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Sürdürülebilirlik Perspektifinden Çok Kriterli Karar Verme Yöntemleri Kullanılarak Girişimcilik Performansının Değerlendirilmesi

Mulla Veli ABLAY*,a

[b] *Osmaniye Korkut Ata Üniversitesi, Rektörlük, OSMANİYE, 80000, TÜRKİYE*

MAKALE BİLGİSİ

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Sorumlu Yazar
e-posta:
veliablay@gmail.com

ÖZET

Sürdürülebilirlik odaklı girişimcilik, ekonomik büyüme ile çevresel sorumluluk hedeflerinin bütünleşik bir şekilde ele alınmasını gerektirmektedir. Bu çalışmada, girişimcilik performansı çok kriterli karar verme (ÇKKV) yöntemleri kullanılarak analiz edilmiştir. Analizde; yeni kurulan işletme sayısı, iş yapma kolaylığı endeksi, gayri safi yurt içi hasıla (GSYH), sera gazı emisyonları ve yenilenebilir enerji tüketimini içeren finansal ve çevresel göstergeler kullanılmıştır. Veriler, Dünya Bankası veri tabanından elde edilmiştir. Veri kısıtı bulunmayan G20 ülkeleri arasından 13 ülke çalışmaya dâhil edilmiştir. Çalışmada, kriter ağırlıkları öncelikle Entropi yöntemi kullanılarak belirlenmiştir. Bu ağırlıklar daha sonra TODIM ve VIKOR yöntemlerinde kullanılarak ülkelerin girişimcilik performans sıralamaları elde edilmiştir. Analiz sonuçları, her iki yöntemin de benzer çıktılar ürettiğini göstermektedir. TODIM yöntemine göre Birleşik Krallık en yüksek performansı sergilerken, Brezilya en düşük performansa sahiptir. VIKOR yönteminde, q parametresinin farklı değerlerine bağlı olarak Japonya, Meksika ve Rusya Federasyonu'nun en düşük performansa sahip olduğu belirlenmiştir. Ayrıca, yöntemin geçerliliğini test etmek amacıyla bir duyarlılık analizi yapılmış ve elde edilen bulgular, her iki yöntemin de güvenilir ve tutarlı sonuçlar sağladığını ortaya koymuştur.

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Evaluating Entrepreneurship Performance Using Multi-Criteria Decision-Making Methods from a Sustainability Perspective

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Corresponding Authors
e-mail:
veliablay@gmail.com

ABSTRACT

Sustainability-focused entrepreneurship requires the integrated consideration of economic growth and environmental responsibility objectives. In this study, entrepreneurial performance was analyzed using multi-criteria decision-making (MCDM) methods. Financial and environmental indicators, including the number of newly registered businesses, ease of doing business score, gross domestic product (GDP), greenhouse gas emissions, and renewable energy consumption, were used in the analysis. The data were obtained from the World Bank database. 13 countries from the G20, with no data constraints, were included in the study. In the study, the criterion weights were first determined using the Entropy method. These weights were then used in the TODIM and VIKOR methods to obtain the rankings of entrepreneurship performance for the countries. The analysis results show that both methods produced similar outputs. In the TODIM method, the United Kingdom showed the highest performance, while Brazil had the lowest performance. In the VIKOR method, depending on different values of the parameter q, Japan, Mexico, and the Russian Federation were found to have the lowest performance. Furthermore, a sensitivity analysis was conducted to test the validity of the method, and the findings revealed that both methods provided reliable and consistent results.

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1. *INTRODUCTION (GİRİŞ)*

Sustainability is defined as a multidimensional concept that safeguards long-term human well-being and embraces the entirety of universal phenomena. Within this framework, elements such as poverty reduction, food security, access to energy, and a renewable environment come to the forefront [21]. The use of renewable energy not only supports issues such as climate change mitigation and energy access but also highlights the strong interdependence among all variables related to sustainability. On the other hand, while policies aimed at increasing agricultural productivity can contribute positively to food security, they can also lead to the excessive use of water resources, thereby threatening long-term sustainability. When such dynamics are overlooked, the lack of integrated policies in areas such as water, energy, poverty, and food can amplify negative risks. Conversely, robust cooperation and comprehensive policy frameworks in these areas help to enhance both environmental and socio-economic benefits [12, 21]. In addition, countries' long-term sustainability objectives play an important role in achieving both environmental sustainability and socio-economic benefits. When national policy goals are aligned with sustainability objectives, the desired outcomes are more likely to be achieved.

The number of newly registered businesses is a key indicator of economic vitality, entrepreneurial activity, growth potential, productivity gains, and employment capacity [20]. At the same time, new enterprises play an encouraging role by contributing to regional development and by amplifying differences in innovation across regions [17]. Thus, the increase in new business creation emerges as a critical factor that not only supports employment but also enhances per capita productivity.

Economic policies are developed by policymakers in order to improve the welfare levels of countries. Through these policies, economic activities are supported and encouraged, entrepreneurial activities are incorporated into support programs, and innovation is promoted by strengthening economic sustainability. This process contributes positively to economic growth by fostering innovation and investment [13]. Considering these circumstances, it is of vital importance that policymakers closely monitor development processes under economic development frameworks and act without delay in implementing necessary improvements. In necessary cases, the state should provide incentives to firms and ensure that the required support is delivered. Because studies have shown that incentives provided by middle-income countries to large enterprises do not have any negative effect on new firm formation [38]. This finding highlights the strategic importance of both supporting the growth of new firms and maintaining incentives for large enterprises in middle-income countries.

Countries are increasingly aiming to move away from energy sources that contribute to global warming, environmental degradation, and climate change. The G20 nations, in particular, are taking steps in this direction and shifting toward renewable energy. Preventing high greenhouse gas emissions, ensuring energy security, and sustaining economic growth are of strategic importance for achieving a sustainable environment. As the share of renewable energy in total consumption rises, environmental sustainability improves [36]. Conversely, if effective solutions to global warming, environmental degradation, and climate change cannot be found or implemented, environmental disasters are likely to become inevitable [7]. In this context, developing policies that promote the transition to renewable energy and ensuring its widespread adoption play a vital role [2].

Improving the ease of doing business has a direct effect on economic development, sustainable growth, and quality enhancement. A business environment that reduces trade barriers and transaction costs contributes to the expansion of international trade and enhances competitiveness [39]. Furthermore, foreign direct investments are closely linked to the ease of doing business, as investors regard this index as one of the most important criteria when deciding where to invest [8].

Gross Domestic Product (GDP) is one of the most widely used indicators for assessing a country's economic growth and level of development [28]. However, current debates on sustainable development make it clear that economic growth must also be considered alongside environmental and social dimensions. While per capita real GDP in countries with lower sustainability levels tends to be strongly linked to the intensive use of natural resources, this relationship weakens or disappears in countries with higher sustainability levels due to the integration of environmental considerations into economic planning [31].

A review of the literature reveals several studies that analyze the relationship between sustainability and entrepreneurial performance, using multi-criteria decision-making methods or multivariate statistical analyses. However, the literature review also indicates a scarcity of research that integrates the specific criteria and techniques applied in this study. The primary aim of this research is, therefore, to evaluate entrepreneurial performance within the framework of sustainability indicators. Due to data limitations, 13 countries from the G20 were included in the analysis. While the G20 countries constitute the alternatives, the evaluation criteria consist of the number of newly registered businesses, renewable energy consumption, greenhouse gas emissions, ease of doing business, and GDP. The data were obtained from the World Bank's

official database. These indicators are regarded as important tools for measuring the sustainable entrepreneurial performance of countries and for providing policymakers with strategic roadmaps. The study is structured as follows: Section 2 presents the literature review, Section 3 outlines the data set, model, and methodology, Section 4 covers the empirical application, and Section 5 concludes with the main findings.

2. *LITERATURE REVIEW* *(LİTERATÜR TARAMASI)*

Multi-Criteria Decision-Making (MCDM) methods provide a crucial analytical framework for addressing complex problems that necessitate the simultaneous consideration of economic, environmental, and social dimensions within the context of sustainability. Within this scope, the use of entropy-based weighting in combination with the comparative application of the VIKOR and TODIM methods enables the evaluation of national performances. It provides comprehensive outcomes for sustainability-oriented decision-making processes.

[24] compared the VIKOR and TOPSIS methods, two of the best-known approaches within MCDM. By applying a numerical example, they examined the functioning and outcomes of both techniques. Their results showed that the methods share certain similarities but also provide different perspectives and thus can complement one another in decision-making processes. In another study, [41] proposed a TODIM-based method to solve linguistic multi-criteria decision-making problems. They supported their approach with an illustrative case study and highlighted TODIM's potential as an effective tool in addressing such linguistic decision contexts.

[23] analyzed the performance of 13 Anatolian universities that joined the ADIM protocol in 1993, using AHP, TOPSIS, and VIKOR methods. Their analysis showed that Süleyman Demirel University ranked first in both the TOPSIS and VIKOR evaluations. Similarly, [35] applied the TODIM method to green supply chain practices, assessing both performance levels and the degree of importance. They found inconsistencies between the perceived importance of such practices and the actual performance levels achieved.

In study [30], the performance of the criteria affecting housing selection was analyzed using a fuzzy expert system and the TODIM method. The results indicated that both methods produced similar outcomes.

In some studies, these methods have been applied to samples from different sectors. Study [18] employed the SWARA, WPM, TODIM, and AHP methods to evaluate the performance of medical device procurement. The analysis revealed that Alternative 2 exhibited the best performance, while Alternative 3 showed the lowest performance. Similarly, [4] analyzed the performance of green-certified ports that published sustainability reports between 2015 and 2018 using the Entropy-TOPSIS method. The study concluded that the use of environmentally friendly energy sources increased port performance, and that factors such as terminal size and the number of handling equipment were directly linked to success.

[9] examined welfare indicators in OECD countries through TOPSIS, VIKOR, and Grey Relational Analysis (GRA). The findings showed that VIKOR and GRA produced results most consistent with the OECD's own ranking system and provided an integrated solution approach. Likewise, [11] evaluated the performance of 11 Turkish banks between 2018 and 2020 using Entropy, VIKOR, and TOPSIS. Their results indicated that Garanti Bank, Ziraat Bank, and İş Bank performed best, while QNB Finansbank, Denizbank, ING Bank, and HSBC ranked lowest.

[26] analyzed 12 companies using BIST data for the 2017–2019 period by applying the Entropy and TOPSIS methods. The findings indicated that financial indicators, as well as social and environmental factors, play a significant role in shaping corporate performance. [27] examined the selection of heating systems using data from Türkiye by applying the AHP and VIKOR methods. Based on the analysis conducted using data from different climatic regions, centralized natural gas systems were identified as providing the best overall performance. The analysis also revealed significant differences between individual and centralized systems in terms of energy efficiency; it was emphasized that this finding has important implications for reducing energy consumption and environmental impact.

[19] measured the sustainability performance of BIST companies between 2015 and 2020 using Entropy-TOPSIS. Their results revealed that the social dimension carried the highest weight, though it declined markedly in 2020. They also produced a visual mapping tool designed to guide decision-makers in identifying priority areas for improving sustainability performance. [32] evaluated the energy sustainability of 36 OECD countries using CRITIC, PROMETHEE, VIKOR, Copeland, and GRA methods. Their findings indicated that electricity generation from solar energy was the most critical factor in achieving this goal. While Switzerland and Germany ranked highest under different methods, South Korea consistently occupied the lowest position.

Recent studies further reinforce the value of MCDM. [15] assessed the Better Life Index of OECD countries using TOPSIS and VIKOR, identifying Luxembourg and Norway as the top performers depending on the

method. [16] examined renewable energy companies listed on the Borsa Istanbul Electricity Index in 2023. His study, which applied Entropy and VIKOR, concluded that PAMEL showed the strongest performance while KARYE ranked lowest. Finally, [25] employed GMM and TODIM to examine the economic impacts of clean technologies. Their results confirmed that clean technologies have a significant positive impact on GDP and contribute broadly to economic performance.

Taken together, these studies highlight the versatility of MCDM approaches in evaluating sustainability and performance. Yet few works integrate entrepreneurship-specific criteria — such as new firm creation, ease of doing business, renewable energy consumption, and emissions — with these methods. This gap provides the rationale for the present research, which aims to bridge the gap between sustainability and entrepreneurship through a comprehensive MCDM framework.

3. *RESEARCH METHODOLOGY* *(ARAŞTIRMA METODOLOJİSİ)*

3.1. Sample and Data Collection *(Örnek ve Veri Toplama)*

The data were obtained from the World Bank database and cover 13 G20 countries with no missing observations for the period 2014–2020. The main reason for choosing the 2014-2020 period for this study is that complete and comparable data were available for all variables during this period. The alternatives of the study consist of G20 countries. The criteria consist of the number of newly established businesses, the ease of doing business index, GDP, greenhouse gas emissions, and renewable energy consumption variables.

3.2. Methodology *(Metodoloji)*

This section provides a detailed discussion of the theoretical foundations underlying the research methods employed. The mathematical formulations of the selected techniques, together with systematic explanations, are presented below.

3.2.1. Entropy method *(Entropi yöntemi)*

Entropy is one of the MCDM methods used to determine the weight of each criterion by analytically measuring the uncertainty in the dataset. The concept was first introduced by Rudolph Clausius in 1865 and later developed by Claude E. Shannon in 1948, who systematized it within the framework of information theory [40].

The steps of the method are outlined as follows [37]:

1. Step: Decision Matrix

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

2. Step: Normalised Decision Matrix

$$P_{ij}=\frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}};A_j \quad (2)$$

3. Step: Entropy value and Eij Matrix

$$E_j=(\frac{-1}{\ln(m)})\sum_{i=1}^{m}[P_{ij}\ln(P_{ij})];A_j \quad (3)$$

4. Step: Determination of Degree Diversification, Dij Values

$$D_j=1\text{-}E_j;A_j \quad (4)$$

5. Step: Computation of Entropy-Based Weighs

$$w_j==\frac{d_j}{\sqrt{\sum_{j=1}^{n} d_j}};A_j \quad (5)$$

3.2.2. TODIM method *(TODIM yöntemi)*

Let the alternatives be indexed by i = 1,2,...,m and the criteria by j = 1, 2,...,n. The steps of the techique are as follows [5]:

1. Step: Decision Matrix

$$X_{ij}=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & & x_{2n} \\ \vdots & & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (6)$$

2. Step: Normalised Decision Matrix

In the normalization process, different formulas are applied depending on whether the criterion is a benefit or a cost type. Equation 7 and Equation 8 are used for the benefit and cost situations, respectively.

$$r_{ij}=\frac{x_{ij}-\min(x_{ij})}{\max(x_{ij})-\min(x_{ij})} \quad (7)$$

$$r_{ij}=\frac{\max(x_{ij})-x_{ij}}{\max(x_{ij})-\min(x_{ij})} \quad (8)$$

Step 3: Calculating Relative Weight According to Reference Criterion

$$w_{jr}=\frac{w_j}{w_r} \quad (9)$$

Step 4: Calculating the Dominance Score

For every i, $i^{|}\ \delta(A_i, A_{i^{|}}) = \sum_{j=1}^{n} \varphi_j(A_i, A_{i^{|}})$

$$\Phi_j(A_i, A_{i|}) = \begin{cases} \sqrt{\frac{w_{jr}(r_{ij}-r_{i|j})}{\sum_{j=1}^{n} w_{jr}}} & , \quad r_{ij} - r_{i|j} > 0 \\ 0 & , \quad r_{ij} - r_{i|j} = 0 \\ \frac{-1}{\theta}\sqrt{\frac{(\sum_{j=1}^{n} w_{jr})(r_{i|j}-r_{ij})}{w_{jr}}} & , \quad r_{ij} - r_{i|j} < 0 \end{cases} \quad (10)$$

Step 5: Calculating the Overall Dominance Score

$$\zeta_i = \frac{\sum_{i|=1}^{m} \delta(A_i, A_{i|}) - \min \sum_{i|=1}^{m} \delta(A_i, A_{i|})}{max \sum_{i|=1}^{m} \delta(A_i, A_{i|}) - \min \sum_{i|=1}^{m} \delta(A_i, A_{i|})} \quad (11)$$

3.2.3. VIKOR method *(VIKOR yöntemi)*

The VIKOR method aims to rank alternatives based on their degree of closeness to the ideal solution by providing a compromise solution between conflicting criteria in multi-criteria decision-making problems. This method provides decision makers with a systematic approach to determining the most suitable alternative by developing a multi-criteria ranking criterion based on the Lp-metric [24]. The steps of the method are as follows [11]:

Step 1: Creating the decision matrix

Decision Units	Evaluation Criteria			
	F_1	F_2	…	F_n
A_1	$F_1(A_1)$	$F_2(A_1)$	…	$F_n(A_1)$
A_2	$F_1(A_2)$	$F_2(A_2)$	…	$F_n(A_2)$
…	…	…	…	…
A_m	$F_1(A_m)$	$F_2(A_m)$		$F_n(A_m)$

(12)

Step 2: Finding the best and worst criteria values

$$f_i^* = \max_j f_{ij}, \quad f_i^- = \min_j f_{ij} \quad (13)$$

$$f_i^* = \min_j f_{ij}, \quad f_i^- = \max_j f_{ij} \quad (14)$$

Step 3: Obtaining S_(j) and R_(j) values

S_(j): Average group score, R_(j): Worst group score

$$S_j = \sum_{k=1}^{m} w_i \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)}, \quad (15)$$

$$R_j = \max_i \left[\sum_{k=1}^{m} w_i \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)}\right] \quad (16)$$

Step 4: Obtaining the Q_(j) value

$$Q_j = v\frac{(S_j - S^*)}{(S^- - S^*)} + (1-v)\frac{R_j - R^*)}{(R^- - R^*)} \quad (17)$$

$$S^* = \min_j S_j, \quad S^- = \max_j S_j \quad (18)$$

$$R^* = \min_j R_j, \quad R^- = \max_j R_j \quad (19)$$

Step 5: Ranking the S_(j), R_(j), and Q_(j) values

The S, R, and Q values are ranked.

Step 6: Determine Acceptable Advantage and Stability

Condition 1: Acceptable Advantage

A1 is the best alternative, A2: the second best alternative and j: the number of other options, and is calculated as follows:

$$DQ = \frac{1}{j-1} \quad (20)$$

$$Q(A2) - Q(A1) >= DQ \quad (21)$$

As the difference between the two best alternatives increases, the superiority of the best alternative becomes more evident.

Condition 2: Acceptable Stability

Acceptable stability is achieved when the alternative corresponding to the optimal value also ranks highest in terms of the S or R criteria.

4. *RESULTS AND DISCUSSION* *(SONUÇLAR VE TARTIŞMA*

In this section, to rank the performance of G20 countries in terms of factors affecting entrepreneurial performance within the sustainability framework, the criteria weights were first determined using the Entropy technique. Then, the performance ranking of the alternatives was performed using the VIKOR and TODIM methods. A comprehensive sensitivity analysis was conducted to test the validity of the data obtained at the end of the analysis.

The code and optimization criteria used in the model are presented in Table 1.

Table 1: Criteria *(Kriterler)*

Indicator	Code	Optimization
Number of newly registered businesses (number)	K1	Max
Renewable energy consumption (% of total final energy consumption)	K2	Max
Greenhouse gas emissions (t CO2e/capita)	K3	Min
Ease of doing business score (0-100)	K4	Max
GDP (constant 2015 US$)	K5	Max

4.1. Calculating Criteria Weights with the Entropy Method *(Entropi Yöntemiyle Kriter Ağırlıklarının Hesaplanması)*

The data used in the study were compiled from the World Bank's official database [33]. The study's criteria are weighted using the entropy method. Table 2 presents the 2020 data on the entrepreneurship performance criteria of G20 countries. As shown in Table 2, the decision matrix includes all criterion values for the selected countries.

Table 2: Decision Matrix *(Karar Matrisi)*

Countries	K1	K2	K3	K4	K5
Australia	236447	11,2	22,79	81,2	58132,8
Brazil	565429	50	5,83	58,2	8435,01
China	232064	14,9	10,27	77,2	10573,64
France	237702	16,8	5,89	76,7	35709,2
Germany	72774	18,5	9,02	78,6	42362,65
India	142000	36,1	2,45	71,1	1806,50
Italy	93103	18,7	6,22	72,8	29469,8
Japan	33411	8,5	9,26	78,3	34642,97
Mexico	68114	12,3	5,08	72,4	9234,64
Russia	214895	3,7	16,49	78,4	9632,33
South Africa	490487	9,8	8,94	66,6	5569,59
Türkiye	101482	13,7	7,00	77,2	12179,66
United Kingdom	774854	13,6	5,99	83,5	42429,19

Source: The World Bank, 2025

Normalized decision matrix values are presented in Table 3. As shown in Table 3, the values were normalized to ensure comparability between the criteria. These values were obtained by applying Equation 2 to the decision matrix.

Table 3: Normalized Decision Matrix (*Normalleştirilmiş Karar Matrisi*)

Countries	K1	K2	K3	K4	K5
Australia	0,07	0,05	0,20	0,08	0,19
Brazil	0,17	0,22	0,05	0,06	0,03
China	0,07	0,07	0,09	0,08	0,04
France	0,07	0,07	0,05	0,08	0,12
Germany	0,02	0,08	0,08	0,08	0,14
India	0,04	0,16	0,02	0,07	0,01
Italy	0,03	0,08	0,05	0,07	0,10
Japan	0,01	0,03	0,08	0,08	0,12
Mexico	0,02	0,05	0,04	0,07	0,03
Russia	0,07	0,02	0,14	0,08	0,03
South Africa	0,15	0,04	0,08	0,07	0,02
Türkiye	0,03	0,06	0,06	0,08	0,04
United Kingdom	0,24	0,06	0,05	0,09	0,14

Table 4 presents the Entropy values obtained from the normalized decision matrix using Equation 3.

Table 4: Ej Values (*Ej Değerleri*)

K1	K2	K3	K4	K5
0,87	0,92	0,94	1,00	0,89

The degrees of differentiation in Table 5 were obtained using the Entropy values of the criteria using Equation 4. Thus, the discriminatory power of each criterion in the decision process was quantitatively revealed.

Table 5: Dij Values *(Dij Değerleri*)

K1	K2	K3	K4	K5
0,128	0,075	0,057	0,001	0,114

The criteria weights given in Table 6 are calculated by dividing the degree of differentiation of each criterion by the total degree of differentiation within the scope of Equation (5). This method enables the objective determination of the relative importance levels of the criteria.

Table 6: Criteria Weights (*Kriter Ağırlıkları*)

K1	K2	K3	K4	K5
0,340	0,200	0,152	0,004	0,304

An examination of Table 6 reveals that the criterion with the highest criterion weight is the number of new information recorded, while the lowest is the business rate score. The relative importance of each criterion was determined using the entropy method, and the results presented in Table 6 revealed a weighting order of K1>K5>K2>K3>K4. This ordering demonstrates the magnitude of the criteria's impact on the decision-making process.

4.2. Performance Measurement with the TODIM Method *(TODIM Yöntemi ile Performans Ölçümü)*

Table 7: Normalized Decision Matrix (*Normalleştirilmiş Karar Matrisi*)

Countries	K1	K2	K3	K4	K5
Australia	0,07	0,05	0,02	0,08	0,19
Brazil	0,17	0,22	0,09	0,06	0,03
China	0,07	0,07	0,05	0,08	0,04
France	0,07	0,07	0,09	0,08	0,12
Germany	0,02	0,08	0,06	0,08	0,14
India	0,04	0,16	0,21	0,07	0,01
Italy	0,03	0,08	0,08	0,07	0,10
Japan	0,01	0,04	0,06	0,08	0,12

Mexico	0,02	0,05	0,10	0,07	0,03
Russia	0,07	0,02	0,03	0,08	0,03
South Africa	0,15	0,04	0,06	0,07	0,02
Türkiye	0,03	0,06	0,07	0,08	0,04
United Kingdom	0,23	0,06	0,09	0,09	0,14

The normalized decision matrix obtained using the TODIM method is presented in Table 7. Table 7 presents the performance of each country according to the specified criteria. These values range from 0 to 1 and reflect the relative performance of the countries. In the K1 criterion, the United Kingdom has the highest value, while Japan has the lowest; in the K2 criterion, Brazil is the highest, and Russia the lowest; in the K3 criterion, India is the highest, and Australia the lowest; in the K4 criterion, the United Kingdom is the highest, and Brazil the lowest; and in the K5 criterion, Australia is the highest, and India the lowest. The resulting normalized decision matrices will be compared again against the reference point, and the final ranking will be determined after obtaining the φ and ζ values.

Table 8: Performance Measurement with the VIKOR Method (*VIKOR Yöntemi ile Performans Ölçümü*)

Countries	φ_i	ζ_i	Ranking
Australia	-35,27	0,76	3
Brazil	-159,66	0	13
China	-48,52	0,68	7
France	-36,17	0,76	4
Germany	-26,32	0,82	2
India	-90,91	0,42	11
Italy	-73,48	0,53	9
Japan	-43,67	0,71	5
Mexico	-88,42	0,44	10
Russia	-58,22	0,62	8
South Africa	-134,44	0,15	12
Türkiye	-46,61	0,69	6
United Kingdom	3,17	1	1

The performance ranking obtained using the TODIM method is given in Table 8. When Table 8 is examined, it is observed that the country with the highest performance is the United Kingdom, while Brazil is in the last place.

Table 9: Obtaining the average group score S_(i) and the worst group score R_(i) Q_(j) (*S_i ortalama grup skoru, R_i en kötü grup skoru ve Q_j değerlerinin hesaplanması*)

Countries	S_i	R_i	q=0	q=0,25	q=0,50	q=0,75	q=1,00
Australia	0,57	0,25	0,49	0,50	0,52	0,53	0,54
Brazil	0,39	0,27	0,61	0,51	0,42	0,32	0,23
China	0,72	0,26	0,54	0,61	0,68	0,74	0,81
France	0,54	0,25	0,49	0,49	0,49	0,49	0,49
Germany	0,59	0,32	0,90	0,82	0,74	0,66	0,58
India	0,66	0,30	0,80	0,78	0,75	0,72	0,70
Italy	0,63	0,31	0,85	0,80	0,75	0,70	0,66
Japan	0,70	0,34	1,00	0,94	0,89	0,83	0,77
Mexico	0,77	0,33	0,91	0,91	0,91	0,91	0,91
Russia	0,82	0,26	0,57	0,68	0,79	0,89	1,00
South Africa	0,64	0,28	0,69	0,69	0,68	0,67	0,67
Türkiye	0,75	0,31	0,83	0,84	0,85	0,86	0,86
United Kingdom	0,27	0,16	0,00	0,00	0,00	0,00	0,00

The values of the average group score S_(i) and the worst group score R_(i) were obtained using Equation 17 and Q_(j) values for different values of v. These values are given in Table 9.

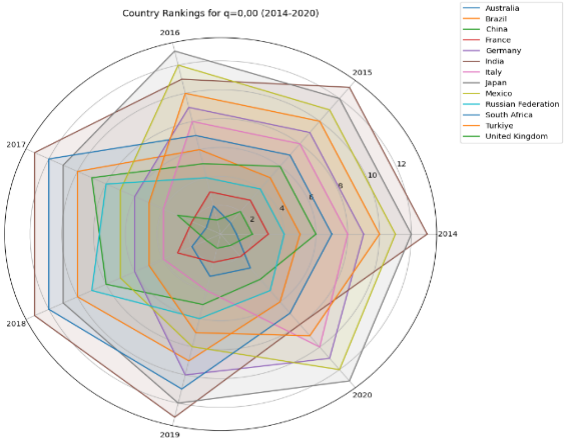
Table 10: Country Performance Ranking According to Different q Values (*Farklı q değerlerine göre ülke performans sıralaması*)

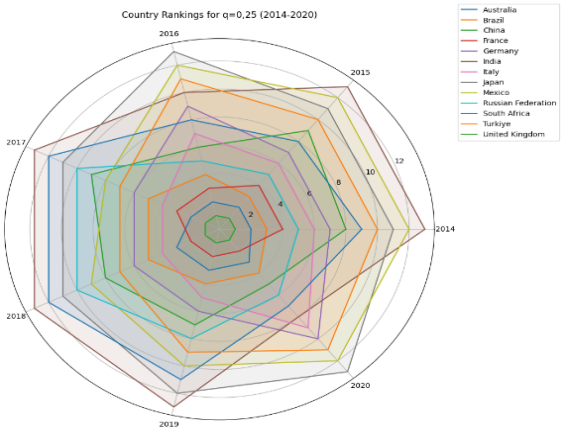
Countries	q=0	q=0,25	q=0,50	q=0,75	q=1,00
Australia	3	3	4	4	4
Brazil	6	4	2	2	2
China	4	5	5	9	10
France	2	2	3	3	3
Germany	11	10	7	5	5
India	8	8	8	8	8
Italy	10	9	9	7	6
Japan	13	13	12	10	9
Mexico	12	12	13	13	12
Russia	5	6	10	12	13
South Africa	7	7	6	6	7

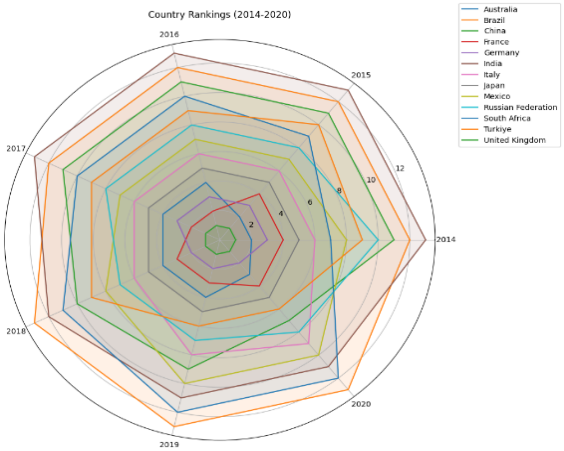
Türkiye	9	11	11	11	11
United Kingdom	1	1	1	1	1
Q(A2)	0,49	0,49	0,42	0,32	0,23
Q(A1)	0	0	0	0	0
Q(A2)-Q(A1)	0,49	0,49	0,42	0,32	0,27
DQ	0,08	0,08	0,08	0,08	0,08
Condition 1	True	True	True	True	True
Condition 2	True	True	True	True	True

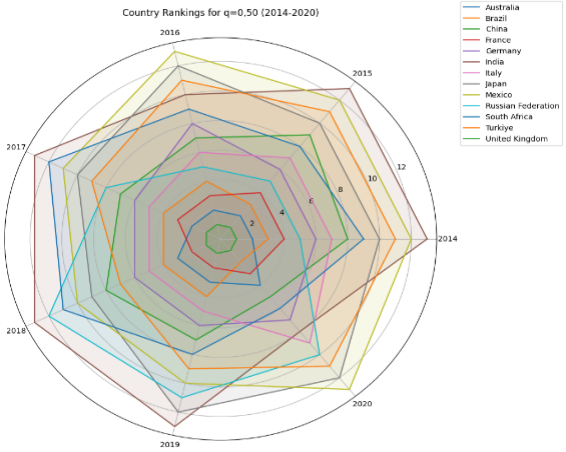
Table 10 shows the ranking of country performances based on different values of the q parameter (0, 0.25, 0.50, 0.75, and 1.00). An examination of Table 10 reveals that the United Kingdom ranks first for all q values, followed by Japan for q=0 and q=0.25, Mexico for q=0.50 and q=0.75, and Russia for q=1.00. Within this ranking, there were generally minor changes in country rankings across different q values. Therefore, the overall ranking of countries remained essentially unchanged.

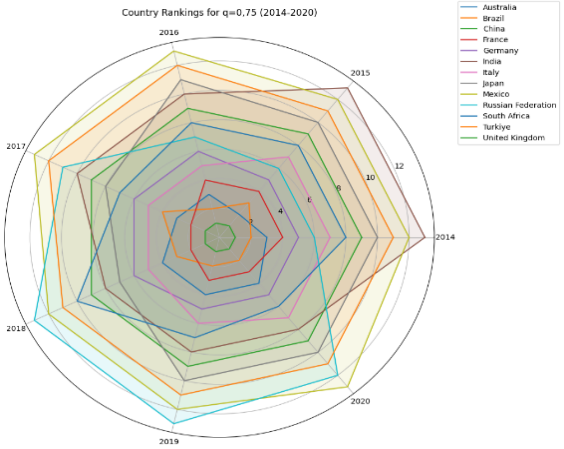
In the VIKOR method, the best score is determined as Q(A1), and the second-best score is determined as Q(A2). If the condition (Q(A2) – Q(A1) ≥ DQ) is met for Condition 1, the best alternative is clearly superior. After Condition 1 is met, with the best score being the best at the S or R values , Condition 2 is also met. When Table 10 is examined, the United Kingdom, which meets both conditions, is determined to be the undisputed best alternative at every q value.











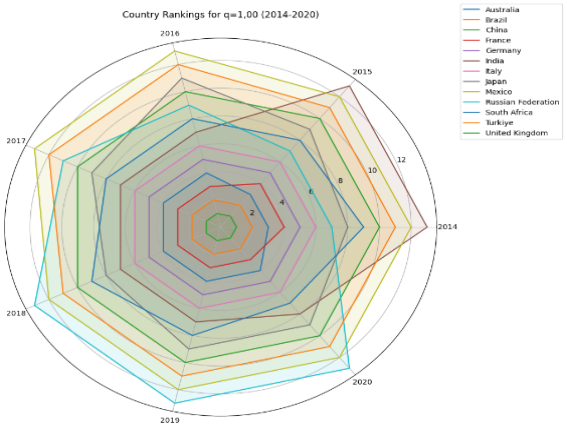


Figure 1: Change in Performance Rankings of Countries by Year (*Yıllara göre ülkelerin performans sıralamalarındaki değişim*)

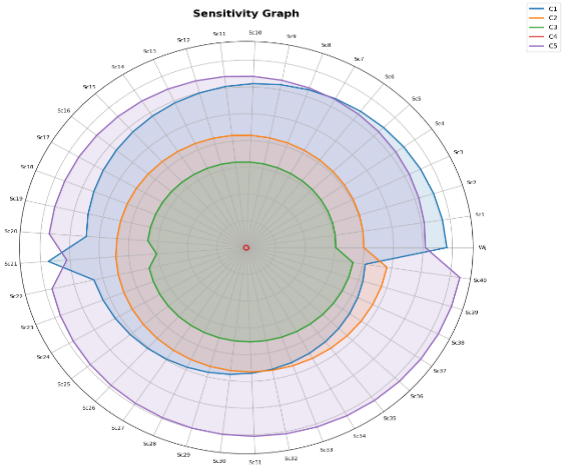


Figure 2: New Weight Scenarios Obtained by Reducing W1 by 1% (*W1'in %1 azaltılmasıyla elde edilen yeni ağırlık senaryoları*)

The performance rankings of G20 countries for the years 2014-2020, as determined by the TODIM and VIKOR methods, are presented in Figure 1. Examining Figure 1, it is observed that the United Kingdom consistently ranked first in all years according to the TODIM method, while India ranked last from 2014 to 2017 and Brazil ranked last from 2018 to 2020. The VIKOR method ranks for different values of q. The United Kingdom maintains first place for all values of q. Only for q = 0 did Australia take first place in 2014, 2015, and 2017. India ranked last for all values of q, while in some years Japan, Mexico, and the Russian Federation ranked last. Generally, the first and last countries in both methods are the same.

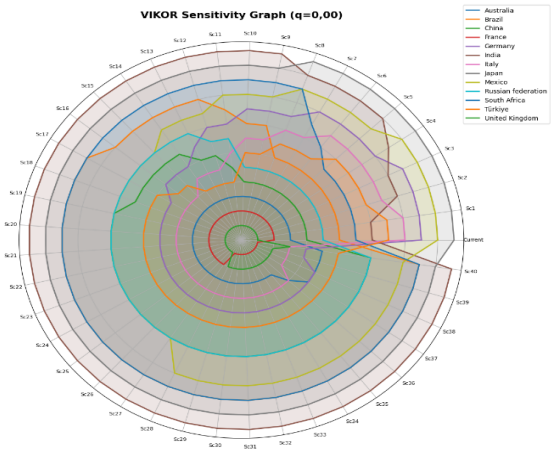
4.3. Sensitivity Analysis *(Duyarlılık Analizi)*

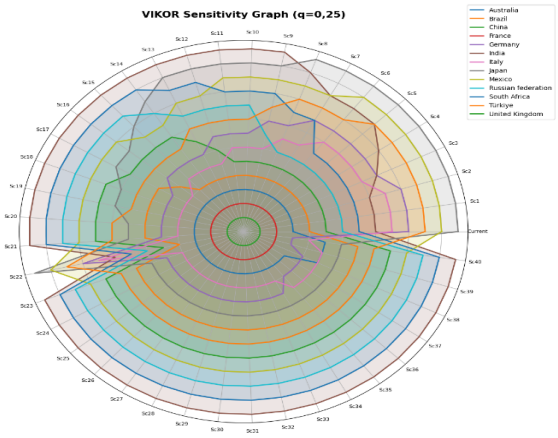
Within the scope of the weights determined by the Entropy method, a Multi-Criteria Decision Making (MCDM) method, the variation in the weight of the most important criterion (K1) and its effect on the weights of other criteria were analyzed. In this analysis, the weight of the most critical criterion was reduced by 1% in each scenario, resulting in the generation of 40 different scenarios using Equation 22 [10]. Details of these 40 scenarios are presented in Table 14.

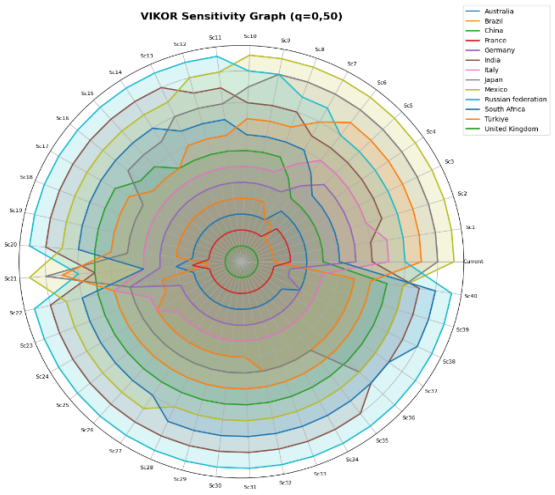
$$\omega_{m\gamma} = (1 - \omega_{m\pi}).\frac{\omega_{\gamma}}{1-\omega_{m}} \qquad (22)$$

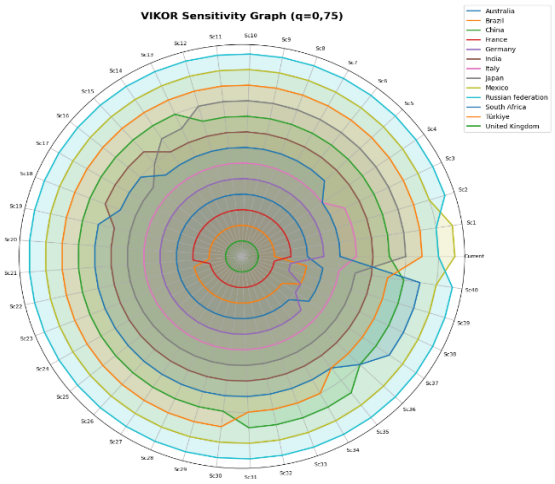
m criteria, ω_mγ represents the modified values of m criteria, ω_mπ represents the reduced value of W1 criterion, ω_γ represents the original value of m, ω_m represents the original value of W1 [10].

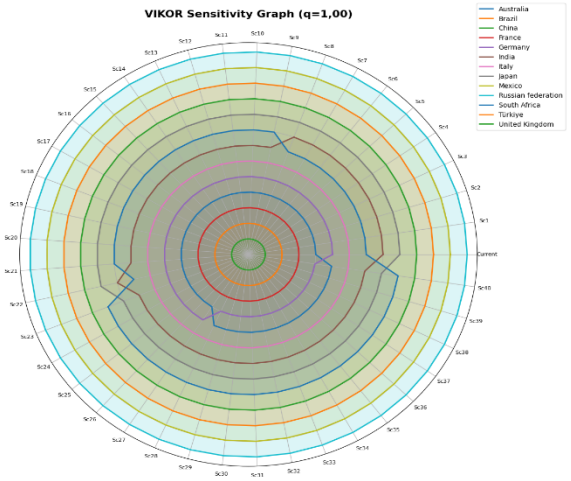
Figure 2 presents the weight values obtained by reweighting the criteria under 40 different scenarios using Equation 22. Figure 2 reveals the effects of a 1% decrease in the weight of K1, the most important criterion, on the weight values of the other criteria.











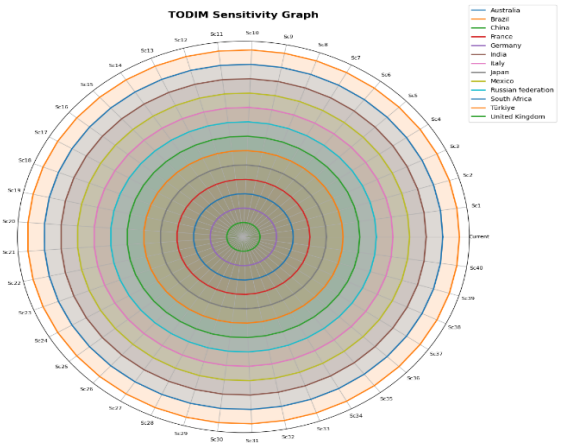


Figure 3: Changes in Country Performances According to Various Scenarios (*Çeşitli senaryolara göre ülkelerin performanslarındaki değişimler*)

Figure 3 shows the changes in the rankings of G20 countries following 40 different scenarios. Forty different scenarios were applied for both the VIKOR and TODIM methods. In the TODIM method, although the scenario changed, the rankings remained unchanged. In the VIKOR method, minor changes were observed in the country rankings when different scenarios were applied for different q values. Overall, countries maintained their rankings despite the different scenarios generated. This demonstrates the validity of the method used.

5. *CONCLUSIONS* *(SONUÇLAR)*

In this study, the sustainability performances of G20 countries were analyzed using the variables of number of newly established businesses, ease of doing business index, GDP, greenhouse gas emissions, and renewable energy consumption, which serve as financial and environmental indicators. In the analysis, multi-criteria decision-making (MCDM) methods, namely ENTROPY, TODIM, and VIKOR, were employed. The data were compiled from the official database of the World Bank. The analysis was conducted using data from 13 G20 countries with no data limitations over the 2014–2020 periodThe weights of the criteria were calculated using the Entropy method, and the resulting weights were used to obtain the performance rankings of the countries through the TODIM and VIKOR methods. For the year 2020, the weights obtained using the Entropy method were ranked in descending order as follows: number of newly established businesses, GDP, renewable energy consumption, greenhouse gas emissions, and ease of doing business.

According to the TODIM method, the top three countries in the performance ranking were the United Kingdom, Germany, and Australia, while the bottom

three countries were India, South Africa, and Brazil. Ranking was performed using the VIKOR method for different values of q. In this ranking, the United Kingdom ranked first for all values of q. In the second position, France and Brazil appeared for some values of q, while Australia and France occupied the third position. In the last three positions, Türkiye, the Russian Federation, Mexico, Japan, and Germany were alternately ranked for different values of q.

It was found that the results obtained from both the VIKOR and TODIM methods were generally consistent with each other. In addition, a sensitivity analysis was conducted to test the effectiveness and validity of the methods used. Considering the best weight configuration, 40 different scenarios were generated, and both methods were subjected to sensitivity analysis using these 40 different scenarios. The sensitivity analysis indicated that both methods preserved the ranking structure, and the obtained results were found to be acceptable.

Sustainable entrepreneurship is shaped not only by economic growth and environmental indicators, but also by the opportunities and constraints presented by the social context. The findings of this study reveal that differences between countries stem not only from technical indicators but also from factors such as social capital, institutional trust, cultural values, and gender roles, which play a critical role in determining entrepreneurial performance [22]; [29], Therefore, sustainable entrepreneurship policies should be designed from a multidimensional perspective. One of the most important dimensions of this multifaceted approach is the level of trust and the culture of cooperation within society.

Social trust and a culture of cooperation have a significant impact on individuals' engagement in entrepreneurial activities. Study [29] emphasizes that a high level of social capital is fundamental to the development of cooperation and the emergence of innovative initiatives. Moreover, trust in institutions influences entrepreneurs' level of risk-taking. Transparency and openness are also highly important in the conduct of entrepreneurial activities. Study [3] found that entrepreneurial activities become more diversified in cases where governments enhance transparency and predictability. In this context, in addition to economic incentives, the establishment of institutional trust is also highly important. However, the entrepreneurial ecosystem is shaped not only by institutional factors; social values and the level of environmental awareness are also among the key determinants of sustainability.

Sustainability cannot be achieved solely through government support. First and foremost, public awareness must be establishedIn this context, the development of public awareness will accelerate the process of sustainability and facilitate its adoption. In other words, public awareness is another factor influencing the pace of transition to renewable energy and the adoption of environmentally friendly technologies. At the same time, the media and educational institutions also play a leading role in the development of this awareness [1]. Societal cultural values also shape perceptions of entrepreneurship. While individualistic cultures tend to be more inclined towards innovative initiatives, collectivist cultures prioritize social enterprises that prioritize the public good [14]. Therefore, designing sustainable entrepreneurship policies compatible with national cultures will contribute to improving overall performance. In addition to these cultural differences, ensuring inclusiveness and equal opportunities in the entrepreneurial process represents another important dimension that strengthens the social aspect of sustainability. In this context, translating these policy principles into a more concrete framework requires identifying strategies that can be implemented at different dimensions:

Economic dimension: Increasing R&D investments, offering tax incentives, and encouraging foreign direct investment.

Environmental dimension: Developing regulations to reduce carbon emissions, support renewable energy investments, and promote environmentally friendly production standards.

Social dimension**:** Strengthening social capital through participatory governance, expanding entrepreneurship training, eliminating structural barriers for women and young entrepreneurs, and promoting environmental awareness through media and education.

Taking these policy areas together, it becomes clear that sustainable entrepreneurship represents not only an economic and environmental transformation process, but also a social transformation.

Consequently, sustainable entrepreneurship cannot be measured solely by economic and environmental indicators; it is a process intrinsically linked to the institutional structures, cultural values, and social capital of societies. Therefore, the results obtained through multi-criteria decision-making methods must be based on comprehensive policies that take into account the social dynamics of each context.

Considering the methodology used in this study, combining the Entropy, TODIM, and VIKOR methods and conducting multiple comparisons between countries to carry out a more robust and comparative analysis would make a positive contribution to the literature. This study contributes to the literature by providing a comprehensive

evaluation of entrepreneurship performance within a sustainability framework and provide valuable guidance for policymakers. Future research could include increasing the number of criteria and comparing results obtained using different multi-criteria decision-making methods.

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CONFLICT OF INTEREST (*ÇIKAR ÇATIŞMASI BEYANI)*

There is no any conflict of interest

DATA AVAILABILITY *(VERİ ERİŞİLEBİLİRLİĞİ)*

The dataset is available from the official World Bank website.

ETHICAL STATEMENT *(ETİK BEYAN)*

No ethical statement is required.

DECLARATION OF AI USAGE (*YAPAY ZEKÂ KULLANIM BEYANI)*

Artificial intelligence or AI-powered tools have been used for correction and translation purposes.

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