses of MCDM techniques, as well as the key criteria commonly considered in renewable energy selection [10-15].

Multi-criteria decision making (MCDM) is a decision-making process that considers multiple criteria to select the best alternative. It is a widely used tool in many fields, including energy planning, environmental management, and engineering design.

In the context of renewable energy, MCDM can be used to select the best renewable energy technology, site, or project. The selection process typically involves considering multiple criteria, such as the cost of the technology, its environmental impact, and its technical feasibility.

There are many different MCDM methods available, each with its own strengths and weaknesses. Some of the most common methods include:

Analytic hierarchy process (AHP): This method is based on the concept of pairwise comparisons. The decision-maker is asked to compare each pair of alternatives based on each criterion. The results of these comparisons are then used to calculate a weight for each criterion.

Data envelopment analysis (DEA): This method is a non-parametric method that does not require the data to be normally distributed. It is used to compare the efficiency of multiple decision-making units (DMUs) [15-18].

Multi-objective optimization (MOO): This method is used to find a solution that optimizes multiple objectives simultaneously. This can be a challenging task, as the objectives may be conflicting.

MCDM methods have been used in a variety of applications in the field of renewable energy, including:

Selecting renewable energy technologies: MCDM methods have been used to select the best renewable energy technology for a particular application. For example, a study in Jordan used MCDM to select the best renewable energy technology for meeting the country's electricity demand [19].

Selecting renewable energy sites: MCDM methods have also been used to select the best site for a renewable energy project. For example, a study in China used MCDM to select the best site for a wind power project [20].

Evaluating renewable energy projects: MCDM methods have also been used to evaluate the performance of renewable energy projects. For example, a study in India used MCDM to evaluate the performance of solar photovoltaic (PV) projects [21].

MCDM methods are a powerful tool that can be used to select renewable energy technologies, sites, and projects. The choice of the MCDM method will depend on the specific application and the preferences of the decision-maker. Overall, MCDM methods are a valuable tool that can be used to make informed decisions about renewable energy. However, it is important to be aware of the advantages and challenges of these methods before using them.

3. Methodology

This section describes the methodology employed to evaluate the application of the MCDM method in the selection of renewable energy sources. The numerical analysis involves the establishment of a decision framework, identification of criteria, selection of suitable MCDM technique(s), data collection, criteria weighting, and the final ranking of renewable energy options based on the MCDM results. The chosen MCDM technique(s) will be explained in detail, along with the reasoning for their selection [22-23].

Applying a Multi-Criteria Decision Making (MCDM) method can be helpful in determining the most suitable renewable energy source or combination of sources for a particular situation. MCDM methods provide a systematic approach to evaluate and prioritize options based on multiple criteria. Here's an example of how MCDM can be used in selecting suitable renewable energy sources:

1. Identify Criteria: Determine the relevant criteria for evaluating renewable energy options. These criteria can include factors such as cost, availability, environmental impact, energy efficiency, scalability, and social acceptance.

2. Weighting the Criteria: Assign weights to each criterion based on their relative importance. For example, if cost is considered more important than environmental impact, assign a higher weight to cost.

3. Establish Alternatives: Identify the possible renewable energy options or combinations to be evaluated. This could include solar energy, wind energy, hydropower, biomass, geothermal, or a hybrid system combining multiple sources.

4. Assess Alternatives: Evaluate each alternative against the established criteria. This can be done by assigning scores or ratings to each alternative for each criterion. For example, solar energy might score high in terms of environmental impact and scalability but lower in terms of cost and availability.

5. Aggregation of Scores: Apply the chosen MCDM method to aggregate the scores for each criterion and alternative. This typically involves mathematical calculations or algorithms to combine the scores and produce an overall ranking or preference order.

6. Sensitivity Analysis: Perform a sensitivity analysis to examine the robustness of the results. This helps to evaluate how changes in criteria weights or scores can impact the final selection.

7. Decision Making: Based on the results of the MCDM analysis, make an informed decision regarding the most suitable renewable energy source or combination of sources for the given context.

Using an MCDM method enables a more comprehensive and systematic analysis, considering multiple criteria and providing a structured approach to decision-making. It helps to overcome potential biases and subjectivity in the decision-making process, leading to a more objective and informed selection of renewable energy sources [24-28].

4. Results and discussion

The numerical results section presents the findings obtained from applying the MCDM method to select renewable energy sources. The results will be based on the criteria evaluation and weighting process, considering the context-specific preferences and constraints. The MCDM outcomes will be presented in the form of rankings, scores, or decision matrices to showcase the comparative performance of different renewable energy alternatives. The analysis will emphasize the advantages and limitations of the chosen MCDM technique(s) and its application in the renewable energy selection process.

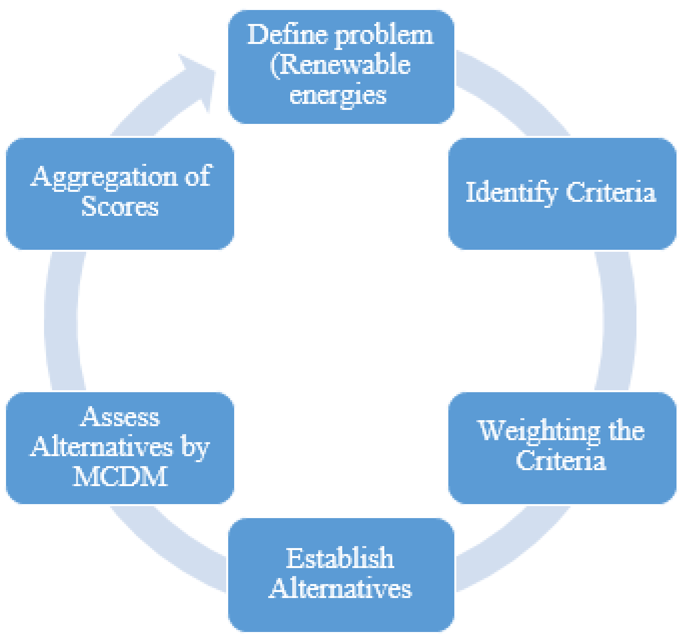

Figure 2: Application of MCDM Method in Selecting Renewable Energy in Iran.

The matrix of decision making for selecting renewable energy that is determined by experts is as follow (Table 1, 2, 3 and Figure 3):

Table 1: Renewable energy type

Renewable energy type	Economic		Environmental		Technological		Sociality	
	Investment cost	Payback period	Effect on Climate change	Effect on Natural environment	Efficiency rate	Knowledge of innovative technology	Job criterion	Regional development
Weight	0.15	0.15	0.1	0.1	0.15	0.1	0.15	0.1
Type	Cost	-	Cost	Cost	-	-	-	-
Solar energy	400000	20%	0	0	80%	95%	5	95%
Wind energy	600000	30%	0	1	85%	95%	10	90%
Bioenergy	500000	25%	0	1	75%	90%	10	85%
Geothermal energy	800000	15%	1	1	80%	95%	8	95%
Hydropower	900000	20%	0	0	85%	90%	10	90%

Table 2: Python code for renewable energy assessment by MCDM

```
import numpy as np
from pymcdm.methods import TOPSIS, VIKOR, COPRAS , PROMETHEE_II, COMET, SPOTIS, ARAS,
    COCOSO, CODAS, EDAS, MABAC, MAIRCA, MARCOS, OCRA, MOORA
from pymcdm.helpers import rrankdata
# Define decision matrix (8 criteria, 5 alternative)
alts = np.array([
    [400000,0.2,0,0,0.8,0.95,5,0.95],
    [600000,0.3,0,1,0.85,0.95,10,0.9],
    [500000,0.25,0,1,0.75,0.9,10,0.85],
    [800000,0.15,1,1,0.8,0.95,8,0.95],
    [900000,0.2,0,0,0.85,0.9,10,0.9]
], dtype='float')
# print (alts)

# Define weights and types
weights = np.array([0.15,0.15,0.1,0.1,0.15,0.1,0.15,0.1])
types = np.array([-1,1,-1,-1,1,1,1,1])

# Create object of the method
topsis = TOPSIS()
# Determine preferences and ranking for alternatives
kkk1= topsis(alts, weights, types)
print ("topsis",kkk1)

# Create object of the method
vikor = VIKOR()
# Determine preferences and ranking for alternatives

kkk=vikor(alts, weights, types)

print ("vikor",kkk)
```

```
# Create object of the method
copras = COPRAS()
# Determine preferences and ranking for alternatives
kkk=copras(alts, weights, types)
print ("copras",kkk)

# Create object of the method
moora = MOORA()
# Determine preferences and ranking for alternatives
kkk=moora(alts, weights, types)
print ("moora",kkk)

# Create object of the method
mabac = MABAC()
# Determine preferences and ranking for alternatives
kkk=mabac(alts, weights, types)
print ("mabac",kkk)
```

Table 3: Results of renewable energy assessment by MCDM

Renewable energy type	TOPSIS	VIKOR	COPRAS	MOORA	MABAC	Total
Solar energy	0.58	0.65	1.00	0.22	0.14	0.52
Wind energy	0.71	0.00	0.71	0.21	0.26	0.38
Bioenergy	0.50	0.91	0.68	0.19	-0.06	0.44
Geothermal energy	0.42	1.00	0.50	0.03	-0.14	0.36
Hydropower	0.56	0.74	0.74	0.20	0.07	0.46

It seems like you have provided the assessment results for different renewable energy types using a Multi-Criteria Decision Making (MCDM) method. Each renewable energy type has been assigned a score. Here are the scores you provided:

- Solar energy: 0.52
- Hydropower: 0.46
- Bioenergy: 0.44
- Wind energy: 0.38
- Geothermal energy: 0.36

These scores represent the performance or suitability of each renewable energy type based on the criteria used in the assessment. The higher the score, the better the performance.

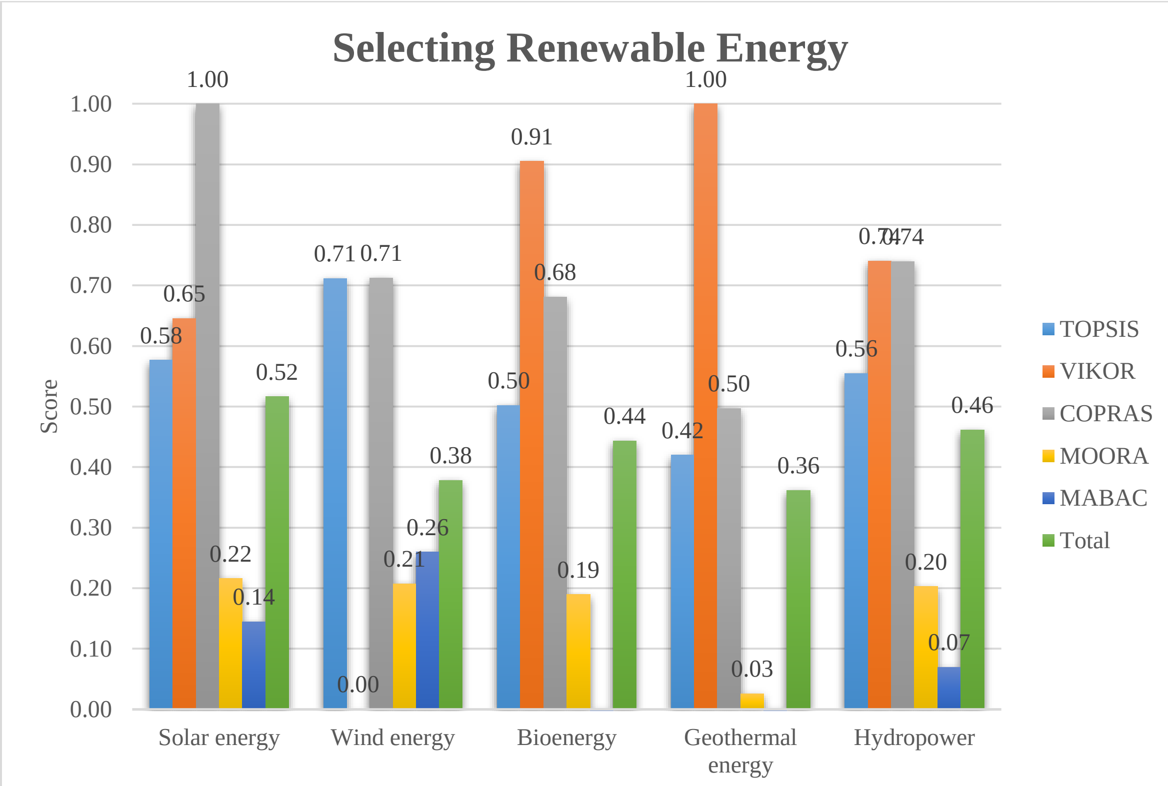

Figure 3: Results of factors affecting environmental pollution.

5. Conclusion

In this section, the paper concludes by summarizing the key findings and implications of the study. It highlights the contribution of the MCDM method in facilitating decision-making processes related to renewable energy selection. The conclusion also discusses the areas of improvement and future research directions to enhance the accuracy and robustness of the MCDM technique(s) for renewable energy decision-making. Ultimately, this research aims to contribute to the promotion and adoption of sustainable energy practices for a greener future.

The application of the MCDM method in selecting renewable energy sources provides a structured and systematic approach for decision-making. Based on the assessment results, we can draw some conclusions:

1. Solar energy has received the highest score of 0.52, indicating its potential as a favorable renewable energy option. This suggests that solar energy should be seriously considered and prioritized in energy planning and investment decisions.

2. Following solar energy, hydropower has scored 0.46, positioning it as another viable renewable energy source. Its relatively high score suggests that hydropower should also be taken into account when making decisions regarding renewable energy implementation.

3. Bioenergy has been assigned a score of 0.44, indicating moderate suitability. It may not have received the highest score, but it still holds potential as a renewable energy option, particularly in regions where biomass resources are abundant.

4. Wind energy has obtained a score of 0.38, suggesting a slightly lower suitability compared to the aforementioned renewable sources. However, it should not be disregarded entirely, as it can still make a significant contribution depending on the geographical and climatic conditions of a particular region.

5. Geothermal energy has received the lowest score of 0.36 among the assessed renewable energy types. While its score may indicate lower suitability in the given assessment, it is important to note that geothermal energy can be a valuable option in areas with suitable geothermal resources.

In summary, the MCDM method provides a comprehensive framework for evaluating and selecting renewable energy sources. However, it is essential to consider other factors such as cost, infrastructure requirements, environmental impacts, and regional constraints when making final decisions on renewable energy adoption.

References:

[1] Ghasempour, R., Nazari, M. A., Ebrahimi, M., Ahmadi, M. H., & Hadiyanto, H. (2019). Multi-Criteria Decision Making (MCDM) Approach for Selecting Solar Plants Site and Technology: A Review. International Journal of Renewable Energy Development, 8(1).

[2] Lak Kamari, M., Isvand, H., & Alhuyi Nazari, M. (2020). Applications of multi-criteria decision-making (MCDM) methods in renewable energy development: A review. Renewable Energy Research and Applications, 1(1), 47-54.

[3] Çolak, M., & Kaya, İ. (2017). Prioritization of renewable energy alternatives by using an integrated fuzzy MCDM model: A real case application for Turkey. Renewable and sustainable energy reviews, 80, 840-853.

[4] Lee, H. C., & Chang, C. T. (2018). Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan. Renewable and sustainable energy reviews, 92, 883-896.

[5] Li, C. (2023). Ranking of factors affecting environmental pollution. International Journal of Industrial Engineering and Operational Research, 5(3), 1-11. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/47

[6] Talebi, M. (2023). Move towards Sustainability and Resiliency: From Industry 4.0 to Industry 5.0. International Journal of Industrial Engineering and Operational Research, 5(2), 82-92. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/46

[7] Raziee, Z. (2023). Artificial Intelligence and Machine Learning as an Antifragile Driver in the Supply Chain. International Journal of Industrial Engineering and Operational Research, 5(1), 60-68.

[8] Sharifi Nevisi, M. M., & Salehi, R. (2023). Eco energy, Energy aware and Net-zero Supply Chain. International Journal of Industrial Engineering and Operational Research, 5(1), 39-49.

[9] Shoushtari, F., & Ghafourian, E. (2023). Antifragile, Sustainable, and Agile Supply Chain Network Design with a Risk Approach. International journal of industrial engineering and operational research, 5(1), 19-28.

[10] Shoushtari, F., Bashir, E., Hassankhani, S., & Rezvanjou, S. (2023). Optimization in Marketing Enhancing Efficiency and Effectiveness. International journal of industrial engineering and operational research, 5(2), 12-23.

[11] Daghighi, A., & Shoushtari, F. (2023). Toward Sustainability of Supply Chain by Applying Blockchain Technology. International Journal of Industrial Engineering and Operational Research, 5(2), 60-72. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/44

[12] Shoushtari, F., Ghafourian, E., & Talebi, M. (2021). Improving Performance of Supply Chain by Applying Artificial Intelligence. International Journal of Industrial Engineering and Operational Research, 3(1), 14-23. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/43

[13] Hosseini Rad, R., Baniasadi, S., Yousefi, P., Morabbi Heravi, H., Shaban Al-Ani, M., & Asghari Ilani, M. (2022). Presented a framework of computational modeling to identify the patient admission scheduling problem in the healthcare system. Journal of Healthcare Engineering, 2022.

[14] Baniasadi, S., Rostami, O., Martín, D., & Kaveh, M. (2022). A novel deep supervised learning-based approach for intrusion detection in IoT systems. Sensors, 22(12), 4459.

[15] Saraei, N., Khanal, M., & Tizghadam, M. (2022). Removing Acidic Yellow Dye from Wastewater Using Moringa Peregrina. Computational Research Progress in Applied Science & Engineering, 8, 1-8.

[16] Ghafourian, H., Ershadi, S. S., Voronkova, D. K., Omidvari, S., Badrizadeh, L., & Nehdi, M. L. (2023). Minimizing Single-Family Homes' Carbon Dioxide Emissions and Life Cycle Costs: An Improved Billiard-Based Optimization Algorithm Approach. Buildings, 13(7), 1815.

[17] Ghafourian, E., Samadifam, F., Fadavian, H., Jerfi Canatalay, P., Tajally, A., & Channumsin, S. (2023). An Ensemble Model for the Diagnosis of Brain Tumors through MRIs. Diagnostics, 13(3), 561.

[18] Fallah, A. M., Ghafourian, E., Shahzamani Sichani, L., Ghafourian, H., Arandian, B., & Nehdi, M. L. (2023). Novel Neural Network Optimized by Electrostatic Discharge Algorithm for Modification of Buildings Energy Performance. Sustainability, 15(4), 2884.

[19] Akbarzadeh, M. R., Ghafourian, H., Anvari, A., Pourhanasa, R., & Nehdi, M. L. (2023). Estimating Compressive Strength of Concrete Using Neural Electromagnetic Field Optimization. Materials, 16(11), 4200.

[20] Talebi, M. (2023). Move towards Sustainability and Resiliency: From Industry 4.0 to Industry 5.0. International Journal of Industrial Engineering and Operational Research, 5(2), 82-92. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/46

[21] Li, C. (2023). Ranking of factors affecting environmental pollution. International Journal of Industrial Engineering and Operational Research, 5(3), 1-11. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/47

[22] Talebi, M., & Daghighi, A. (2023). Forecasting Renewable Energy Generation in Iran by Data Science Method. International Journal of Industrial Engineering and Operational Research, 5(3), 12-22. Retrieved from https://bgsiran.ir/journal/ojs-3.1.1-4/index.php/IJIEOR/article/view/48

[23] Ishfaq, S., Ali, S., & Ali, Y. (2018). Selection of optimum renewable energy source for energy sector in Pakistan by using MCDM approach. Process Integration and Optimization for Sustainability, 2, 61-71.

[24] Wu, Y., Xu, C., & Zhang, T. (2018). Evaluation of renewable power sources using a fuzzy MCDM based on cumulative prospect theory: A case in China. Energy, 147, 1227-1239.

[25] Lotfi, R., Zare, S. G., Gharehbaghi, A., Nazari, S., & Weber, G. W. (2023). Robust optimization for energy-aware cryptocurrency farm location with renewable energy. Computers & Industrial Engineering, 177, 109009.

[26] Lotfi, R., Kargar, B., Gharehbaghi, A., Afshar, M., Rajabi, M. S., & Mardani, N. (2022). A data-driven robust optimization for multi-objective renewable energy location by considering risk. Environment, Development and Sustainability, 1-22.

[27] Lotfi, R., Kargar, B., Hoseini, S. H., Nazari, S., Safavi, S., & Weber, G. W. (2021). Resilience and sustainable supply chain network design by considering renewable energy. International journal of energy research, 45(12), 17749-17766.

[28] Lotfi, R., Mardani, N., & Weber, G. W. (2021). Robust bi-level programming for renewable energy location. International journal of energy research, 45(5), 7521-7534.