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Analysis of G20 Countries in terms of Scientific Publication Performances

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Abstract

The achievement of countries in generating scientific publications is also a reflection of their efforts in the scientific domain. The quantitative volume of these publications is not a criterion alone, but the fact that they are a source of inspiration for other scientists carrying out their studies in other countries is an important indicator in terms of evaluating the quality of publications. Based on this emphasis on scientific publications, this research aimed to assess the performance of nineteen G20 countries upon scientific publication data issued by The SCImago Journal & Country Rank and covering the years 1996-2022. The evaluation criteria do not only consist of the number of scientific documents, but also number of citable documents, number of citations, number of self-citations, number of citations per document and H-index values. Fuzzy Step-wise Weight Assessment Ratio Analysis (Fuzzy SWARA) method is employed to determine the priorities of the criteria with the participation of ten researchers from different scientific disciplines. As an outcome of the application of this method, the order of importance of the criteria is determined as H-index, number of citable documents, number of citations per document, number of citations, number of documents and self-citation. The performance order of nineteen countries is performed by using the CODAS-LN method, which includes a logarithmic normalization version of the COmbinative Distance-based ASsessment (CODAS) method and is a very convenient approach in cases where the data is not normally distributed. The results revealed that the United States has a superior position in terms of scientific publication performance, while the United Kingdom, Germany, Canada and France are aligned in the top five order. The consistency of the applied method is also confirmed by two different sensitivity analyses.

Keywords: Scientific Publication, G20 Countries, Fuzzy SWARA, CODAS-LN

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1. INTRODUCTION

Scientific publications generated within a nation serve as pivotal indicators of the level of recognition and esteem that relevant country holds within the scientific community. The quality of the publications, on the other hand, contributes to the progress of science and gives idea about scientific disciplines at the forefront in that country. Moreover, these milestones hold significant importance as they enable external stakeholders to assess the country's strategies regarding innovation, technological advancement, intellectual depth, perspective on research and development activities, and the emphasis placed on collaborative work among scientists. Besides, the quality of such publications are highly favourable tools for enabling international collaborations in the scientific field. While scientific publications with high quality content attract international attention among scientists involved in the same fields, they also have the characteristics of an important instrument in terms of ensuring mutual knowledge transfer. As a consequence, the quality level of a particular country's scientific publications is an evidence for that country's endeavour to achieve a strong scientific position at the international level, beyond its own borders.

The G20 countries, which are also known as the Group of Twenty, encompass the nations that possess the most formidable economies in the contemporary global landscape. This group comprises Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Türkiye, the United Kingdom, and the United States (Huang et al., 2023; Mar'I et al., 2023) as illustrated in Figure 1. The countries in the Group possess approximately 85 per cent of the global Gross Domestic Product (GDP) and cover two-thirds of the world's population. The main objective of these countries can be summarized as the promotion of financial stability and sustainable economic growth through mutual exchange of views and cooperation. Moreover, the G20 Community has become a forum that aims to offer solutions on addressing issues such as trade disputes and problems in front of investments. G20 countries, which are geographically located across different continents but have different concerns and priorities, are perceived as a professional platform that bears responsibility for global economic and social issues. Furthermore, they also aim to design a road map in the pursuit of common solutions to ensure social welfare around the world.

Undoubtedly, scientific research plays a crucial role in the economic well-being and living standards of contemporary societies, making significant contributions to the advancement of global science. The level of prosperity that developed countries have reached today is a concrete outcome of the contribution and support they have provided to scientific research. From this point of view, the level of prosperity achieved by the G20 countries is a result of their orientation towards development and innovation on the basis of scientific studies. G20 countries, renowned for their robust financial resources, extensive infrastructure, and exceptional expertise, consistently prioritize investment in cutting-edge technological research. Moreover, they proactively propose incentive policies to facilitate the global transfer of knowledge. Considering the World Bank's 2022 data (World Bank, 2023), it is evident that the deep efforts of these countries in the scientific field are in a direct relationship with their Gross Domestic Product (GDP) values. Recognizing that scientific research is the most important initial point to increase the level of social welfare and quality of life, the success achieved by the G20 countries can easily be observed through their economic indicators.

Figure 1. Map of G20 Countries

From this perspective, the primary objective of this study is to analyze the performance of G20 countries, which lead the world economy, in terms of their capacity to generate scientific publications. In line with The SCImago Journal & Country Rank data covering the period between 1996 and 2022, these countries mentioned are evaluated not only in terms of number of documents, but also in terms of number of citable documents, number of citations, number of self-citations, number of citations per document and H-Index parameters. The importance levels of these parameters are determined by participation of ten researchers involved in different scientific disciplines by using the Fuzzy Step-wise Weight Assessment Ratio Analysis (Fuzzy-SWARA) method and then the logarithmic version of COmbinative Distance-based ASsessment (CODAS-LN) method is utilized for ordering these countries. Ultimately, sensitivity analyses with different approaches are carried out to determine the robustness of the multi-criteria decision-making (MCDM) method used.

The remaining sections of the study discuss the following topics and content. Section 2 provides a comprehensive literature review of previous research studies relevant to the current study. In Section 3, the proposed methods are presented in detail. Section 4 includes a detailed examination of a real-life problem application along with sensitivity analyses. Finally, Section 5 focuses on the conclusion of the study and suggestions for future research.

2. LITERATURE REVIEW

Considering the previous studies on the scientific publication performance of G20 countries, Lin et al. (2018) analyzed the relationship between the number of scientific publications available in

Web of Science and Gross Domestic Product data of the same countries. In addition, a hierarchical clustering analysis of G20 countries is carried out by taking the scientific fields of publications into account.

In order to minimize the freight costs of companies dealing with coal production and marketing, Xiang et al. (2022) aimed to determine the criterion weights by using the trapezoidal fuzzy SWARA method in the process of selecting the most appropriate logistics company. To facilitate the selection of medical tourism travel destinations for Iranian citizens, Ghasemi et al. (2021) aimed to determine the weights of five main criteria and twenty sub-criteria by fuzzy SWARA method for prioritization process of eight different countries. In seeking to propose solutions to effectively minimize risks in the sustainable remanufacturing supply chain, Ansari et al. (2020) aimed to weight twenty-four sub-criteria according to their level of importance, whereby environmental, economic and social risks were considered as the main criteria. In an attempt to identify the barriers to administrative transformation in the organizational structure of an airport and to determine the order of importance of these impediments, a prioritization of seven criteria was carried out by Ghasemian Sahebi et al. (2020). Finally, Epifanić et al. (2020) aimed to prioritize the effects of school administrators, school infrastructure, students' prior knowledge, teachers' merit, quality of the curriculum, students' motivation and the quality of the teaching process on students' learning outcomes in Serbia.

In order to take advantage of the logarithmic transformation in cases where the criterion values differ significantly and the data are not normally distributed, the CODAS-LN method was proposed by Biswas and Pamucar (2021) and this method was used to measure the performance of smartphones. In the literature review, no other publication utilizing this method is coincided.

Some other researches conducted with the traditional form of SWARA and CODAS methods can be summarized as in Table 1;

Table 1. Literature Review for SWARA and CODAS Methods

Author	Subject
(Işık et al., 2023)	Determination of the causality relationship between financial performance and premium production of non-life insurance companies
(Şaylan et al., 2023)	Determination of four different marketing strategies in line with expert opinions
(Koca et al., 2022)	Analysing the drivers and challenges of circular economy in the apparel industry through SWARA and BWM methods
(Kumar et al., 2022)	Spray Painting Robot Selection
(Karabašević et al., 2016)	Personnel selection
(Zolfani et al., 2013)	Identification of critical and vital criteria in producing products

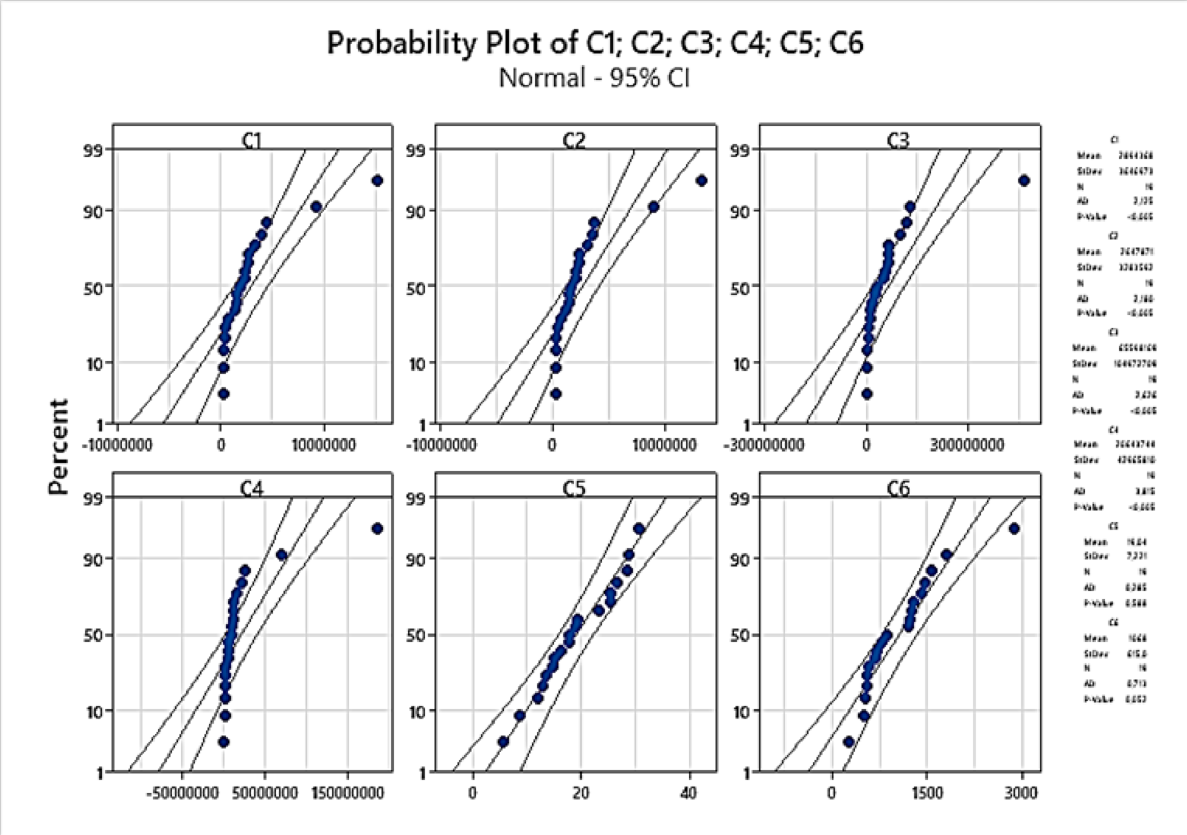
(Anand et al., 2023)	Identification of prominent smell factors around different software development environments
(Dominguez et al., 2023)	Machine selection to increase process and product quality in the pastry sector
(Wankhede et al., 2023)	Selection of natural composites for use in substitution of synthetic materials
(Kumari & Acherjee, 2022)	Selection of non-conventional machining process
(Wei et al., 2021)	Green supplier selection

3. METHODS

The Step-wise Weight Assessment Ratio Analysis (SWARA) method used in the criteria weighting stage of the study was introduced by Kersuliene, Zavadskas and Turskis in 2010 (Keršulienė et al., 2010). In SWARA method, the relative importance and initial prioritization of alternatives for each criterion are determined in line with the opinion of decision makers and then the relative weight of each criterion is determined (Alinezhad & Khalili, 2019, Chapter 14, p. 99). For evaluations and calculation of criterion weights, all experts acting as a Decision Maker (DM) have a significant role in SWARA method. During the evaluation process, each DM determines the level of importance for each criterion and assigns a rank to all the criteria. In a nutshell, each expert uses their individual knowledge and experience (Zolfani & Šaparauskas, 2013). Although SWARA method is perceived as a subjective evaluation process, it is a very meaningful approach in terms of the contribution of each decision maker to the process in line with their own expertise and experience (Stanujkic et al., 2015). Therefore, this method is preferred due to its distinctive feature and importance levels for each criterion are determined in accordance with the opinions of ten academics who have publications in the fields of engineering, economics, social sciences, medicine and basic sciences.

COmbinative Distance-based ASsessment (CODAS) method, which is used to perform success rankings of G20 countries in terms of scientific publication performance, was introduced to the literature by Ghorabaee, Zavadskas, Turskis and Antucheviciene in 2016. The proposed method measures an alternative's overall performance by Euclidean and Taxicab distances from the negative ideal point. While Euclidean distance is the primary measure of assessment in this approach, use of Taxicab distance is also taken into consideration in case that the Euclidean distances between two alternatives are quite close to each other. In addition, a threshold parameter determines the proximity of Euclidean distances (Ghorabaee et al., 2016). From this perspective, the CODAS approach emerges as a highly convenient method for assessing and ranking the scientific publication performance of the G20 countries. However, a logarithmic transformation becomes unavoidable if the data are not normally distributed (Feng et al., 2014; Zavadskas & Turskis, 2008). Given that our data does not display a normal distribution as depicted in Figure 2, it is preferred to utilize the CODAS-LN (Biswas & Pamucar, 2021) approach in this study instead of traditional versions as it represents a similar version of the CODAS method.

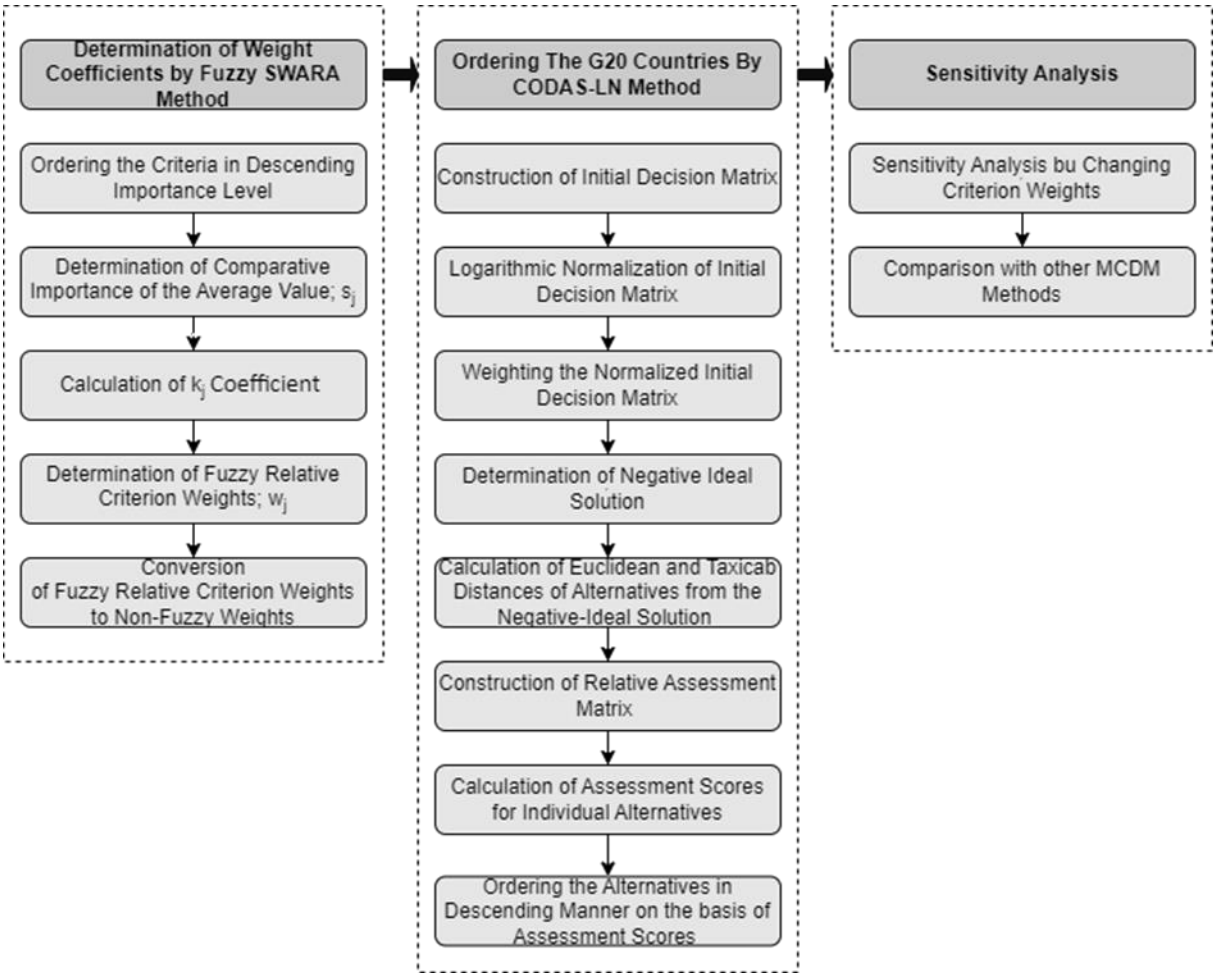
Figure 2. Normality Test of Data



In the last stage of the study, a sensitivity analysis is carried out by gradually changing the criteria weights (Yazdani et al., 2019; Qahtan et al., 2023) and by conducting different MCDM methods (Pamucar et al., 2021; Puška et al., 2022; Bouraima et al., 2023) to confirm the robustness of the ranking method. Different MCDM methods are employed including ARAS (Zavadskas & Turskis, 2010), EDAS (Ghorabaee et al., 2015), MABAC (Pamucar & Ćirović, 2015), MAIRCA (Pamucar et al., 2018), MAUT (Keeney et al., 1979), WASPAS (Zavadskas et al., 2012), WEDBA (Rao & Singh, 2011) and MARCOS-LN (Komasi et al., 2023) to realize a comparison among the orders obtained by each approach.

The flowchart of the research is summarized as illustration in Figure 3.

Figure 3. Flowchart of the Research



3.1. Fuzzy SWARA Method

While SWARA is a very worthwhile method in terms of reflecting the experience and profession of the experts involved in the decision-making process, application of fuzzy logic generates more expressive results when there are no strict boundaries among the criteria in terms of their significance level. Therefore, the significance levels and weights of the criteria are determined by following the steps specified below, using the linguistic scale presented in Table 2 (Mavi et al., 2017).

Table 2. Linguistic Scale

Linguistic Scale	Response Scale
Equally Important	(1, 1, 1)
Moderately Less Important	(2/3, 1, 3/2)
Less Important	(2/5, 1/2, 2/3)
Very Less Important	(2/7, 1/3, 2/5)
Much Less Important	(2/9, 1/4, 2/7)

Step 1. Ranking the criteria from the most important to the least important by taking the order of their significance into account.

Step 2. Beginning from the second criterion j, a comparison is performed between the previous criterion $j-1$ by taking the linguistic scale into account. By doing so, the $\tilde{s}_j$ value, which is the comparative importance of the average value, is obtained. In fuzzy approach, the $\tilde{s}_j$ value is indicated as $\tilde{s}_j = (\tilde{s}_j^l, \tilde{s}_j^m, \tilde{s}_j^u)$.

Step 3. Calculation of $\tilde{k}_j$ coefficient through Equation (1).

$$\tilde{k}_j = \begin{cases} 1 & ,j=1 \\ \tilde{S}_j + 1 & ,j>1 \end{cases} \qquad \tilde{k}_j = (\tilde{k}_j^l, \tilde{k}_j^m, \tilde{k}_j^u) \tag{1}$$

Step 4. Determination of recalculated fuzzy weights $\tilde{q}_j$ through Equation (2).

$$\tilde{q}_j = \begin{cases} 1 & ,j=1 \\ \dfrac{\tilde{q}_{j-1}}{\tilde{k}_j} & ,j>1 \end{cases} \qquad \tilde{q}_j = (\tilde{q}_j^l, \tilde{q}_j^m, \tilde{q}_j^u) \tag{2}$$

Step 5. Determination of fuzzy relative criterion weights $\tilde{\omega}_j$ through Equation (3).

$$\tilde{\omega}_j = \frac{\tilde{q}_j}{\sum_{k=1}^{n} \tilde{q}_k} \qquad \tilde{w}_j = (\tilde{w}_j^l, \tilde{w}_j^m, \tilde{w}_j^u) \tag{3}$$

Step 6. Conversion of the fuzzy relative criterion weights $\tilde{\omega}_j$ to non-fuzzy (crisp value) w_j according to the Centre of Area (COA) method through equation (4).

$$w_j = \frac{w_j^l + w_j^m + w_j^u}{3} \tag{4}$$

The basic arithmetic operations with the triangular fuzzy numbers should be carried out in accordance with the following principles indicated in Table 3 (Kaufmann & Gupta, 1988, p. 28).

Table 3. Arithmetic Operations with Triangular Fuzzy Numbers

Addition	$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$
Subtraction	$\tilde{A}_1 \ominus \tilde{A}_2 = (l_1 - u_2, m_1 - m_2, u_1 - l_2)$
Multiplication	$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1.l_2, m_1.m_2, u_1.u_2)$
Division	$\tilde{A}_1 \oslash \tilde{A}_2 = (l_1/u_2, m_1/m_2, u_1/l_2)$
Multiplication by a fixed number	$k \otimes \tilde{A} = (k.l, k.m, k.u)$
Reverse operation	$\tilde{A}^{-1} = (l,m,u)^{-1} \approx (1/u\,, 1/m\,, 1/l)$

3.2. CODAS-LN Method

The application steps of this multi-criteria decision-making method, which recommends the use of logarithmic normalisation approach in case that the available data do not display a normal distribution, are listed as follows (Biswas & Pamucar, 2021).

Step 1. Construction of initial decision matrix.

$$X = [x_{ij}]_{mxn} \qquad \begin{matrix} m: number\ of\ alternatives \\ n: number\ of\ criteria \end{matrix}$$

Step 2. Logarithmic normalization of initial decision matrix by Equation (5) and Equation (6).

$$R = [r_{ij}]_{mxn} \qquad R: normalized\ decision\ matrix$$

$$r_{ij} = \frac{\ln(x_{ij})}{\ln(\prod_i^m x_{ij})} \qquad \textit{for benefit criteria} \tag{5}$$

$$r_{ij} = \frac{1 - \frac{\ln(x_{ij})}{\ln(\prod_i^m x_{ij})}}{m-1} \qquad \textit{for cost criteria} \tag{6}$$

Step 3. Weighting the normalized initial decision matrix by Equation (7).

$$R^* = [r_{ij}^*]_{mxn} \qquad R^*: \textit{weighted normalized decision matrix}$$

$$r_{ij}^* = w_j . r_{ij} \qquad w_j: \textit{weight of the } j^{th} \textit{ criterion} \tag{7}$$

Step 4. Determination of negative ideal solution by Equation (8).

$$S^- = [s_j^-]_{1xn} \qquad S^-: \textit{negative ideal solution matrix}$$

$$s_j^- = \min_i r_{ij}^* \qquad s_j^-: \textit{negative ideal solution of the } j^{th} \textit{ criterion} \tag{8}$$

Step 5. Calculation of Euclidean and Taxicab distances of alternatives from the negative-ideal solution by Equation (9) and Equation (10).

$$E_i = \sqrt{\sum_{j=1}^{n} (r_{ij}^* - s_j^-)^2} \qquad E_i: \textit{Euclidean distance of } i^{th} \textit{alternative} \tag{9}$$

$$T_i = \sum_{j=1}^{n} |r_{ij}^* - s_j^-| \qquad T_i: \textit{Taxicab distance of } i^{th} \textit{alternative} \tag{10}$$

Step 6. Construction of relative assessment matrix by Equation (11).

$$R_a = [h_{ik}]_{mxm} \qquad R_a: \textit{relative assesment matrix}$$

$$h_{ik} = (E_i - E_k) + (\psi . (E_i - E_k) . (T_i - T_k)) \qquad k = 1,2, \dots, m \tag{11}$$

The parameter ψ indicates the threshold function representing the equality of Euclidean distances between two alternatives where;

$$\psi(d) = \begin{cases} 1; & |x| \geq \tau \\ 0; & |x| < \tau \end{cases}$$

The term τ corresponds to a threshold parameter which is recommended as $\tau = 0{,}02$ (Keshavarz-Ghorabaee et al., 2016).

Step 7. Calculation of assessment scores for individual alternatives by Equation (12).

$$H_i = \sum_{k=1}^{n} h_{ik} \qquad k = 1,2, \dots, m \tag{12}$$

Step 8. Ordering the alternatives in descending manner on the basis of assessment scores.

3.3. Sensitivity Analysis

In order to determine the robustness of the applied ranking method, sensitivity analysis, which involves gradually changing the most important criterion weights, is employed. Estimating how much influence the most important criterion has on the ranking performance of the proposed model is the key objective of conducting a sensitivity analysis. The following steps will be implemented during the execution of the method (Pamucar et al., 2020);

Step 1. Selection of the criterion with highest priority and listing the remaining criteria.

Step 2. Determination of weight coefficient of elasticity by Equation (13).

$$\alpha_c = \frac{w_c^0}{W_c^0} \tag{13}$$

α_c: *weight coefficient of elasticity*

w_c^0: *original weights of criteria excluding the most important criterion*

W_c^0: *sum of the original weights of the criteria excluding the most important criterion*

The parameter α_c is defined as the weight coefficient of elasticity, which represents the relative exchange of the remaining weights in response to certain shifts in the weight of the most influential criterion. At this stage, it should be noted that the value of the weight elasticity coefficient for the most important criterion (α_s) should always be considered as 1. In calculations following the most important criterion, the proportion of changing weights will remain fixed.

Step 3. Determination of the amount of change in the weight values of the criteria.

The parameter Δx represents the amount of change in the weight values of the criteria in line with the relevant weight coefficient of elasticity. Unless the shift in the weight of the most important criterion is realised within certain limits, the weights of the remaining criteria may be generated as negative values and this situation will violate the proportionality constraint for weights. The upper and lower limits for Δx are set between the negative value of the most important criterion and the maximum amount of weight change as indicated in Equation (14).

$$-w_s^0 \leq \Delta x \ \leq min\{w_c^0/\alpha_c\} \tag{14}$$

w_s^0: *original weight of the most important criterion*

Δx: *amount of change in the weights of the criteria*

Step 4. Calculation of new criterion weights for different scenarios.

New criterion weights are determined by means of Equation (15) and Equation (16).

$$w_s = w_s^0 + \alpha_s . \Delta x \qquad ; for\ the\ most\ important\ criterion \tag{15}$$

$$w_c = w_c^0 - \alpha_c . \Delta x \qquad ; for\ the\ remaing\ criteria \tag{16}$$

α_s: *weight coefficient of elasticity for the most importanrt criterion* $= 1$

w_c: $recalculated\ weights\ of\ criteria\ excluding\ the\ most\ important\ criterion$

w_s: $recalculated\ weight\ of\ the\ most\ important\ criterion$

An important point to note is that the criteria weights obtained according to each scenario must comply with the condition that $\sum w_s + \sum w_c = 1$.

4. PERFROMANCE EVALUATION OF G20 COUNTRIES

In this study, the contributions of nineteen G20 countries, with the exception of the European Union, to scientific research is analysed, and each country's performance is evaluated. The countries taken into consideration are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Türkiye, United Kingdom and United States and these countries correspond to the alternatives used in the decision matrices. Furthermore, the parameters as Number of Documents, Number of Citable Documents, Number of Citations, Number of Self-Citations, Number of Citations per Document and H-Index used in the evaluation express the criteria of the same decision matrices as indicated in Table 4.

Table 4. List of Criteria

	CRITERION	CRITERION TYPE
$C1$	Number of Documents	benefit
$C2$	Number of Citable Documents	benefit
$C3$	Number of Citations	benefit
$C4$	Number of Self Citations	benefit
$C5$	Number of Citations per Document	benefit
$C6$	H-Index	benefit

4.1. Determination of Priorities and Weights of Criteria

The weighting process of the criteria is carried out by participation of ten academics as decision makers from the fields of engineering, economics, social sciences, medicine and basic sciences, and the prioritisation proposal according to linguistic scale are submitted by each. Comparative importance of the average value $\tilde{s}_j$, $\tilde{k}_j$ coefficient, recalculated fuzzy weights $\tilde{q}_j$ and fuzzy relative criterion weights $\tilde{\omega}_j$ are determined by means of Equation (1), Equation (2) and Equation (3) by taking the arithmetic operations with triangular fuzzy operations into consideration and are summarized in Table 5.

Table 5. $\tilde{s}_j$, $\tilde{k}_j$, $\tilde{q}_j$ and $\tilde{\omega}_j$ Values Obtained by Fuzzy SWARA Method

		$\tilde{s}_j$			$\tilde{k}_j$			$\tilde{q}_j$			$\tilde{\omega}_j$		
		l	m	u	l	m	u	l	m	u	l	m	u
$DM1$	$C5$				1.000	1.000	1.000	1.000	1.000	1.000	0.436	0.472	0.513
	$C6$	1.000	1.000	1.000	2.000	2.000	2.000	0.500	0.500	0.500	0.218	0.236	0.257
	$C3$	0.667	1.000	1.500	1.667	2.000	2.500	0.200	0.250	0.300	0.087	0.118	0.154
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.120	0.167	0.214	0.052	0.079	0.110
	$C2$	0.400	0.500	0.667	1.400	1.500	1.667	0.072	0.111	0.153	0.031	0.052	0.079
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.056	0.089	0.125	0.024	0.042	0.064
$DM2$	$C6$				1.000	1.000	1.000	1.000	1.000	1.000	0.477	0.494	0.511
	$C3$	1.000	1.000	1.000	2.000	2.000	2.000	0.500	0.500	0.500	0.239	0.247	0.256

Table 5. (Continued)

		$\tilde{s}_j$			$\tilde{k}_j$			$\tilde{q}_j$			$\tilde{\omega}_j$		
		l	m	u	l	m	u	l	m	u	l	m	u
	$C5$	1.000	1.000	1.000	2.000	2.000	2.000	0.250	0.250	0.250	0.119	0.123	0.128
	$C2$	0.667	1.000	1.500	1.667	2.000	2.500	0.100	0.125	0.150	0.048	0.062	0.077
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.060	0.083	0.107	0.029	0.041	0.055
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.047	0.067	0.088	0.022	0.033	0.045
$DM3$	$C2$				1.000	1.000	1.000	1.000	1.000	1.000	0.387	0.467	0.562
	$C5$	0.667	1.000	1.500	1.667	2.000	2.500	0.400	0.500	0.600	0.155	0.233	0.337
	$C6$	0.667	1.000	1.500	1.667	2.000	2.500	0.160	0.250	0.360	0.062	0.117	0.202
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.096	0.167	0.257	0.037	0.078	0.145
	$C3$	0.286	0.333	0.400	1.286	1.333	1.400	0.069	0.125	0.200	0.027	0.058	0.112
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.053	0.100	0.164	0.021	0.047	0.092
$DM4$	$C6$				1.000	1.000	1.000	1.000	1.000	1.000	0.367	0.432	0.518
	$C2$	0.667	1.000	1.500	1.667	2.000	2.500	0.400	0.500	0.600	0.147	0.216	0.311
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.240	0.333	0.429	0.088	0.144	0.222
	$C5$	0.400	0.500	0.667	1.400	1.500	1.667	0.144	0.222	0.306	0.053	0.096	0.158
	$C3$	0.400	0.500	0.667	1.400	1.500	1.667	0.086	0.148	0.219	0.032	0.064	0.113
	$C4$	0.286	0.333	0.400	1.286	1.333	1.400	0.062	0.111	0.170	0.023	0.048	0.088
$DM5$	$C2$				1.000	1.000	1.000	1.000	1.000	1.000	0.387	0.467	0.562
	$C1$	0.667	1.000	1.500	1.667	2.000	2.500	0.400	0.500	0.600	0.155	0.233	0.337
	$C6$	0.667	1.000	1.500	1.667	2.000	2.500	0.160	0.250	0.360	0.062	0.117	0.202
	$C5$	0.400	0.500	0.667	1.400	1.500	1.667	0.096	0.167	0.257	0.037	0.078	0.145
	$C3$	0.286	0.333	0.400	1.286	1.333	1.400	0.069	0.125	0.200	0.027	0.058	0.112
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.053	0.100	0.164	0.021	0.047	0.092
$DM6$	$C2$				1.000	1.000	1.000	1.000	1.000	1.000	0.392	0.472	0.569
	$C3$	0.667	1.000	1.500	1.667	2.000	2.500	0.400	0.500	0.600	0.157	0.236	0.341
	$C6$	0.667	1.000	1.500	1.667	2.000	2.500	0.160	0.250	0.360	0.063	0.118	0.205
	$C5$	0.400	0.500	0.667	1.400	1.500	1.667	0.096	0.167	0.257	0.038	0.079	0.146
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.058	0.111	0.184	0.023	0.052	0.104
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.045	0.089	0.150	0.018	0.042	0.085
$DM7$	$C6$				1.000	1.000	1.000	1.000	1.000	1.000	0.392	0.472	0.569
	$C3$	0.667	1.000	1.500	1.667	2.000	2.500	0.400	0.500	0.600	0.157	0.236	0.341
	$C2$	0.667	1.000	1.500	1.667	2.000	2.500	0.160	0.250	0.360	0.063	0.118	0.205
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.096	0.167	0.257	0.038	0.079	0.146
	$C5$	0.400	0.500	0.667	1.400	1.500	1.667	0.058	0.111	0.184	0.023	0.052	0.104
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.045	0.089	0.150	0.018	0.042	0.085
$DM8$	$C2$				1.000	1.000	1.000	1.000	1.000	1.000	0.353	0.413	0.493
	$C3$	0.667	1.000	1.500	1.667	2.000	2.500	0.400	0.500	0.600	0.141	0.207	0.296
	$C1$	0.400	0.500	0.667	1.400	1.500	1.667	0.240	0.333	0.429	0.085	0.138	0.211
	$C5$	0.286	0.333	0.400	1.286	1.333	1.400	0.171	0.250	0.333	0.061	0.103	0.164
	$C6$	0.286	0.333	0.400	1.286	1.333	1.400	0.122	0.188	0.259	0.043	0.077	0.128
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.095	0.150	0.212	0.034	0.062	0.105
$DM9$	$C6$				1.000	1.000	1.000	1.000	1.000	1.000	0.344	0.403	0.481
	$C2$	1.000	1.000	1.000	1.667	2.000	2.500	0.400	0.500	0.600	0.138	0.201	0.289
	$C1$	0.667	1.000	1.500	1.400	1.500	1.667	0.240	0.333	0.429	0.083	0.134	0.206
	$C5$	0.400	0.500	0.667	1.286	1.333	1.400	0.171	0.250	0.333	0.059	0.101	0.160
	$C3$	0.286	0.333	0.400	1.222	1.250	1.286	0.133	0.200	0.273	0.046	0.081	0.131
	$C4$	0.222	0.250	0.286	1.000	1.000	1.000	0.133	0.200	0.273	0.046	0.081	0.131
$DM10$	$C6$				1.000	1.000	1.000	1.000	1.000	1.000	0.432	0.467	0.507
	$C5$	1.000	1.000	1.000	2.000	2.000	2.000	0.500	0.500	0.500	0.216	0.233	0.254
	$C3$	0.667	1.000	1.500	1.667	2.000	2.500	0.200	0.250	0.300	0.086	0.117	0.152
	$C2$	0.400	0.500	0.667	1.400	1.500	1.667	0.120	0.167	0.214	0.052	0.078	0.109
	$C1$	0.286	0.333	0.400	1.286	1.333	1.400	0.086	0.125	0.167	0.037	0.058	0.085
	$C4$	0.222	0.250	0.286	1.222	1.250	1.286	0.067	0.100	0.136	0.029	0.047	0.069

The arithmetic mean of the fuzzy weight coefficients for each criterion is computed and the crisp values of these fuzzy weights are calculated by means of the Centre of Area method expressed in Equation (4). The ultimate criteria weights obtained by the application of fuzzy SWARA method are summarised in Table 6.

Table 6. Crisp Criterion Weights

$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
0.106	0.252	0.143	0.052	0.158	0.290

Considering the numerical values in Table 6, it is revealed that the most important criterion is determined as H-Index ($C6$). The most important criterion, H-Index, is followed by Number of Citable Documents ($C2$), Number of Citations per Document ($C5$), Number of Citations ($C3$), Number of Documents ($C1$) and Number of Self Citations ($C4$). In this respect, the priority order of the criteria is summarised as $C6 > C2 > C5 > C3 > C1 > C4$.

4.2. Ranking the Performance of G20 Countries in terms of Scientific Publications

On the basis of the SCImago Journal & Country Rank data covering the period from 1996 to 2022, this research is carried out depending on the scientific publication indicators of each country. Relevant data, which is the reference source of the study and will also be used as the initial decision matrix $X = [x_{ij}]_{mxn}$, is presented in Table 7.

Table 7. Initial Decision Matrix

	Country	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	Argentina	277,943	259,333	5,259,896	904,800	18.92	534
$A2$	Australia	1,877,629	1,649,784	50,051,440	8,960,215	26.66	1,276
$A3$	Brazil	1,328,702	1,255,994	19,520,361	5,787,274	14.69	729
$A4$	Canada	2,281,865	2,037,734	66,166,875	10,119,371	29.00	1,460
$A5$	China	9,239,029	9,080,674	118,957,559	68,874,802	12.88	1,210
$A6$	France	2,647,084	2,443,975	67,490,155	12,213,066	25.50	1,420
$A7$	Germany	3,873,344	3,548,032	99,121,817	21,401,170	25.59	1,584
$A8$	India	2,636,181	2,425,509	31,553,699	10,603,600	11.97	795
$A9$	Indonesia	311,467	303,489	1,756,261	493,086	5.64	288
$A10$	Italy	2,353,407	2,124,484	54,884,768	11,744,998	23.32	1,255
$A11$	Japan	3,331,619	3,174,415	64,389,095	14,594,565	19.33	1,236
$A12$	Mexico	448,756	419,131	6,808,913	1,203,511	15.17	563
$A13$	Russian Federation	1,592,214	1,549,285	13,720,248	4,515,841	8.62	702
$A14$	Saudi Arabia	356,058	342,343	5,767,151	937,928	16.20	517
$A15$	South Africa	410,007	369,466	7,279,740	1,379,596	17.76	597
$A16$	South Korea	1,497,603	1,451,865	26,838,401	4,585,098	17.92	863
$A17$	Türkiye	838,530	779,735	11,280,898	2,197,485	13.45	562
$A18$	United Kingdom	4,502,915	3,775,825	127,998,813	25,755,418	28.43	1,815
$A19$	United States	15,188,630	13,318,470	467,519,124	185,959,311	30.78	2,880

Since all criteria used in the study are benefit oriented, only the Equation (5) is applied for logarithmic normalisation and the calculated values of the elements in the normalized decision matrix $R = [r_{ij}]_{mxn}$ are presented in Table 8.

Table 8. Normalized Decision Matrix

	Country	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	Argentina	0.04616	0.04615	0.04747	0.04603	0.05402	0.04842
$A2$	Australia	0.05319	0.05300	0.05438	0.05372	0.06032	0.05513
$A3$	Brazil	0.05192	0.05199	0.05150	0.05225	0.04937	0.05082
$A4$	Canada	0.05391	0.05379	0.05524	0.05413	0.06186	0.05617
$A5$	China	0.05906	0.05932	0.05704	0.06057	0.04695	0.05472

Table 8. (Continued)

	Country	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A6$	France	0.05446	0.05446	0.05530	0.05476	0.05950	0.05596
$A7$	Germany	0.05586	0.05584	0.05648	0.05664	0.05956	0.05680
$A8$	India	0.05444	0.05443	0.05297	0.05429	0.04561	0.05148
$A9$	Indonesia	0.04658	0.04674	0.04411	0.04399	0.03178	0.04366
$A10$	Italy	0.05403	0.05394	0.05467	0.05463	0.05786	0.05500
$A11$	Japan	0.05531	0.05543	0.05516	0.05536	0.05441	0.05489
$A12$	Mexico	0.04792	0.04793	0.04826	0.04698	0.04996	0.04882
$A13$	Russian Federation	0.05259	0.05277	0.05041	0.05142	0.03957	0.05052
$A14$	Saudi Arabia	0.04707	0.04718	0.04776	0.04615	0.05116	0.04817
$A15$	South Africa	0.04759	0.04746	0.04847	0.04744	0.05285	0.04928
$A16$	South Korea	0.05236	0.05253	0.05247	0.05147	0.05302	0.05212
$A17$	Türkiye	0.05023	0.05023	0.04981	0.04900	0.04775	0.04881
$A18$	United Kingdom	0.05642	0.05607	0.05726	0.05726	0.06150	0.05785
$A19$	United States	0.06089	0.06074	0.06124	0.06390	0.06296	0.06141

The weighted matrix $R^* = [r_{ij}^*]_{mxn}$ in Table 9 is obtained by multiplying the criterion weight values calculated by the Fuzzy SWARA method and the elements of normalised matrix by means of Equation (7).

Table 9. Weighted Normalized Decision Matrix

	Country	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
$A1$	Argentina	0.004895	0.011625	0.006790	0.002379	0.008510	0.014030
$A2$	Australia	0.005641	0.013351	0.007779	0.002777	0.009503	0.015976
$A3$	Brazil	0.005506	0.013096	0.007366	0.002701	0.007778	0.014726
$A4$	Canada	0.005718	0.013548	0.007901	0.002798	0.009747	0.016277
$A5$	China	0.006264	0.014941	0.008159	0.003131	0.007397	0.015858
$A6$	France	0.005776	0.013717	0.007910	0.002831	0.009374	0.016215
$A7$	Germany	0.005924	0.014065	0.008079	0.002928	0.009384	0.016459
$A8$	India	0.005774	0.013710	0.007576	0.002806	0.007185	0.014919
$A9$	Indonesia	0.004940	0.011772	0.006309	0.002274	0.005007	0.012651
$A10$	Italy	0.005730	0.013587	0.007819	0.002824	0.009116	0.015939
$A11$	Japan	0.005865	0.013961	0.007889	0.002862	0.008572	0.015905
$A12$	Mexico	0.005082	0.012073	0.006904	0.002429	0.007871	0.014148
$A13$	Russian Federation	0.005577	0.013292	0.007211	0.002658	0.006235	0.014641
$A14$	Saudi Arabia	0.004992	0.011884	0.006831	0.002385	0.008061	0.013958
$A15$	South Africa	0.005047	0.011955	0.006933	0.002452	0.008327	0.014279
$A16$	South Korea	0.005553	0.013232	0.007505	0.002661	0.008353	0.015103
$A17$	Türkiye	0.005327	0.012652	0.007125	0.002533	0.007523	0.014144
$A18$	United Kingdom	0.005983	0.014123	0.008191	0.002960	0.009689	0.016763
$A19$	United States	0.006458	0.015298	0.008759	0.003303	0.009919	0.017795

The negative ideal solution values for each criterion $S^- = [s_j^-]_{1xn}$ is obtained using equation (8) and the values are presented in Table 10.

Table 10. Negative Ideal Solution Values for Each Criterion

	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
s_j^-	0.004895	0.011625	0.006309	0.002274	0.005007	0.012651

Table 11 summarizes the Euclidean distance E_i and Taxicab distance T_i of alternatives from the negative-ideal solution calculated through Equation (9) and Equation (10).

Table 11. Euclidean and Taxicab Distances of Alternatives

	Country	E_i	T_i
$A1$	Argentina	0.003797	0.005469
$A2$	Australia	0.006101	0.012266
$A3$	Brazil	0.003977	0.008412
$A4$	Canada	0.006542	0.013227
$A5$	China	0.005746	0.012988
$A6$	France	0.006309	0.013061
$A7$	Germany	0.006651	0.014078
$A8$	India	0.004111	0.009210
$A9$	Indonesia	0.000153	0.000191
$A10$	Italy	0.005901	0.012253
$A11$	Japan	0.005704	0.012293
$A12$	Mexico	0.003325	0.005745
$A13$	Russian Federation	0.003110	0.006853
$A14$	Saudi Arabia	0.003376	0.005350
$A15$	South Africa	0.003772	0.006233
$A16$	South Korea	0.004669	0.009645
$A17$	Türkiye	0.003245	0.006542
$A18$	United Kingdom	0.007090	0.014948
$A19$	United States	0.008578	0.018771

Relative assessment matrix $R_a = [h_{ik}]_{mxm}$ is constructed by Equation (11) and assessment scores for individual alternatives H_i are calculated by Equation (12) sequentially. In line with the values obtained, the performance order of the G20 countries, which are included as alternatives in the study, is illustrated in Table 12 and Figure 4.

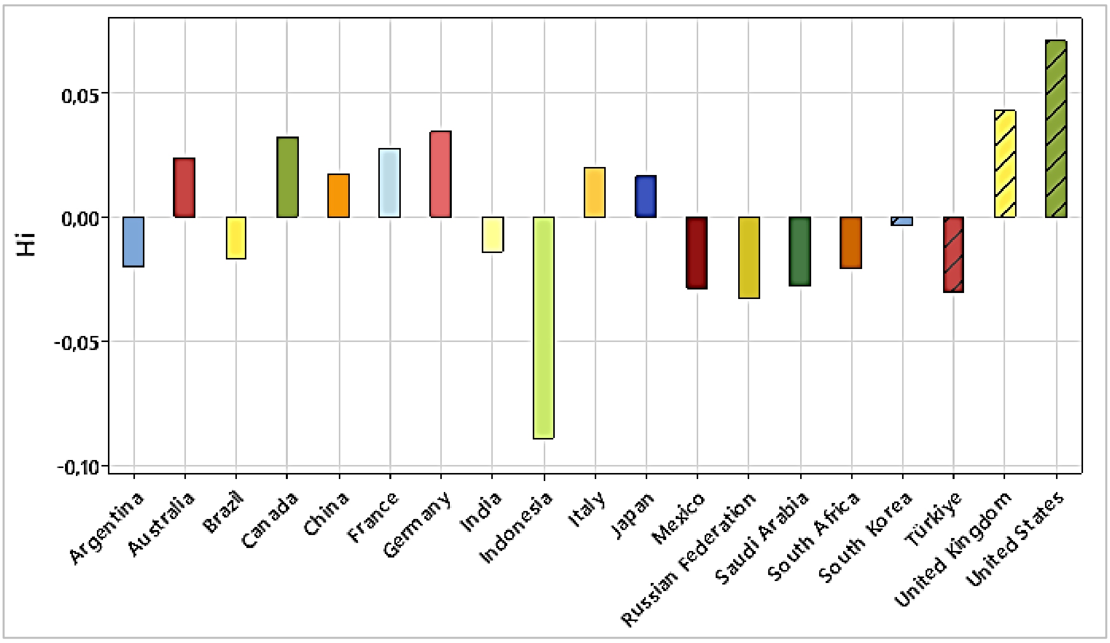
Table 12. R_a Matrix. H_i Values and orders of Alternatives

	$A1$	$A2$	$A3$	$A4$	$A5$	$A6$	$A7$	$A8$	$A9$	$A10$	$A11$	$A12$	$A13$	$A14$	$A15$	$A16$	$A17$	$A18$	$A19$	H_i	**Rank**
$A1$	0.0000	-0.0023	-0.0002	-0.0027	-0.0019	-0.0025	-0.0029	-0.0003	0.0036	-0.0021	-0.0019	0.0005	0.0007	0.0004	0.0000	-0.0009	0.0006	-0.0033	-0.0048	-0.0200	13
$A2$	0.0023	0.0000	0.0021	-0.0004	0.0004	-0.0002	-0.0006	0.0020	0.0059	0.0002	0.0004	0.0028	0.0030	0.0027	0.0023	0.0014	0.0029	-0.0010	-0.0025	0.0238	6
$A3$	0.0002	-0.0021	0.0000	-0.0026	-0.0018	-0.0023	-0.0027	-0.0001	0.0038	-0.0019	-0.0017	0.0007	0.0009	0.0006	0.0002	-0.0007	0.0007	-0.0031	-0.0046	-0.0166	12
$A4$	0.0027	0.0004	0.0026	0.0000	0.0008	0.0002	-0.0001	0.0024	0.0064	0.0006	0.0008	0.0032	0.0034	0.0032	0.0028	0.0019	0.0033	-0.0005	-0.0020	0.0321	4
$A5$	0.0019	-0.0004	0.0018	-0.0008	0.0000	-0.0006	-0.0009	0.0016	0.0056	-0.0002	0.0000	0.0024	0.0026	0.0024	0.0020	0.0011	0.0025	-0.0013	-0.0028	0.0170	8
$A6$	0.0025	0.0002	0.0023	-0.0002	0.0006	0.0000	-0.0003	0.0022	0.0062	0.0004	0.0006	0.0030	0.0032	0.0029	0.0025	0.0016	0.0031	-0.0008	-0.0023	0.0277	5
$A7$	0.0029	0.0006	0.0027	0.0001	0.0009	0.0003	0.0000	0.0025	0.0065	0.0008	0.0009	0.0033	0.0035	0.0033	0.0029	0.0020	0.0034	-0.0004	-0.0019	0.0342	3
$A8$	0.0003	-0.0020	0.0001	-0.0024	-0.0016	-0.0022	-0.0025	0.0000	0.0040	-0.0018	-0.0016	0.0008	0.0010	0.0007	0.0003	-0.0006	0.0009	-0.0030	-0.0045	-0.0141	11
$A9$	-0.0036	-0.0059	-0.0038	-0.0064	-0.0056	-0.0062	-0.0065	-0.0040	0.0000	-0.0057	-0.0056	-0.0032	-0.0030	-0.0032	-0.0036	-0.0045	-0.0031	-0.0069	-0.0084	-0.0892	19
$A10$	0.0021	-0.0002	0.0019	-0.0006	0.0002	-0.0004	-0.0008	0.0018	0.0057	0.0000	0.0002	0.0026	0.0028	0.0025	0.0021	0.0012	0.0027	-0.0012	-0.0027	0.0200	7

Table 12. (Continued)

	A1	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***	***A8***	***A9***	***A10***	***A11***	***A12***	***A13***	***A14***	***A15***	***A16***	***A17***	***A18***	***A19***	H_i	**Rank**
A11	0.0019	-0.0004	0.0017	-0.0008	0.0000	-0.0006	-0.0009	0.0016	0.0056	-0.0002	0.0000	0.0024	0.0026	0.0023	0.0019	0.0010	0.0025	-0.0014	-0.0029	0.0162	9
A12	-0.0005	-0.0028	-0.0007	-0.0032	-0.0024	-0.0030	-0.0033	-0.0008	0.0032	-0.0026	-0.0024	0.0000	0.0002	-0.0001	-0.0004	-0.0013	0.0001	-0.0038	-0.0053	-0.0290	16
A13	-0.0007	-0.0030	-0.0009	-0.0034	-0.0026	-0.0032	-0.0035	-0.0010	0.0030	-0.0028	-0.0026	-0.0002	0.0000	-0.0003	-0.0007	-0.0016	-0.0001	-0.0040	-0.0055	-0.0331	18
A14	-0.0004	-0.0027	-0.0006	-0.0032	-0.0024	-0.0029	-0.0033	-0.0007	0.0032	-0.0025	-0.0023	0.0001	0.0003	0.0000	-0.0004	-0.0013	0.0001	-0.0037	-0.0052	-0.0280	15
A15	0.0000	-0.0023	-0.0002	-0.0028	-0.0020	-0.0025	-0.0029	-0.0003	0.0036	-0.0021	-0.0019	0.0004	0.0007	0.0004	0.0000	-0.0009	0.0005	-0.0033	-0.0048	-0.0205	14
A16	0.0009	-0.0014	0.0007	-0.0019	-0.0011	-0.0016	-0.0020	0.0006	0.0045	-0.0012	-0.0010	0.0013	0.0016	0.0013	0.0009	0.0000	0.0014	-0.0024	-0.0039	-0.0034	10
A17	-0.0006	-0.0029	-0.0007	-0.0033	-0.0025	-0.0031	-0.0034	-0.0009	0.0031	-0.0027	-0.0025	-0.0001	0.0001	-0.0001	-0.0005	-0.0014	0.0000	-0.0038	-0.0053	-0.0305	17
A18	0.0033	0.0010	0.0031	0.0005	0.0013	0.0008	0.0004	0.0030	0.0069	0.0012	0.0014	0.0038	0.0040	0.0037	0.0033	0.0024	0.0038	0.0000	-0.0015	0.0426	2
A19	0.0048	0.0025	0.0046	0.0020	0.0028	0.0023	0.0019	0.0045	0.0084	0.0027	0.0029	0.0053	0.0055	0.0052	0.0048	0.0039	0.0053	0.0015	0.0000	0.0708	1

Figure 4. H_i Values of Alternatives



According to the data in Table 12 and Figure 4, the United States stands in the first position in terms of the scientific publication performance of G20 countries. United States is followed by United Kingdom, Germany, Canada, France, Australia, Italy, China, Japan, South Korea, India, Brazil, Argentina, South Africa, Saudi Arabia, Mexico, Türkiye, Russia and Indonesia.

4.3. Sensitivity Analysis of the Method Employed

C6, determined as the most important criterion in line with the process steps proposed by the method, is assigned to the first row of the column and the other criteria are allocated into the remaining rows. The weight coefficient of elasticity α_c is calculated by means of Equation (13) and the limits within which the most important criteria will be exposed to change is determined by means of Equation (14) as represented in Table 13.

Table 13. α_c and Δx Values for Each Criterion

Criteria	w_i	α_c	Δx
$C6$	0.2898	1	
$C1$	0.1061	0.1493	0.71021
$C2$	0.2519	0.3547	0.71021
$C3$	0.1430	0.2014	0.71021
$C4$	0.0517	0.0728	0.71021
$C5$	0.1576	0.2218	0.71021

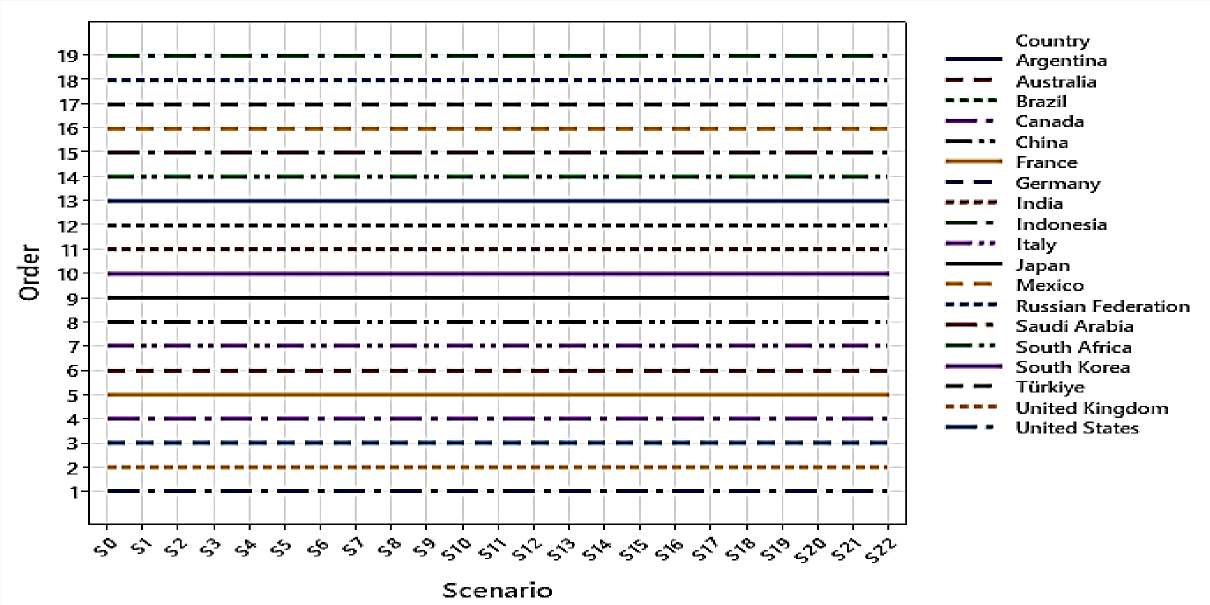
In accordance with Equation (14), the limits of variation for the most important criterion are set as $-0.2898 \leq \Delta x \leq 0.7102$. The weight of the most important criterion is altered within the limits of calculated interval by means of Equation (15) involving twenty-two different scenarios (S) and the corresponding change in the weights of remaining criteria are determined by Equation (16) as represented in Table 14.

Table 14. Recalculated Criterion Weights Within Limited Interval

	Δx	w_6	w_1	w_2	w_3	w_4	w_5	$\sum w_i$
$S1$	-0.2898	0.0000	0.1493	0.3547	0.2014	0.0728	0.2218	1.000
$S2$	-0.25	0.0398	0.1434	0.3405	0.1934	0.0699	0.213	1.000
$S3$	-0.20	0.0898	0.1359	0.3228	0.1833	0.0662	0.2019	1.000
$S4$	-0.15	0.1398	0.1285	0.3051	0.1732	0.0626	0.1908	1.000
$S5$	-0.10	0.1898	0.121	0.2873	0.1632	0.059	0.1797	1.000
$S6$	-0.05	0.2398	0.1135	0.2696	0.1531	0.0553	0.1686	1.000
$S7$	0.00	0.2898	0.1061	0.2519	0.143	0.0517	0.1576	1.000
$S8$	0.05	0.3398	0.0986	0.2341	0.133	0.0481	0.1465	1.000
$S9$	0.10	0.3898	0.0911	0.2164	0.1229	0.0444	0.1354	1.000
$S10$	0.15	0.4398	0.0837	0.1987	0.1128	0.0408	0.1243	1.000
$S11$	0.20	0.4898	0.0762	0.181	0.1028	0.0371	0.1132	1.000
$S12$	0.25	0.5398	0.0687	0.1632	0.0927	0.0335	0.1021	1.000
$S13$	0.30	0.5898	0.0613	0.1455	0.0826	0.0299	0.091	1.000
$S14$	0.35	0.6398	0.0538	0.1278	0.0725	0.0262	0.0799	1.000
$S15$	0.40	0.6898	0.0463	0.11	0.0625	0.0226	0.0688	1.000
$S16$	0.45	0.7398	0.0389	0.0923	0.0524	0.0189	0.0577	1.000
$S17$	0.50	0.7898	0.0314	0.0746	0.0423	0.0153	0.0466	1.000
$S18$	0.55	0.8398	0.0239	0.0568	0.0323	0.0117	0.0355	1.000
$S19$	0.60	0.8898	0.0165	0.0391	0.0222	0.008	0.0244	1.000
$S20$	0.65	0.9398	0.009	0.0214	0.0121	0.0044	0.0134	1.000
$S21$	0.70	0.9898	0.0015	0.0036	0.0021	0.0007	0.0023	1.000
$S22$	0.7102	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000

The order of the countries is recalculated using the new criteria weights that emerged by applying these twenty-two different scenarios and is illustrated in Figure 5.

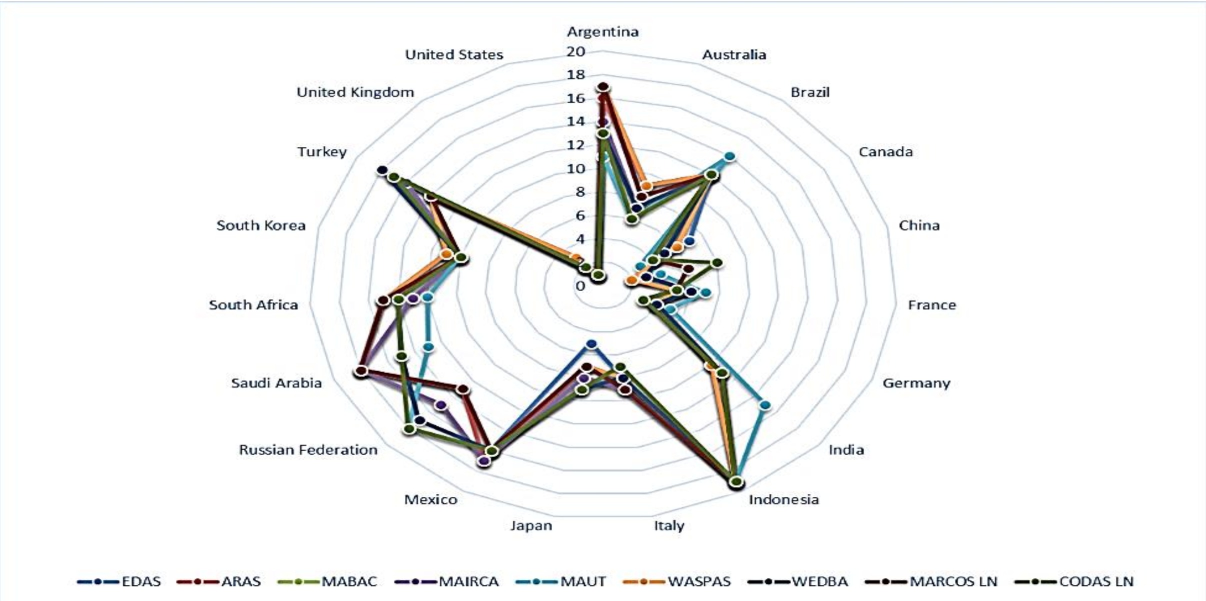
Figure 5. Sensitivity Analysis of MCDM Method



The chart depicted in Figure 5 illustrates that the alteration in the significance weights of the remaining criteria, resulting from the reduction in the weight of the most important criterion, does not influence the ranking of the countries under any circumstance. This situation indicates that whatever the weights of the criteria are, there will be no variations in the performance order of the countries.

Apart from the sensitivity analysis carried out depending on the variation of the criteria weights within a certain interval, the orders obtained by CODAS-LN method are also investigated with different MCDM methods and the results obtained are illustrated in Figure 6.

Figure 6. Comparison with Different MCDM Methods



The ranking results depicted in Figure 6 indicate that there may be minor variations in the rankings when employing different MCDM methods, but these discrepancies do not yield any significant differences. Moreover, it is firmly established that the United States consistently exhibits the highest level of performance in terms of scientific publications across all scenarios.

5. RESULTS AND DISCUSSION

Based on the idea that the level of development of a country is directly related to its achievements in the scientific domain, investigating the contributions of economically influential countries to science in today's world constituted the main reference point of this study. The scientific publications of the G20 countries were analysed not only in terms of their numerical size, but also by other criteria, including the extent to which they are taken into consideration by other scientists. The remaining criteria considered in this regard are number of citable documents, number of citations, number of self-citations, number of citations per document and H-Index parameters. Another important point is that it is required to determine which criterion has the highest impact for the assessment of scientific publication performance of these countries. On the other hand, the priority of the other criteria against each other should be expressed in numerical terms.

In order to fulfil these prerequisites, the opinions of ten academicians involved in the fields of engineering, economics, social sciences, medicine and basic sciences are requested and the priority levels of the mentioned criteria are determined by employing the Fuzzy SWARA method. By virtue of results derived from the relevant procedure, it can be inferred that the H-Index stands out as carrying maximum weight in relation to other criteria. Furthermore, the importance of Number of Citable Documents, Number of Citations per Document, Number of Citations, Number of Documents and Number of Self Citations criteria are ordered in descending order.

Following the transaction for determination of the importance level of the criteria, ordering of G20 countries in terms of scientific publication performance is conducted. Since the scientific publication data considered for each country are skewed and therefore not normally distributed, the CODAS-LN method involving logarithmic normalisation is preferred. The ranking results obtained through the application of the method indicate that the United States is in a very superior position in terms of scientific publication performance. The other countries in the top five are the United Kingdom, Germany, Canada and France, while Australia, Italy, China, Japan, South Korea, India, Brazil, Argentina, South Africa, Saudi Arabia, Mexico, Türkiye, Russia and Indonesia are the other countries in the descending order. Considering the 2022 data of the World Bank, it is clearly observed that the deep efforts of these countries in the scientific field directly reflect their Gross Domestic Product (GDP) values. Therefore, the contribution of scientific endeavours to economic welfare of countries is undeniable.

As a result of the sensitivity analysis carried out to determine whether the method used in the research provides a stable and consistent ranking, it is determined that although the weight of the most important criterion is reduced within a certain interval, no deviation is detected. Therefore, it is confirmed that the analysis conducted for the ranking of the countries yields sound results. In addition to this sensitivity analysis, a comparison with other multi-criteria decision-making methods is also carried out and it is observed that there is no significant difference between the results generated by these methods.

The method applied for G20 countries in this study reveals that it can be a reference for universities, institutes, research institutions and scientific journals in terms of their own performance evaluation.

In this respect, generation of scientific publications in a country is an indicative measure of that country's contribution to the scientific field. In addition, it is a concrete sign that reveals the country's efforts in research and development activities, the quality of their scientific research institutions and the knowledge generation capacity of the country's scientists. The significant increase in the number of publications indicates the existence of a determined and enthusiastic scientific community. However, it is essential to evaluate scientific publications not only in terms of quantity but also in terms of their quality. Satisfying both quantity and quality criteria in scientific publications will be a more meaningful achievement in terms of reliability and credibility of such studies. While the high volume of scientific publications may give an idea about the efforts in the scientific field, it is the quality of their content that determines the impact and importance of these publications. Other aspects to be considered are whether scientific publications lead to tangible productivity and whether they are taken as references by other researchers.

The study does not necessitate Ethics Committee permission.

The study has been crafted in adherence to the principles of research and publication ethics.

The authors declare that there exists no financial conflict of interest involving any institution, organization, or individual(s) associated with the article. Furthermore, there are no conflicts of interest among the authors themselves.

The authors contributed equally to the entire process of the research.

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