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ANALYZING CLIMATE CHANGE PERFORMANCE OVER THE LAST FIVE YEARS OF G20 COUNTRIES USING A MULTI-CRITERIA DECISION-MAKING FRAMEWORK

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ABSTRACT

Today, limited resources are decreasing/depleting with the increase in the human population living on Earth. The increased human population brings with it various problems. Different events cause important climate events at the global level, such as the decrease or depletion of water resources with the increase in demand, damage to the ecosystem, health risks, and deterioration of biological diversity. Due to the use of fossil fuels, the formation of GHG (greenhouse gas) emissions and global warming cause significant climate changes. Climate change causes the restriction of environmental and vital activities, the increase of natural disasters, and the extinction of species. This study aimed to evaluate the climate change performance of G20 countries which emit more than 75% of the world's GHG emissions from 2019 to 2023, using MCDM methods. An objective method, LOPCOW, was used to assign weights while SPOTIS, WISP, and RSMVC methods were used to determine the climate change performances of G20 countries. The findings showed that among G20 countries, the highest performance was found in the United Kingdom and India, while the United States, Canada and Saudi Arabia were found in the last ranks.

Keywords: Climate Change Performance, G20, MCDM, Decision Making, Comparative Analysis.
JEL Classification: C44, D81, Q54.

G20 ÜLKELERİNİN SON BEŞ YILLIK İKLİM DEĞİŞİKLİĞİ PERFORMANSININ ÇOK KRİTERLİ KARAR VERME ÇERÇEVESİ İLE ANALİZ EDİLMESİ

ÖZ

Günümüzde Dünya nüfusunun hızla artması, sınırlı kaynakların azalmasına/hızla tükenmesine neden olmaktadır. Artan nüfus, talebin artmasına bağlı olarak su kaynaklarının azalması veya tükenmesi, ekosistemin zarar görmesi, sağlık sorunları ve biyolojik çeşitliliğin bozulması gibi küresel düzeyde önemli sorunları da beraberinde getirmektedir. Fosil yakıtların kullanılmasına bağlı olarak GHG (sera gazı) emisyonlarının oluşumu ve küresel ısınma önemli iklim değişikliklerine neden olmaktadır. İklim değişikliği ise çevresel ve yaşamsal faaliyetlerin kısıtlanmasına, doğal afetlerin artmasına ve türlerin yok olmasına neden olmaktadır. Bu çalışmada, Dünyadaki sera gazı emisyonlarının %75'inden fazlasını oluşturan G20 ülkelerinin 2019-2023 dönemi iklim değişikliği performansının ÇKKV yöntemleri kullanılarak değerlendirilmesi amaçlanmıştır. Kriter ağırlıklarının belirlenmesinde objektif bir yöntem olan LOPCOW kullanılırken, G20 ülkelerinin iklim değişikliği performanslarını belirlemek için ise SPOTIS, WISP ve RSMVC yöntemleri kullanılmıştır. Bulgular, G20 ülkeleri arasında en yüksek performansa İngiltere ve Hindistan'ın sahip olduğunu, Amerika Birleşik Devletleri, Kanada ve Suudi Arabistan'ın ise son sıralarda yer aldığını göstermiştir.

Anahtar Kelimeler: İklim Değişikliği Performansı, G20, ÇKKV, Karar Verme, Karşılaştırmalı Analiz.
JEL Sınıflandırması: C44, D81, Q54.

INTRODUCTION

So as to understand the importance of the challenge facing society/humanity, it is sufficient to look at the intense heat waves followed by severe storms, hurricanes, rising sea levels, floods, environmental degradation, wildfires, and some developments such as ecosystem damage and extinction, leading to remarkable transformations and significant economic losses (Puertas & Marti, 2021, p. 2). Events such as extreme

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meteorological movements, natural disasters, water scarcity, and species extinction worldwide generate an intense increase in risks of climate change. These changes can have crucial impacts on human health, agriculture, and ecosystems, and can lead to economic, social, and political instability. Research has been increasing recently to draw attention to climate change's crucial-adverse effects and analyze minimum necessities. Countries in different parts of the world are influenced by climate change, which is a global problem, in different ways (Bozkus, Kahyaoglu, Lawali, 2020, p. 413). The consequences of climate change are deeply felt worldwide and humanity is becoming more likely to be exposed to the severe and intense results of climate change in the near future (Tam, Chan, Clayton, 2023, p. 1). Global greenhouse gas (GHG) emissions from population growth and industrial processes as the leading causes of global warming and climate change are at their highest in history, recently (Leal Filho et al., 2023b, p. 21). With the effects of climate change, the global average temp has increased by 0.74°C since the late 1800s, and the rate of warming has more increased in recent decades. It is foreseen that the temperature will rise between the range of 1.4-5.8 °C between 1990 and 2100. Further warming is expected due to the ever-increasing GHG emissions (Ooi, Goh, Yeap, Loo, 2018, p. 234). This warming trend is primarily driven by human activities, particularly the burning of fossil fuels, and released CO_2 emissions. Among the biggest part of the GHG emissions which is carbon dioxide (CO_2) is the biggest damaged/responsible to global temperature, trap heat in the Earth's atmosphere and contribute to the warming of the planet, and also makes the biggest contribution to increasing climate change. And the others are methane, and nitrous oxide. The share of CO_2 emissions arising from various reasons, especially from the transportation, energy, industry, and waste-management sectors, constitutes much more than half of all GHG emissions (Khan & Khan, 2019, p. 623).

So as to manage the challenges posed by climate change, countries around the world are working to reduce their GHG emissions and transition to cleaner sources of energy such as wind and solar power. On the subject of climate change, the Paris Agreement was signed in 2015 nearly 200 countries to strengthen the capacity of countries to respond to climate change by keeping global warming below 2 ◦C. In the Paris Agreement, there are suppressive elements such as national climate action plans aimed at reducing emissions, a commitment to transparency between countries and citizens about the progress made, and a commitment to adapt to the consequences of climate change. Another suppressive/positive element regarding climate change is the Council of the European Parliament's commitment in April 2021 to reduce GHG by 55% by 2030 and to become climate neutral by 205 (Puertas & Marti, 2021, p. 2). By the way, CCPI (Climate Change Performance Index) measures emissions, efficiency, renewable energy, and climate policy components CCPI sets weighting for 40% GHG emissions, 20% renewable energy, 20% energy use, and 20% climate policy in the overall score (Codal, Ari, Codal, 2021, p. 2). The CCPI consists of four components and a total of 14 sub-components. Standard and rough weights are given to components such as 20%, and 40% and sub-components such as 5% and 10%. It is controversial how accurate these rough weights are given in the presence of the decision matrix of the alternatives and components.

The weights of the components could be determined by expert groups on the subject. However, it would also be controversial how the subjectively determined weights would be valid due to reasons such as how the experts of the subject were determined, how expert they were, and their level of knowledge. Instead of these, it would be much more realistic, reasonable, and valid to use objective methods to find criterion weights from the existence of the decision matrix. This study aimed to determine the weights of the CCPI components of G20 countries, which have the world's largest economy, and to evaluate the CCPI performances of G20 countries. LOPCOW (LOgarithmic Percentage Change-driven Objective Weighting), which is an objective method, was preferred in determining the criterion weights, and SPOTIS (Stable Preference Ordering Towards Ideal Solution), WISP (Simple Weighted Sum-Product Method), and RSMVC "(Ranking the Solutions based on the Mean Value of Criteria) methods were used to identify and compare the CCPI performances of G20 countries. The originality and contribution of this study to the literature can be summarized as follows:

- The comparative climate change performance of G20 countries has been evaluated for the first time retrospectively using MCDM methods.
- The proposed model in this study is used for the first time in the literature.
- The SPOTIS and RSMVC methods are tested for the first time in the domestic literature. Besides, the determination of criteria weights with an objective method and the comparison of country performances with each other within the scope of efforts to protect the climate highlight the importance of the study.

The remainder of the study is organized as follows. In the second part, the literature is examined. In the third part, the methods used in the study are explained. In the fourth part, results and discussion are shown. In the final part, overall important conclusions about the study are underlined.

LITERATURE REVIEW

Climate change has been a fairly limited research topic in terms of multi-criteria decision-making (MCDM) methods although the issue of climate change has been researched by many authors in many different fields. In a study (Altıntaş, 2021a) in the field of MCDM based on the subject of climate change, ROV and MAUT methods were used without determining any criterion weight, and G20 countries were ranked according to their performance. In a second study which is the same author, Altıntaş (2021b) investigated the CCPI of G7 countries' performance using CODAS and EDAS methods. On the other hand, some other studies discussed climate change from different perspectives.

Bernauer & Böhmelt (2013) measured the climate change cooperation index by presenting a new data set of 172 countries in the 1996-2008 periods for a valid and reliable measurement of the climate policy performance of countries concerning political behavior and emissions, as well as overall performance. Balsara, Jain, Ramesh (2019) used an integrated approach for evaluating the climate change reduction strategies using AHP and DEMATEL in the cement industry. Golfam, Ashofteh, Rajaee, Chu (2019) determines the most appropriate scenario for prioritization of water distribution in adapting to climate change in agriculture for Northwest Iran over 30 years using the AHP and TOPSIS methods. Khan & Khan (2019) analyze the relationship between gas emissions and global temperature. Codal et al. (2021) examined the performance evaluation of G20 countries on climate change actions from a balanced scorecard approach and a multidimensional perspective of their national situation. Puertas & Marti (2021) used CCPI indicators to cluster 57 countries and compare countries by CCPI clusters and GDP per capita. Ding & Beh (2022) evaluated sustainability and climate change in ASEAN countries, which are among the biggest victims of climate-related disasters and economic losses, it was found that despite the concerted and comprehensive efforts of environmental performance to reduce emissions and construct capacity to adapt to climate-related disasters, shows that it lags behind other regions. Gokasar, Deveci, Kalan (2022) evaluated the impact on the environment from the perspective of prioritizing bridge maintenance projects based on CO_2 emissions using T2NN-based WASPAS and TOPSIS. Simic, Gokasar, Deveci, Švadlenka (2022) investigated the reduction of climate change impacts on urban transportation according to the T2NN-MEREC-MARCOS model to change the rate of spread of climate change. Arndt (2023) argues that it is the balance between climate change and energy security that affects energy supply choices. Leal Filho et al. (2023a) focused on threats to human health due to the increase in temperature and emphasized the health risks related to the livability of cities around the world. Leal Filho et al. (2023b) investigated climate change's impact on mental health which tending extreme events and reported the relationship between climate change and others. Tam et al. (2023) investigated the differences in climate change sensitivities and durability between countries from the top emitters (China, Japan, India, and the United States) using the climate change anxiety scale.

No other study has been found in the literature that measures the CCPI performances of countries with MCDM methods, except for Altıntaş's (2021a, 2021b) study. However, Altıntaş (2021a, 2021b) did not make an effort to find the weights of the CCPI components. In the current study, it will be an important contribution to finding the weights of the CCPI components by using various MCDM methods.

On the other hand, although the SPOTIS, WISP, and RSMVC methods applied in the study are relatively new, the number of studies conducted with these methods in the literature is quite limited. No study was found in the domestic literature that uses the SPOTIS and RSMVC methods. The RSMVC method developed by Van Dua & Thinh (2023) is presented by considering two case examples. The SPOTIS method proposed by Dezert, Tchamova, Han, Tacnet (2020) is applied based on two case examples in the relevant study. Bączkiewicz et al. (2021a) addressed the solar panel selection problem using COMET, TOPSIS, and SPOTIS methods. Bączkiewicz et al. (2021b) used the COMET, SPOTIS, VIKOR, and TOPSIS methods for the monitor selection problem. Although it is new, it is possible to come across many studies in the literature on the WISP method. Pala (2023) measured the financial performance of companies operating in the BIST food sector using the WISP method. Ulutaş et al. (2022a) used the MEREC-WISP-S model for pallet truck selection. Ulutaş et al.

(2022b) selected the most sustainable supplier for a textile manufacturer using the Grey BWM-Grey WISP model. Kirmizi, Karakas, Uçar (2023) used integer linear programming, TOPSIS, and WISP methods for the selection of design alternatives for optimal naval ship drainage systems. Deveci et al. (2022), used MEREC, SWARA, and WISP models to prioritize sustainable public transport in the Metaverse based on q-ROFS. Zavadskas, Stanujkic, Karabasevic (2022a) aimed to test the max normalization procedure used in the WISP method. Stanujkić et al. (2021a) compared the WISP method with various MCDM methods (TOPSIS, SAW, ARAS, WASPAS, and CoCoSo) using Python programming language and its NumPy library.

In addition, this study contributes to the literature by considering the climate change problem from a broader perspective and presenting an assessment specific to G20 countries.

METHODS

This section provides descriptions, concepts, and mathematical notations of the LOPCOW, SPOTIS, WISP, and RSMVC methods applied in the study.

LOPCOW Method

The LOPCOW method proposed by Ecer & Pamucar (2022) is a relatively new method where the criterion weights are objectively determined. Using both positive and negative data in the weighting process has significant advantages, including eliminating gaps in the data caused by its wider dimensionality (Keleş, 2023, p. 124). The steps of the method are as follows (Ecer & Pamucar, 2022, pp. 4-5).

Step 1. A decision matrix is created.

Step 2. The decision matrix is normalized using Equations 1-2.

$$r_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}} \qquad cost\ criterion \qquad (1)$$

$$r_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}} \qquad benefit\ criterion \qquad (2)$$

x_{max} and x_{min} represent the highest and lowest values in the relevant column.

Step 3. Percentage values (PV) of criteria are calculated using Equation 3.

$$PV_{ij} = \left| In\left(\frac{\sqrt{\frac{\sum_{i=1}^{m} r_{ij}^2}{m}}}{\sigma}\right) * 100 \right| \qquad (3)$$

σ and m represent the standard deviation and the number of alternatives, respectively.

Step 4. The criterion weights are calculated using Equation 4.

$$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}} \qquad \sum_{i=1}^{n} w_j = 1 \qquad (4)$$

SPOTIS Method

The SPOTIS method developed by Dezert et al. (2020) has a highly simple algorithm as well as being resistant to the rank reversal problem (Bączkiewicz et al., 2021b, p. 993). The main presumption of the method is the definition of data boundaries used to determine the “Ideal Solution Point” (ISP) (Więckowski & Zwiech, 2021, p. 4597). The steps of the method are as follows (Więckowski & Zwiech, 2021, p. 4597):

Step 1. Normalized distances to the Ideal Solution Point are calculated using Equation 5.

$$d_{ij}\left(A_i, S_j^*\right) = \frac{\left|S_{ij} - S_j^*\right|}{\left|S_j^{max} - S_j^{min}\right|} \tag{5}$$

For each criterion C_j, it is necessary to select the maximum and minimum S bounds. The ISP S_j^* is defined as $S_j^* = S_j^{max}$ and $S_j^* = S_j^{min}$ for the benefit and cost-oriented criteria, respectively.

Step 2. Weighted normalized distances ($d(A_i, S^*) \in [0,1]$) are calculated using Equation 6.

$$d(A_i, S^*) = \sum_{j=1}^{N} w_j d_{ij}(A_i, S^*) \tag{6}$$

Step 3. The final ranking is specified based on the values of $d(A_i, S^*)$. Smaller values of $d(A_i, S^*)$ are desirable.

WISP Method

Stanujkić et al. (2021b) proposed the WISP method, which is based on “Weighted Sum” (WS) and “Weighted Product” (WP) methods, Stanujkić and determines the impact of beneficial and non-beneficial criteria. The steps of the method are as follows (Zavadskas, Stanujkic, Turskis, Karabasevic, 2022b, pp. 3-5; Stanujkić et al., 2021a, pp. 2-3).

Step 1. A decision matrix is constituted and criterion weights are determined.

Step 2. The decision matrix is normalized using Equation 7.

$$r_{ij} = \frac{x_{ij}}{max_i x'_{ij}} \tag{7}$$

Here, r_{ij} is a dimensionless number representing the normalized i-th alternative concerning the j-th criterion. $max_i x'_{ij}$ represent the highest values in the relevant column.

Step 3. Four different benefit scores are calculated using Equations 8-11.

$$u_i^{sd} = \sum_{j \in \Omega_{max}} r_{ij}\, w_j - \sum_{j \in \Omega_{min}} r_{ij}\, w_j \tag{8}$$

$$u_i^{pd} = \prod_{j \in \Omega_{max}} r_{ij} w_j - \prod_{j \in \Omega_{min}} r_{ij} w_j \tag{9}$$

$$u_i^{sr} = \frac{\sum_{j \in \Omega_{max}} r_{ij}\, w_j}{\sum_{j \in \Omega_{min}} r_{ij}\, w_j} \tag{10}$$

$$u_i^{pr} = \frac{\prod_{j \in \Omega_{max}} r_{ij} w_j}{\prod_{j \in \Omega_{min}} r_{ij} w_j} \quad (11)$$

u_i^{sd} and u_i^{pd} represent the additive and multiplicative difference scores of the i-th alternative, while u_i^{sr} and u_i^{pr} represent the sum and product ratios. Ωmax and Ωmin indicate the benefit and cost criteria, respectively.

Step 4. The benefit scores are standardized using Equations 12-15.

$$\bar{u}_i^{sd} = \frac{1 + u_i^{sd}}{1 + max_i u_i^{sd'}} \quad (12)$$

$$\bar{u}_i^{pd} = \frac{1 + u_i^{pd}}{1 + max_i u_i^{pd'}} \quad (13)$$

$$\bar{u}_i^{sr} = \frac{1 + u_i^{sr}}{1 + max_i u_i^{sr'}} \quad (14)$$

$$\bar{u}_i^{pr} = \frac{1 + u_i^{pr}}{1 + max_i u_i^{pr'}} \quad (15)$$

Here, $\bar{u}_i^{sd}$, $\bar{u}_i^{pd}$, $\bar{u}_i^{sr}$, and $\bar{u}_i^{pr}$ represent the recalculated values of u_i^{sd}, u_i^{pd}, u_i^{sr}, and u_i^{pr}, respectively.

Step 5. The final scores of the alternatives are calculated using Equation 16 and the alternatives are ranked. It is desirable for an alternative to have a high score.

$$u_i = \frac{1}{4}\left(\bar{u}_i^{sd} + \bar{u}_i^{pd} + \bar{u}_i^{sr} + \bar{u}_i^{pr}\right) \quad (16)$$

The authors of the WISP method initially proposed a method for solving decision problems involving benefit and cost criteria. However, decision problems may include only benefit or only cost criteria. In such a case, Equations 10 and 11 are modified as follows:

$$u_i^{sr} = \sum\nolimits_{j \in \Omega_{max}} r_{ij}\, w_j \quad (17)$$

$$u_i^{pr} = \prod\nolimits_{j \in \Omega_{max}} r_{ij} w_j \quad (18)$$

when $\Omega_{min} = \emptyset$

$$u_i^{sr} = \frac{1}{\sum_{j \in \Omega_{min}} r_{ij}\, w_j} \quad (19)$$

$$u_i^{pr} = \frac{1}{\prod_{j \in \Omega_{min}} r_{ij} w_j} \quad (20)$$

when $\Omega_{max} = \emptyset$

RSMVC Method

The RSMVC method proposed by Van Dua & Thinh (2023) ensures the ranking of alternatives even when the decision matrix includes interval values, which sets it apart from other MCDM methods. The steps of the method are as follows (Van Dua & Thinh, 2023, p. 2):

Step 1. A decision matrix is created.

$$\begin{matrix} A1 \\ A2 \\ A_m \end{matrix} \begin{bmatrix} a_{11}+b_{11} & \cdots & a_{1n}+b_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1}+b_{m1} & \cdots & a_{mn}+b_{mn} \end{bmatrix} \quad (21)$$

Step 2. The average values of the criteria are calculated using Equation 21.

$$\bar{x}_{ij} = \frac{a_{ij}+b_{ij}}{2} \quad (22)$$

Equation (21) is used when the criterion value is in the range of [a_{ij}, b_{ij}]. If the criterion value is an integer, the same formula is used while taking into account the $a_{ij} = b_{ij}$ case.

Step 3. Each criterion is ranked based on its average value

Benefit criterion: The solution with the highest and lowest average value is ranked first and last, respectively.

Cost criterion: The solution with the lowest and highest average value is ranked first and last, respectively.

If there are n criteria, the rankings for the solutions need to be made in n time.

Step 4. The scores of the alternatives are calculated using Equation 22.

$$S_i = r_{ij} * w_j \quad (23)$$

r_{ij} represents the ranking of the criterion determined in step 3, and w_j represents the weight of criterion j.

Step 5. The alternatives are ranked

The alternative with the lowest S_i score is the best solution.

RESULTS AND DISCUSSION

This study aimed to evaluate the climate change performance of G20 countries using MCDM methods. The study is based on the period of 2019-2023 due to the unavailability of 2018 and previous year data. The LOPCOW method was used to determine the weights of the criteria, while SPOTIS, WISP, and RSMVC methods were used to rank the alternatives. The data was obtained through CCPI on 08/04/2023.

The CCPI has been published annually since 2005 and is an independent monitoring tool used to monitor the climate protection performance of 59 selected countries. The CCPI purposed to increase transparency in international climate policies and provides a comparison of climate protection efforts and progress made by each country. The selected 59 countries account for 92% of GHG emissions, the CCPI is evaluated in four categories: GHG emissions, renewable energy, energy use, and climate policy (Burck, Uhlich, Bals, Höhne, Nascimento, 2023, p. 3). In this study, The G20 countries were selected because they represent 85% of global economic output and 75% of world trade, as well as emitting more than 75% of global GHG emissions (Burck, Hagen, Bals, Höhne, Nascimento, 2022, p. 6). Nineteen countries of the G20 have been identified as alternatives to the study. GHG emissions (C1), renewable energy (C2), energy use (C3), and climate policy (C4) are the indicators used in the study, and all criteria are the larger the better criteria.

Determining the Criteria Weights Using the LOPCOW Method

So as to calculate the criteria weights using the LOPCOW method, first, a decision matrix was created (Table 1). In this study, the 2019-2023 periods is considered, and only the 2023 analysis results will be included to maintain the integrity of the text. The results for all years will be presented in the final section.

Table 1: Decision Matrix

2023	C1	C2	C3	C4
United Kingdom	30.38	6.44	16.37	9.88
India	29.69	7.77	16.03	13.85
France	26.52	4.97	13.15	8.33
Brazil	20.63	11.46	14.66	1.65
Italy	22.81	6.87	13.93	9.29
Germany	27.36	6.82	13.76	13.17
Türkiye	21.89	10.25	10.7	0.48
South Africa	20.09	3.17	15.16	7.27
Russia	15.17	1.27	8.85	0
Mexico	26.52	2.38	15.97	6.9
Japan	19.92	4.62	12.98	3.33
Australia	18.39	2.94	7.43	7.51
Indonesia	20.97	11.09	13.16	9.37
Argentina	17.9	4	15.43	3.87
China	11.56	9.59	5.95	11.7
Canada	10.45	3.3	4.45	8.26
United States	14.24	2.65	8	13.64
Korea	10.51	3.49	5.93	4.98
Saudi Arabia	6.43	5.81	6.01	4.17

Source: (https://ccpi.org/downloads/).

In the second step, decision matrix elements were normalized using Equation 2, and the results are presented in Table 2. In the third step, the percentage values (PV) of each criterion were calculated using Equation 3, and in the final step, alternatives were ranked using Equation 4 (Table 3).

Table 2: Normalized Decision Matrix

	C1	C2	C3	C4
United Kingdom	1.0000	0.5074	1.0000	0.7134
India	0.9712	0.6379	0.9715	1.0000
France	0.8388	0.3631	0.7299	0.6014
Brazil	0.5929	1.0000	0.8565	0.1191
Italy	0.6839	0.5496	0.7953	0.6708
Germany	0.8739	0.5447	0.7810	0.9509
Türkiye	0.6455	0.8813	0.5243	0.0347
South Africa	0.5704	0.1865	0.8985	0.5249
Russia	0.3649	0.0000	0.3691	0.0000
Mexico	0.8388	0.1089	0.9664	0.4982
Japan	0.5633	0.3288	0.7156	0.2404

Australia	0.4994	0.1639	0.2500	0.5422
Indonesia	0.6071	0.9637	0.7307	0.6765
Argentina	0.4789	0.2679	0.9211	0.2794
China	0.2142	0.8165	0.1258	0.8448
Canada	0.1678	0.1992	0.0000	0.5964
United States	0.3261	0.1354	0.2978	0.9848
Korea	0.1704	0.2179	0.1242	0.3596
Saudi Arabia	0.0000	0.4455	0.1309	0.3011

Table 3: PV Values and Criterion Weights

Year		C1	C2	C3	C4
2019	PV	88.7027	68.9688	79.6435	73.4757
	w	0.2854	0.2219	0.2563	0.2364
2020	PV	81.8676	75.1120	73.2637	62.8495
	w	0.2793	0.2563	0.2500	0.2144
2021	PV	75.3370	62.8449	75.7829	59.4053
	w	0.2756	0.2299	0.2772	0.2173
2022	PV	66.5459	54.6617	73.0135	60.0377
	w	0.2617	0.2150	0.2872	0.2361
2023	PV	67.7924	48.5795	61.6849	60.7935
	w	0.2838	0.2034	0.2583	0.2545

According to the results presented in Table 3, C1 (GHG emissions) was identified as the most important criterion for the years 2019, 2020, and 2023, while C3 (energy use) was identified as the most important criterion for the year 2021, and 2023, respectively. On the other hand, C4 (climate policy) and C2 (renewable energy) were identified as the criterion with the lowest importance degree for the years 2019-2023, respectively. The criteria weights by year can be presented as a whole.

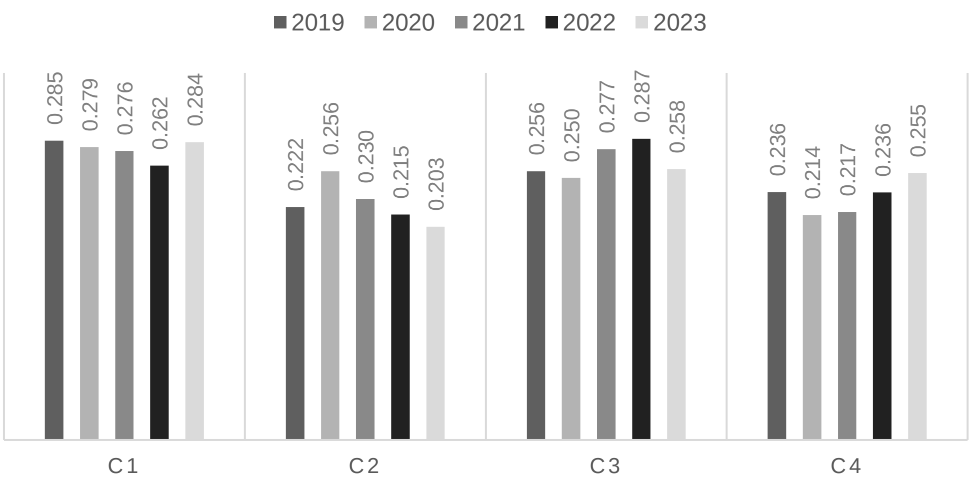

Figure 1: LOPCOW Method Weights for 2019-2023

It can be seen that the criteria weights for different years do not differ much from each other, and there are very close weights for 2019-2023 years.

Evaluating Alternatives Using the SPOTIS Method

Firstly, the decision matrix was normalized using Equation 5 to evaluate the alternatives using the SPOTIS method. Then, weighted normalized distances were calculated using Equation 6, and the final ranking was obtained (Table 5).

Table 4: Normalized Decision Matrix

	C1	C2	C3	C4
United Kingdom	0.0000	0.4926	0.0000	0.2866
India	0.0288	0.3621	0.0285	0.0000
France	0.1612	0.6369	0.2701	0.3986
Brazil	0.4071	0.0000	0.1435	0.8809
Italy	0.3161	0.4504	0.2047	0.3292
Germany	0.1261	0.4553	0.2190	0.0491
Türkiye	0.3545	0.1187	0.4757	0.9653
South Africa	0.4296	0.8135	0.1015	0.4751
Russia	0.6351	1.0000	0.6309	1.0000
Mexico	0.1612	0.8911	0.0336	0.5018
Japan	0.4367	0.6712	0.2844	0.7596
Australia	0.5006	0.8361	0.7500	0.4578
Indonesia	0.3929	0.0363	0.2693	0.3235
Argentina	0.5211	0.7321	0.0789	0.7206
China	0.7858	0.1835	0.8742	0.1552
Canada	0.8322	0.8008	1.0000	0.4036
United States	0.6739	0.8646	0.7022	0.0152
Korea	0.8296	0.7821	0.8758	0.6404
Saudi Arabia	1.0000	0.5545	0.8691	0.6989

Table 5: Weighted Matrix and Ranking Results

	C1	C2	C3	C4	∑	Rank
United Kingdom	0.0000	0.1002	0.0000	0.0730	0.1732	2
India	0.0082	0.0737	0.0074	0.0000	0.0892	1
France	0.0457	0.1295	0.0698	0.1014	0.3465	6
Brazil	0.1155	0.0000	0.0370	0.2242	0.3768	8
Italy	0.0897	0.0916	0.0529	0.0838	0.3180	5
Germany	0.0358	0.0926	0.0565	0.0125	0.1974	3
Türkiye	0.1006	0.0242	0.1228	0.2457	0.4933	10
South Africa	0.1219	0.1655	0.0262	0.1209	0.4345	9
Russia	0.1803	0.2034	0.1629	0.2545	0.8011	19
Mexico	0.0457	0.1812	0.0087	0.1277	0.3634	7
Japan	0.1240	0.1365	0.0734	0.1933	0.5273	13
Australia	0.1421	0.1701	0.1937	0.1165	0.6224	15
Indonesia	0.1115	0.0074	0.0695	0.0823	0.2708	4
Argentina	0.1479	0.1489	0.0204	0.1834	0.5006	11

China	0.2230	0.0373	0.2258	0.0395	0.5256	12
Canada	0.2362	0.1629	0.2583	0.1027	0.7600	16
United States	0.1913	0.1758	0.1813	0.0039	0.5523	14
Korea	0.2355	0.1591	0.2262	0.1630	0.7838	17
Saudi Arabia	0.2838	0.1128	0.2245	0.1779	0.7990	18

According to Table 5, India (0.0892), United Kingdom (0.1732), and Germany (0.1974) ranked in the top three in terms of climate change performance, while Korea (0.7838), Saudi Arabia (0.7990), and Russia (0.8011) rank last three.

Evaluating Alternatives Using the WISP Method

So as to evaluate the alternatives using the WISP method, first, the decision matrix was normalized using Equation 7 (Table 6). Then, since there was no cost-oriented criterion in the study, the benefit scores were calculated using Equations 8-9 and 17-18, and then standardized using Equations 12-15. Finally, total performance scores were determined using Equation 16 (Table 7).

Table 6: Normalized Decision Matrix

	C1	C2	C3	C4
United Kingdom	1.0000	0.5620	1.0000	0.7134
India	0.9773	0.6780	0.9792	1.0000
France	0.8729	0.4337	0.8033	0.6014
Brazil	0.6791	1.0000	0.8955	0.1191
Italy	0.7508	0.5995	0.8509	0.6708
Germany	0.9006	0.5951	0.8406	0.9509
Türkiye	0.7205	0.8944	0.6536	0.0347
South Africa	0.6613	0.2766	0.9261	0.5249
Russia	0.4993	0.1108	0.5406	0.0000
Mexico	0.8729	0.2077	0.9756	0.4982
Japan	0.6557	0.4031	0.7929	0.2404
Australia	0.6053	0.2565	0.4539	0.5422
Indonesia	0.6903	0.9677	0.8039	0.6765
Argentina	0.5892	0.3490	0.9426	0.2794
China	0.3805	0.8368	0.3635	0.8448
Canada	0.3440	0.2880	0.2718	0.5964
United States	0.4687	0.2312	0.4887	0.9848
Korea	0.3460	0.3045	0.3622	0.3596
Saudi Arabia	0.2117	0.5070	0.3671	0.3011

Table 7: Total Performance Scores and Ranking

	$\bar{u}_i^{sd}$	$\bar{u}_i^{pd}$	$\bar{u}_i^{sr}$	$\bar{u}_i^{pr}$	u_i	Rank
United Kingdom	0.9559	0.9991	0.9559	0.9991	0.9775	3
India	1.0040	1.0000	1.0040	1.0000	1.0020	1
France	0.8859	0.9982	0.8859	0.9982	0.9420	6
Brazil	0.8656	0.9978	0.8656	0.9978	0.9317	8
Italy	0.9010	0.9985	0.9010	0.9985	0.9497	5

Germany	0.9586	0.9991	0.9586	0.9991	0.9788	2
Türkiye	0.8167	0.9976	0.8167	0.9976	0.9071	11
South Africa	0.8442	0.9978	0.8442	0.9978	0.9210	9
Russia	0.6808	0.9975	0.6808	0.9975	0.8392	19
Mexico	0.8714	0.9978	0.8714	0.9978	0.9346	7
Japan	0.8010	0.9977	0.8010	0.9977	0.8994	14
Australia	0.7724	0.9976	0.7724	0.9976	0.8850	15
Indonesia	0.9256	0.9989	0.9256	0.9989	0.9622	4
Argentina	0.8108	0.9977	0.8108	0.9977	0.9043	13
China	0.8287	0.9979	0.8287	0.9979	0.9133	10
Canada	0.7196	0.9976	0.7196	0.9976	0.8586	16
United States	0.8130	0.9977	0.8130	0.9977	0.9053	12
Korea	0.7024	0.9976	0.7024	0.9976	0.8500	17
Saudi Arabia	0.6969	0.9975	0.6969	0.9975	0.8472	18

As can be seen from Table 7, India (1.0020), Germany (0.9788), and the United Kingdom (0.9775) are the top three countries in terms of climate change performance, while Korea (0.8500), Saudi Arabia (0.8472), and Russia (0.8392) are among the countries with the lowest performance.

Evaluating Alternatives Using the RSMVC Method

So as to rank the alternatives using the RSMVC method, the criteria in the decision matrix (Table 1) were first ranked according to their optimization directions (Table 8). As there was no interval value in the decision matrix, it was directly used. In the second step, a weighted matrix was created using Equation 22 and the alternatives were ranked. The results obtained are presented in Table 9.

Table 8: Criteria Rankings

	C1	C2	C3	C4
United Kingdom	1	8	1	5
India	2	5	2	1
France	4.5	10	10	8
Brazil	9	1	6	17
Italy	6	6	7	7
Germany	3	7	8	3
Türkiye	7	3	12	18
South Africa	10	15	5	11
Russia	14	19	13	19
Mexico	4.5	18	3	12
Japan	11	11	11	16
Australia	12	16	15	10
Indonesia	8	2	9	6
Argentina	13	12	4	15
China	16	4	17	4
Canada	18	14	19	9
United States	15	17	14	2

Korea	17	13	18	13
Saudi Arabia	19	9	16	14

Table 9: Weighted Matrix and Ranking Results

	C1	C2	C3	C4	∑	Rank
United Kingdom	0.2838	1.6271	0.2583	1.2726	3.4418	1
India	0.5677	1.0169	0.5165	0.2545	2.3556	2
France	1.2772	2.0339	2.5826	2.0362	7.9299	6
Brazil	2.5545	0.2034	1.5495	4.3269	8.6343	7
Italy	1.7030	1.2203	1.8078	1.7817	6.5128	4
Germany	0.8515	1.4237	2.0661	0.7636	5.1048	3
Türkiye	1.9868	0.6102	3.0991	4.5815	10.2775	10
South Africa	2.8383	3.0508	1.2913	2.7998	9.9802	9
Russia	3.9736	3.8644	3.3573	4.8360	16.0313	19
Mexico	1.2772	3.6610	0.7748	3.0543	8.7673	8
Japan	3.1221	2.2373	2.8408	4.0724	12.2726	14
Australia	3.4059	3.2542	3.8739	2.5453	13.0793	15
Indonesia	2.2706	0.4068	2.3243	1.5272	6.5289	5
Argentina	3.6898	2.4407	1.0330	3.8179	10.9813	12
China	4.5412	0.8136	4.3904	1.0181	10.7633	11
Canada	5.1089	2.8474	4.9069	2.2907	15.1540	17
United States	4.2574	3.4576	3.6156	0.5091	11.8397	13
Korea	4.8251	2.6441	4.6486	3.3088	15.4266	18
Saudi Arabia	5.3927	1.8305	4.1321	3.5634	14.9187	16

According to the ranking results of RSMVC in Table 9, the top three countries with the highest and lowest climate change performance are the United Kingdom (3.4418), India (2.3556), and Germany (5.1048); Russia (16.0313), Korea (15.4266), and Canada (15.1540), respectively. The ranking results for all years are presented in Table 10.

Table 10. Comparative results

	SPOTIS					WISP					RSMVC				
	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
United Kingdom	1	1	1	1	2	1	1	1	1	3	1	1	1	1	1
India	2	2	2	2	1	2	2	2	2	1	2	2	2	2	2
France	5	5	7	4	6	5	5	7	4	6	5	5	6	4	6
Brazil	3	3	5	6	8	3	3	5	6	8	3	3	3	5	7
Italy	4	6	6	7	5	4	6	6	7	5	4	6	7	7	4
Germany	7	4	3	3	3	7	4	3	3	2	7	4	4	3	3
Türkiye	12	11	11	11	10	12	12	11	11	11	12	7	11	12	10
South Africa	11	10	10	10	9	11	10	10	10	9	11	11	10	10	9
Russia	14	15	15	15	19	14	14	15	15	19	16	14	15	15	19
Mexico	6	8	9	8	7	6	8	9	9	7	6	8	8	8	8
Japan	13	14	12	13	13	13	13	12	13	14	13	13	13	13	14
Australia	16	16	16	16	15	17	17	16	16	15	17	16	17	16	15
Indonesia	9	9	4	5	4	9	9	4	5	4	8	10	5	6	5
Argentina	10	12	13	12	11	10	11	13	12	13	10	12	12	11	12

China	8	7	8	9	12	8	7	8	8	10	9	9	9	9	11
Canada	15	17	18	19	16	15	15	18	18	16	15	18	18	18	17
United States	18	19	19	14	14	18	19	19	14	12	18	19	19	14	13
Korea	17	18	14	17	17	16	16	14	17	17	14	15	14	17	18
Saudi Arabia	19	13	17	18	18	19	18	17	19	18	19	17	16	19	16

According to Table 10, rankings obtained by three different methods have shown slight deviations. The results obtained by different MCDM methods with different algorithms may vary using the same dataset. Many studies in the literature (Mathew & Sahu, 2018; Goswami et al. 2021; Ecer & Pamucar, 2022; Nguyen, Le, Nguyen, Tran, Vu, 2022; Pamučar & Ćirović, 2015) can serve as examples of this situation.

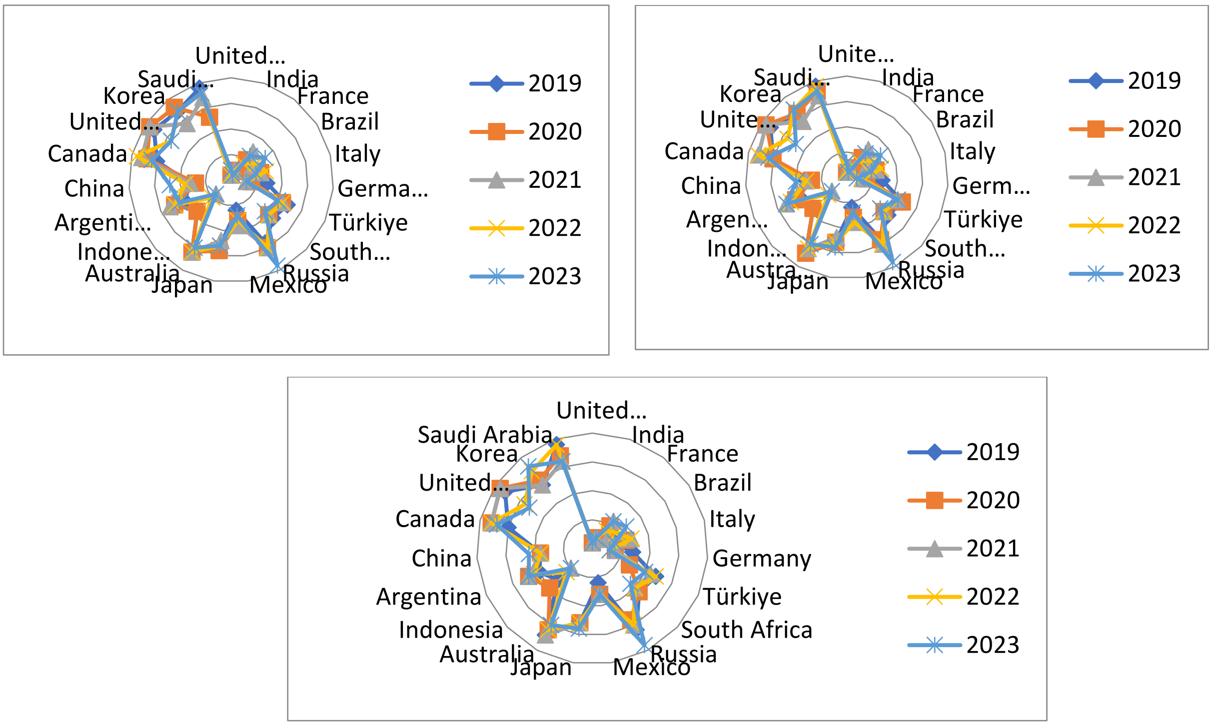

Figure 2: Rankings for SPOTIS, WISP, and RSMVC Methods for 2019-2023

The relationships between the methods can be examined in more detail by Spearman Rank correlation analysis.

Table 11: Spearman Rank Correlation Coefficients

	Spearman p	SPOTIS	WISP	RSMVC
2019	SPOTIS		0.996	0.986
	WISP	0.996		0.989
	RSMVC	0.986	0.989	
2020	Spearman p	SPOTIS	WISP	RSMVC
	SPOTIS		0.946	0.942
	WISP	0.946		0.982

	RSMVC	0.942	0.982	
2021	Spearman p	SPOTIS	WISP	RSMVC
	SPOTIS		1	0.989
	WISP	1		0.989
	RSMVC	0.989	0.989	
2022	Spearman p	SPOTIS	WISP	RSMVC
	SPOTIS		0.993	0.995
	WISP	0.993		0.991
	RSMVC	0.995	0.991	
2023	Spearman p	SPOTIS	WISP	RSMVC
	SPOTIS		0.991	0.991
	WISP	0.991		0.986
	RSMVC	0.991	0.986	

* shows significance at the 1% level.

According to Table 11, a strongly positive relationship was found among the results obtained by three different methods (SPOTIS, WISP, RSMVC).

On the other hand, in all three methods, some countries are in the same rank. The United Kingdom and India for 2019-2022 ranked first and second in all rankings, respectively. Saudi Arabia for 2019 and the United States for 2020-2021, and Russia for 2023 ranked last. Others differed from each other. For this and a better analysis, the ranking findings found by different methods can be integrated with the Borda ranking.

Table 12. Borda Results

	2019	2020	2021	2022	2023	Total
United Kingdom	1	1	1	1	2	1
India	2	2	2	2	1	2
France	5	5	7	4	6	5
Brazil	3	3	4	6	8	4
Italy	4	6	6	7	5	6
Germany	7	4	3	3	3	3
Türkiye	12	10	11	11	10	11
South Africa	11	11	10	10	9	10
Russia	14	14	15	15	19	14
Mexico	6	8	9	8	7	8
Japan	13	13	12	13	14	13
Australia	17	16	16	16	15	15
Indonesia	9	9	4	5	4	7
Argentina	10	12	13	12	12	12
China	8	7	8	9	11	9
Canada	15	18	18	18	16	18
United States	18	19	19	14	13	17
Korea	16	16	14	17	17	15
Saudi Arabia	19	15	17	19	17	19

By using the ranking results of SPOTIS, WISP, and RSMVC methods, the Borda ranking was separately integrated for the years 2019-2023, and then the total ranking results were found.

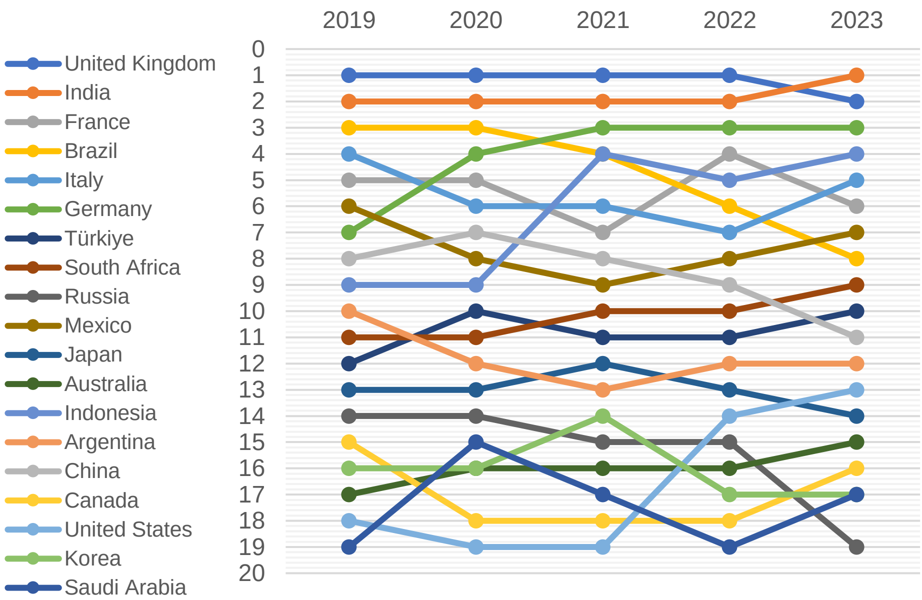

Figure 3: Compromise Rankings for 2019-2023

According to different methods, the United Kingdom was in the first rank, followed by India, Germany, Brazil, France, and Italy. The last three ranks are the United States, Canada, and Saudi Arabia.

The impact of criterion weights on the results was tested using the equal weighting technique, and the results are presented in Figure 4. Accordingly, the results obtained based on LOPCOW and Mean Weight (MW) techniques have shown the slight deviations.

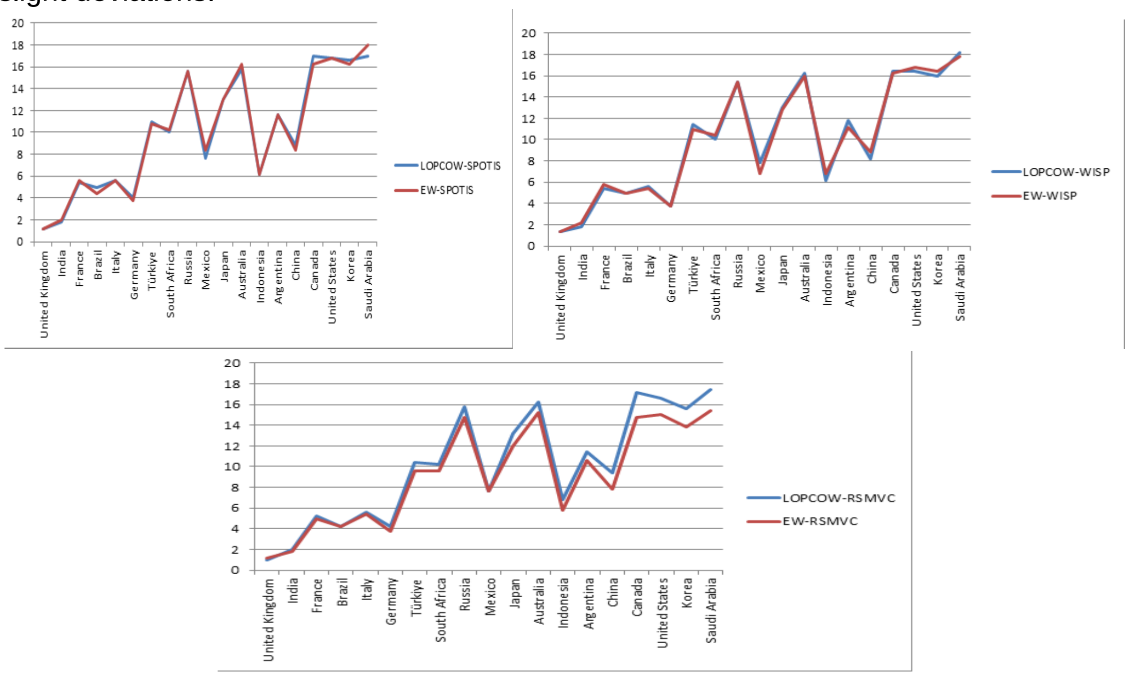

Figure 4: The Impact of Criterion Weights on the Results

No study has been found in the literature that measures the climate change performance of G20 countries retrospectively using MCDM methods. However, Altintas (2021a) measured the climate change performance of G20 countries in 2021 using the MAUT and ROV methods. In mentioned study using CCPI data, the equal weight technique was used and the rankings obtained with MAUT and ROV methods showed small deviations. In that study, in terms of climate change performance, the United Kingdom, India, and Indonesia ranked in the top three, while Saudi Arabia, Canada, and Korea ranked in the bottom three. In the current study, the top three countries in terms of climate change performance in 2021 were the United Kingdom, India, and Germany/Brazil, while the bottom three were the United States, Canada, and Saudi Arabia/Australia. There may be a slight similarity. However, for more overall comparison, it can be said that there are very little similarities in the integrated ranking according to different methods because England, India, and Germany are in the first 3 rankings, and then the United States, Canada, and Saudi Arabia are in the last 3 rankings. On the other hand, when the similarities between the total ranking results and Altintas (2021a) were analyzed on the basis of Spearman rank correlation analysis, low levels of negative correlations (for MAUT r=-0.137, for ROV r=-0.123) were found.

CONCLUSION

The CCPI sets weighting for 40% GHG emissions, 20% renewable energy, 20% energy use, and 20% climate policy in the overall score. These weights are standard and rough. Evaluation and ranking of multiple alternatives can be better done by using varying criterion weights, which are obtained when mathematical methods are used, rather than using rough and same weights like that. When the objective LOPCOW method calculations are used according to the decision matrix, weights of 26-28% for the C1 (GHG emissions) criterion, 20-25% for the C2 (renewable energy) criterion, 25-28% for the C3 (energy use) criterion, and 21-25% for the C4 (climate policy) criterion were found. It has been shown that more valid and reasonable weights can be used with decision making methods. The G20 country rankings obtained by SPOTIS, WISP, and RSMVC methods based on LOPCOW showed a small deviation. Besides, the rank of the first and last countries remained the same for the rankings obtained by all three methods. United Kingdom for 2019-2022 ranked first and second in all rankings. Saudi Arabia for 2019 and the United States for 2020-2021, and Russia for 2023 ranked last. The overall performance in the G20 countries, the United Kingdom was in the first rank, followed by India, Germany, Brazil, France, and Italy. The last three ranks are the United States, Canada, and Saudi Arabia. Three countries draw attention in the increase/decrease in climate change performance over the years. Brazil ranked 3rd in 2019, 4th in 2021, and 6th in 2022 and 8th in 2023. Germany ranked 7th in 2019 and 3rd in 2021, 2022 and 2023. Indonesia performed well, ranking 9th in 2019 and 2020, 4th in 2021, 5th in 2022, and 4th again in 2023.

The impacts of climate change are already being felt around the worldwide. In order to achieve climate change aims, countries can invest in renewable energy sources, increase energy efficiency and promote sustainable transportation. For low-performing countries, it may be advisable to follow up on agreements on climate change and adapt. Low-performing countries can revise their targets on climate change and increase their ambitions. Countries can adopt new technologies that help reduce emissions, such as using energy efficient buildings and transportation, such as carbon capture and storage. Cooperation can be made with countries that perform better on climate change. An upper limit for carbon emissions may be determined by the countries and taxes may be imposed on factories and businesses that do not comply with this limit. It is important that they make more efforts to reduce C02 rates in preventing climate change. Low-performing countries can strive to adapt to the effects of climate change, such as improving water management, building seawalls, and implementing agricultural practices that are more resistant to drought and floods. Educational campaigns and promotional advertisements can be implemented by governments through mass media to raise public awareness of reducing emissions.

In future studies, the climate change components used in this study can be examined by assigning subjective weights according to the decision maker's preference or by using other different objective weight determination methods. Then, if desired, the findings can be compared using different MCDM methods.

REFERENCES

Altıntaş, F. F. (2021a). Measuring the climate change protection performance of G20 group countries with ROV and MAUT methods. *Journal of Current Researches on Social Sciences, 11*(1), 147-166. doi: 10.26579/jocress.429.

Altıntaş, F. F. (2021b). G7 grubu ülkelerin iklim değişikliği koruma performanslarının CODAS ve EDAS yöntemleri ile incelenmesi. *Electronic Turkish Studies, 16*(4),1181-1201. doi: 10.7827/TurkishStudies.51022.

Arndt, C. (2023). Climate change vs energy security? The conditional support for energy sources among Western Europeans. *Energy Policy*, *174*(2023), 1-11. doi: 10.1016/j.enpol.2023.113471.

Bączkiewicz, A., Kizielewicz, B., Shekhovtsov, A., Wątróbski, J., Więckowski, J., & Salabun, W. (2021b, December 7-8). Towards an e-commerce recommendation system based on MCDM methods. In 2021 International Conference on Decision Aid Sciences and Application (DASA).

Bączkiewicz, A., Kizielewicz, B., Shekhovtsov, A., Yelmikheiev, M., Kozlov, V., & Sałabun, W. (2021a). Comparative analysis of solar panels with determination of local significance levels of criteria using the MCDM methods resistant to the rank reversal phenomenon. *Energies, 14*(18), 1-21. doi: 10.3390/en14185727

Balsara, S., Jain, P. K., & Ramesh, A. (2019). An integrated approach using AHP and DEMATEL for evaluating climate change mitigation strategies of the Indian cement manufacturing industry. *Environmental pollution*, 252, 863-878. doi: 10.1016/j.envpol.2019.05.059.

Bernauer, T., & Böhmelt, T. (2013). National climate policies in international comparison: the climate change cooperation index. *Environmental Science & Policy*, 25, 196-206. doi: 10.1016/j.envsci.2012.09.007.

Bozkus, S. K., Kahyaoglu, H., & Lawali, A. M. M. (2020). Multifractal analysis of atmospheric carbon emissions and OECD industrial production index. *International Journal of Climate Change Strategies and Management, 12*(4), 411-430. doi: 10.1108/IJCCSM-08-2019-0050.

Burck, J., Hagen, U., Bals, C., Höhne, N., & Nascimento, L. (2022). *2023 Climate Change Performance Index – Results*, 1-32. Retrieved April 8, 2023, fromhttps://ccpi.org/wp-content/uploads/CCPI-2023-Results-3.pdf

Burck, J., Uhlich, T., Bals, C., Höhne, N., & Nascimento, L. (2023). CCPI Climate Change Performance Index, 1-17. Retrieved April 8, 2023, from https://www.germanwatch.org/sites/default/files/ccpi-ksi-2023-kurzfassung.pdf

Climate Change Performance Index, Retrieved April 8, 2023, from https://ccpi.org/downloads/

Codal, K. S., Ari, I., & Codal, A. (2021). Multidimensional perspective for performance assessment on climate change actions of G20 countries. *Environmental Development*, *39*(2021), 1-14. doi: 10.1016/j.envdev.2021.100639.

Deveci, M., Mishra, A. R., Gokasar, I., Rani, P., Pamucar, D., & Özcan, E. (2022). A decision support system for assessing and prioritizing sustainable urban transportation in metaverse. IEEE Transactions on Fuzzy Systems, 31(2), 475-484.

Dezert, J., Tchamova, A., Han, D., & Tacnet, J. M. (2020, July 6-9). The SPOTIS rank reversal free method for multi-criteria decision-making support. In 2020 IEEE 23rd International Conference on Information Fusion (FUSION).

Ding, D. K., & Beh, S. E. (2022). Climate Change and sustainability in ASEAN countries. *Sustainability, 14*(2), 1-17. doi: 10.3390/su14020999.

Ecer, F., & Pamucar, D. (2022). A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology: An application in developing country banking sector. *Omega, 112*(2022), 1-17. doi: 10.1016/j.omega.2022.102690

Gokasar, I., Deveci, M., & Kalan, O. (2022). CO2 Emission based prioritization of bridge maintenance projects using neutrosophic fuzzy sets based decision making approach. *Research in Transportation Economics*, *91*, 1-13. doi: 10.1016/j.retrec.2021.101029.

Golfam, P., Ashofteh, P. S., Rajaee, T., & Chu, X. (2019). Prioritization of water allocation for adaptation to climate change using multi-criteria decision making (MCDM). *Water Resources Management*, 33, 3401-3416. doi: 10.1007/s11269-019-02307-7.

Goswami, S. S., Behera, D. K., Afzal, A., Razak Kaladgi, A., Khan, S. A., Rajendran, P., ... & Asif, M. (2021). Analysis of a robot selection problem using two newly developed hybrid MCDM models of TOPSIS-ARAS and COPRAS-ARAS. *Symmetry, 13*(8), 1-35. doi: 10.3390/sym13081331

Keleş, N. (2023). Türkiye'nin 81 İlinin Sağlık Performansının Güncel Karar Verme Yöntemleriyle Değerlendirilmesi. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, (75), 120-141. doi: 10.51290/dpusbe.1134082

Khan, M. Z., & Khan, M. F. (2019). Application of ANFIS, ANN and fuzzy time series models to CO2 emission from the energy sector and global temperature increase. *International Journal of Climate Change Strategies and Management, 11*(5), 622-642. doi: 10.1108/IJCCSM-01-2019-0001.

Kirmizi, M., Karakas, S., & Uçar, H. (2023). Selecting the optimal naval ship drainage system design alternative based on ınteger linear programming, TOPSIS, and simple WISP methods. *Journal of Ship Production and Design*, 1-12.

Leal Filho, W., Krishnapillai, M., Minhas, A., Ali, S., Nagle Alverio, G., Hendy Ahmed, M. S., ... & Kovaleva, M. (2023b). Climate change, extreme events and mental health in the Pacific region. *International Journal of Climate Change Strategies and Management, 15*(1), 20-40. doi: 10.1108/IJCCSM-03-2022-0032.

Leal Filho, W., Tuladhar, L., Li, C., Balogun, A. L. B., Kovaleva, M., Abubakar, I. R., ... & Donkor, F. K. K. (2023a). Climate change and extremes: implications on city livability and associated health risks across the globe. *International Journal of Climate Change Strategies and Management, 15*(1), 1-19. doi: 10.1108/IJCCSM-07-2021-0078.

Mathew, M., & Sahu, S. (2018). Comparison of New multi-criteria decision making methods for material handling equipment selection. *Management Science Letters, 8*(3), 139-150. doi: 10.5267/j.msl.2018.1.004

Nguyen, H. Q., Le, X. H., Nguyen, T. T., Tran, Q. H., & Vu, N. P. (2022). A comparative study on multi-criteria decision-making in dressing process for ınternal grinding. *Machines, 10*(5), 1-14. doi: 10.3390/machines10050303

Ooi, S. K., Goh, S., Yeap, J. A., & Loo, K. S. (2018). Linking corporate climate change and financial performance: Evidence from Malaysia. *Global Business & Management Research, 10*(1), 231-246.

Pala, O. (2023). SD ve WISP yaklaşımları ile gıda sektöründe finansal performans analizi. *Doğuş Üniversitesi Dergisi, 24*(1), 59-79. doi: 10.31671/doujournal.1118061.

Pamučar, D. and Ćirović, G. (2015). The selection of transport and handling resources in logistics centers using multi-attributive border approximation area comparison (MABAC). *Expert Systems with Applications, 42*(6), 3016-3028. doi: 10.1016/j.eswa.2014.11.057

Puertas, R., & Marti, L. (2021). International ranking of climate change action: An analysis using the indicators from the climate change performance index. *Renewable and Sustainable Energy Reviews*, *148*(2021), 1-11. doi: 10.1016/j.rser.2021.111316.

Simic, V., Gokasar, I., Deveci, M., & Švadlenka, L. (2022). Mitigating climate change effects of urban transportation using a type-2 neutrosophic MEREC-MARCOS model. *IEEE Transactions on Engineering Management*, 1-17. doi: 10.1109/TEM.2022.3207375.

Stanujkić, D., Karabašević, D., Popović, G., Zavadskas, E. K., Saračević, M., Stanimirović, P. S., ... & Meidute-Kavaliauskiene, I. (2021a). Comparative analysis of the simple WISP and some prominent MCDM methods: A Python approach. *Axioms, 10*(4), 1-14. doi: 10.3390/axioms10040347.

Stanujkić, D., Popovic, G., Karabasevic, D., Meidute-Kavaliauskiene, I., & Ulutaş, A. (2021b). An integrated simple weighted sum product method—WISP. *IEEE Transactions on Engineering Management*, 1933-1944, doi: 10.1109/TEM.2021.3075783

Tam, K. P., Chan, H. W., & Clayton, S. (2023). Climate change anxiety in China, India, Japan, and the United States. *Journal of Environmental Psychology*, 87, 1-14. https://doi.org/10.1016/j.jenvp.2023.101991.

Ulutaş, A., Stanujkic, D., Karabasevic, D., Popovic, G., & Novaković, S. (2022a). Pallet truck selection with MEREC and WISP-S methods. *Strategic Management-International Journal of Strategic Management and Decision Support Systems in Strategic Management*, *27*(2022), 23-29. doi: 10.5937/StraMan2200013U.

Ulutaş, A., Topal, A., Pamučar, D., Stević, Ž., Karabašević, D., & Popović, G. (2022b). A New Integrated Multi-Criteria Decision-Making Model for Sustainable Supplier

Selection Based on a Novel Grey WISP and Grey BWM Methods. *Sustainability, 14*(24), 1-20. doi: 10.3390/su142416921

Van Dua, T., & Thinh, H. X. (2023). RSMVC: A new-simple method to select the cutting tool base on multi criteria. *Journal of Applied Engineering Science, 21*(1), 167-175. doi: 10.5937/jaes0-39772.

Więckowski, J., & Zwiech, P. (2021). Can weighting methods provide similar results in MCDA problems? Selection of energetic materials study case. *Procedia Computer Science*, 192, 4592-4601. doi: 10.1016/j.procs.2021.09.237.

Zavadskas, E. K., Stanujkic, D., Karabasevic, D., & Turskis, Z. (2022a). Analysis of the simple WISP method results using different normalization procedures. *Studies in Informatics and Control, 3*1(1), 5-12.

Zavadskas, E. K., Stanujkic, D., Turskis, Z., & Karabasevic, D. (2022b). An intuitionistic extension of the simple WISP method. *Entropy, 24(*2), 1-11. doi: 10.3390/e24020218.