MULTI-CRITERIA ANALYSES OF DIGITAL TRANSFORMATION AMONG G20 COUNTRIES: MAIRCA & MULTIMOORA APPLICATIONS

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ABSTRACT
In recent years, digital transformation has gained significant importance for companies at the micro level and states at the macro level, becoming a critical factor that determines economic competitiveness and sustainability. The main purpose of this study is to comprehensively evaluate the macro-level digital transformation performance of G20 countries, which represent 85% of the global economy, using Multi-Criteria Decision-Making (MCDM) methods. In order to evaluate countries' digital transformation performance, ten criteria were determined within the areas of infrastructure, economy and trade, innovation and security, and accessibility. The analyses were conducted in two stages. In the first stage, the CRITIC method was used to calculate objective criteria weights. In the second stage, these weights were used to evaluate the countries' digital performance separately through the MAIRCA and MULTIMOORA methods. According to the CRITIC results, the weights were relatively evenly distributed across the ten criteria. In the performance analysis, South Korea ranked first in both methods. The U.S., Germany, China, Japan, the U.K., and France formed the top seven in both methods, while Indonesia and Argentina were among the lowest ranked countries. The rankings differed for some of middle ranked countries. The strong positive relationship between the two methods (Spearman's ρ=0.896 and Kendall's τ_b=.801) supports the reliability of the findings. Overall, the study provides a comparative and objective assessment that can help decision-makers.
Keywords: Digital transformation, G20, MCDM, CRITIC, MAIRCA, MULTIMOORA.

INTRODUCTION
Digital technologies have become an important factor of economic development and international competitiveness. Countries that effectively integrate digital technologies into production and service activities may strengthen their competitiveness in international markets. Digital transformation also affects economic and social processes. The World Bank (2016) emphasizes the role of digital technologies especially in expanding access to economic opportunities and public services. Fixed broadband, in particular, enables businesses to increase productivity and compete in international markets, and it has been shown to be positively associated with economic growth (Czernich et al., 2011; Qiang et al., 2009). Therefore, comparing the digital transformation performance of G20 countries can provide a better perspective on differences in digital infrastructure, innovation, accessibility, and digital trade among major economies.

The G20 countries account for a major share of global economic activity, representing around 85% of the global GDP and about 75% of international trade (Australian Government Dep. of Foreign Affairs and Trade), and play an important role in technological innovation and the development of digital infrastructure. The digital policies and performance of these countries influence global competitiveness and establish the standards for global digital governance leading to Fourth Industrial Revolution.

In this context, this study evaluates the digital transformation performance of G20 countries and identifies differences of major developed and emerging economies. The analysis covers the 19 individual G20 member countries, excluding the European Union and the African Union because of being regional organizations. In order to assess these countries, ten indicators were determined and obtained from three different data sources and analyzed with a multi-stage multicriteria decision-making (MCDM) model. First, the CRITIC method is used to determine the importance of each criterion objectively. Then these weights are used as an input for MAIRCA and MULTIMOORA methods to evaluate and compare the countries.

The paper is organized as follows. The literature review is presented in the second section, followed by the data and methodology in the third section. The fourth section reports and discusses the results, and the final section concludes with the main findings.

LITERATURE REVIEW

Digital transformation extends beyond internet connectivity or software (Baker, 2014). It relies on integrated framework covering digital infrastructure, the use of digital technologies by firms and households, innovation capacity, digital trade and security of these systems. Achieving long-term progress requires aligning data systems, networks and trade channels (Ebert and Duarte, 2018).

The digital divide across nations involves more than basic metrics. Examining digital transformation across European countries, Malkowska et al. (2021) identified differences in areas such as high technology exports and enterprise digital usage. Fidan (2024) similarly demonstrated that digital performance of countries is related with the role of digital skills and technological capabilities.

Differences in digital development can also be observed among G20 economies (Cayir Ervural, 2026). Accounting for majority of the global economy and world trade, G20 countries shape international standards for technology and digital markets (Acharjee et al., 2025), but the progress of member countries is unbalanced. Countries such as South Korea, the United States, and Germany lead across digital infrastructure, R&D expenditure, and digital trade (Öztaş and Öztaş, 2024). Developing member countries struggle with structural obstacles including high broadband pricing, local network limitations, and weaker cybersecurity readiness (Keleş and Ersoy, 2023; Acharjee et al., 2025).

Different indicators may not always align with each other, factors like broadband availability, price adjustments, and high-tech exports often move in opposite directions (Öztaş and Öztaş, 2024; Demir et al., 2023). An economy might have top ranking in secure servers, but still struggle with expensive costs for users or low export numbers. In these kinds of situations, relying on simple averages or subjective scores may not reflect the real case (Cayir Ervural, 2026; Keleş and Ersoy, 2023). For this reason comparing national digital transformation performance is challenging, since the indicators used as measurement may differ in scale and may not move in the same direction. MCDM methods provide a suitable framework for these kind of comparisons because the allow multiple conflicting criteria with different measurement scales to be considered simultaneously (Can and Kıran, 2020; Demir et al., 2023).

An important issue in MCDM is the determination of criterion weights. Subjective approaches such as Analytic Hierarchy Process (AHP) relies on expert assessments, objective weighting methods derive the information from the data. While expert interviews are popular in literature, they bring personal opinions and sometimes their biases into their decisions (Demir et al., 2023; Öztaş and Öztaş, 2024). CRITIC method proposed by Diakoulaki et al. (1995) considers the variability of each criterion and its correlation with other criteria, that is directly obtained from data. If an indicator has a high standard deviation and low correlation, it gives more useful and unique information for the final ranking (Diakoulaki et al., 1995; Cayir Ervural, 2026).

After the weights are determined, the ranking method needs to balance trade-offs between countries (Öztaş and Öztaş, 2024; Demir et al., 2023). MAIRCA method, proposed by Pamucar et al. (2018), evaluates alternatives by comparing their observed performance with a theoretical reference based on equal prior preferences. The resulting gap values provide a basis for ranking alternatives according to their distance from ideal performance. To cross-check these distance-based results, this study incorporates the MULTIMOORA method into the analysis, developed by Brauers and Zavadskas (2010).

Although previous studies have examined digital transformation, innovation, open data, and related dimensions of G20 countries using MCDM approaches, the existing literature identified in this study does not appear to have combined CRITIC-based objective weighting with both MAIRCA and MULTIMOORA for a comprehensive comparison of G20 digital transformation performance. This study addresses this gap by applying the three methods within a common analytical framework.

MATERIALS AND METHODS

In this study, the digital performance of G20 nations is evaluated using ten criteria that represent different dimensions of digitalization. Eight indicators are taken form World Bank's World Development Indicators (WDI) database (World Bank, 2025). The National Cyber Security Index (NCSI), compiled by the e-Governance Academy, represents digital security, and the average cost of broadband is obtained from World Population Review.

Table 1. Decision Matrix for G20 Digital Transformation Analysis

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	B	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*B*	*C*
Argentina	90	5453	140	25.36	0.0001*	4	0.55	15.7	58.33	149.12
Australia	97	44295	113	36.6	0.7	25	1.86	3	87.5	61.99
Brazil	84	6941	102	22.42	0.3	11	1.15	12.9	71.67	39.57
Canada	94	39713	94.1	42.52	1.4	17	1.7	12	96.67	84.93
China	92	1413	132	44.73	22.6	26	2.56	16.9	60	8.45
France	89	57275	117	48.67	3.6	23	2.23	7.6	89.17	45.86
Germany	94	152114	129	45.38	4.8	18	3.13	11.5	90.83	45.5
India	70	1212	79.4	2.75	2.8	19	0.65	47.4	75.83	23.66
Indonesia	73	2939	123	4.82	2.9	9	0.28	9.6	47.5	32.37
Italy	89	30647	133	31.84	2	12	1.39	5.9	88.33	46.01
Japan	87	32929	178	38.63	8.2	18	3.41	4.8	82.5	43.48
Mexico	81	532	116	20.09	13.7	19	0.27	3.9	38.33	31.77
Russia	94	26130	186	25.82	0.5	10	0.93	5.5	71.43	18.99
Saudi Arabia	100	483	160	43.57	0.4	1	0.56	3.5	78.33	15.94
South Africa	76	16658	179	3.41	0.7	6	0.62	9.5	51.67	40.9
South Korea	98	11902	173	46.57	27.7	36	5.21	10.4	83.33	37.15
Türkiye	87	11103	108	22.46	0.7	5	1.32	4.2	71.67	43.02
U.K.	96	68449	122	41.44	3.4	30	2.9	9.2	75	48.32
U.S.	93	196554	113	38.15	7.8	24	3.59	7.9	84.17	54.44

Note: *B: Benefit Criteria, C: Cost Criteria*
C1: Individuals using the Internet, C2: Secure Internet servers, C3: Mobile cellular subscriptions, C4: fixed broadband subscriptions, C5: ICT goods exports, C6: High technology exports, C7: R&D expenditure, C8: ICT service export, C9: National cyber security Index, C10: Average cost of broadband adjusted

The criteria are grouped into four dimensions to cover the different aspects of digital transformation discussed in the literature. Infrastructure comprises the basic connectivity and secure-server capacity on which digital activity relies (C1-C4). Economy & Trade captures how far digital capabilities are converted to export performance (C5, C6, C8). Innovation & Security reflects a country's capacity for technological development and its institutional preparedness against cyber threats (C7, C9). Accessibility reflects the price users pay for fixed broadband (C10). Such a multi-level dimensional structure follows earlier studies (Malkowska et al., 2021). In this study the dimensions serve only to organize the criteria, all ten criteria are weighted to evaluated individually.

The broadband cost data was adjusted according to purchasing power parity to ensure more accurate comparisons. In the decision matrix, "average cost of broadband" is treated as a cost criterion, while the remaining nine indicators are considered as benefit criteria. Due to the lack of available ICT goods export data for Argentina, a negligible value (0.0001) was assigned to this criterion to ensure mathematical calculations within decision matrix.

CRITIC

The relative importance of each criterion is determined using the CRITIC (Criteria Importance Through Intercriteria Correlation) method. Unlike subjective weighting techniques that rely on expert judgement, CRITIC method assigns weights by quantifying information included within the decision matrix. The method consists of four steps:

Step 1: Construction and Normalization of the Decision Matrix

An evaluation matrix containing n alternatives and m criteria is constructed. Let f_i (a_i) represent the performance score of alternatives a_i under criterion j. To eliminate the impact of different measurement units and scales, the initial decision matrix is transformed into a normalized matrix of relative scores x_{ij}, where all values range between 0 and 1. For benefit criteria, normalization is calculated likewise:

$$x_{ij} = \frac{f_j(\alpha) - f_{j*}}{f_j^* - f_{j*}}$$

where f_j^* represents the ideal value (the best performance) and f_{j*} represents the anti-ideal value (the worst performance) achieved for criterion j among all alternatives under consideration.

Step 2: Calculation of Contrast Intensity

The standard deviation, which measures the contrast intensity of each criterion, is calculated for each normalized criterion vector. A higher standard deviation indicates that the criterion provides more useful information for the decision-making process.

Step 3: Calculation of Intercriteria Correlation and Conflict

A symmetric correlation matrix of size m*m is constructed. The element r_{jk} represents the linear correlation coefficient between the normalized vectors of criterion j and criterion k. The total conflict created by criterion j relative to all other criteria is calculated using the following formula:

$$\sum_{k=1}^{m}(1 - r_{jk})$$

If the linear correlation coefficient between two criteria is low, it means their results are discordant and create more conflict within the decision situation.

Step 4: Determination of Intrinsic Information and Objective Weights

The total amount of intrinsic information contained in the j-th criterion is calculated by multiplying its contrast intensity with its conflict measure. The mathematical formula is shown:

$$C_j = \sigma_j * \sum_{k=1}^{m}(1 - r_{jk})$$

A higher Cj value shows that the criterion transmits a larger amount of information and has higher importance. The objective weights are calculated by normalizing these values to unity as shown below:

$$w_j = \frac{C_j}{\sum_{k=1}^{m} C_k}$$

MAIRCA

The MAIRCA (Multi-Attributive Ideal-Real Comparative Analysis) method, originally developed by Pamučar, Vasin, and Lukovac (2018), is a MCDM tool, whose core philosophy relies on determining the gap between ideal and real performance ratings. The final ranking is achieved by calculating the total gap values across all criteria; the alternative with the lowest total gap is identified as the closest to the ideal solution. MAIRCA method consists of six steps:

Step 1: Construction of the Initial Decision Matrix

An evaluation matrix containing m alternatives and n criteria is established. Let x_{ij} represent the performance score of alternatives i (i = 1, 2, …, m) under criterion j (j = 1, 2, …, n):

$$X=\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}$$

Step 2: Determination of Preferences for Selecting Alternatives

In this step, the selection probabilities or prior preferences for choosing each alternative are determined. Assuming neutrality and equal preference for all alternatives in the decision-making process, the preference probability for each alternative is calculated as follows:

$$P_{ai} = \frac{1}{m}$$

Where m represents the total number of alternatives under consideration.

Step 3: Construction of the Theoretical Ranking Matrix

The theoretical ranking matrix is established by multiplying the selection preferences by the objective criterion weights derived from the CRITIC method:

$$T_p=\begin{bmatrix} t_{11} & \cdots & t_{1n} \\ \vdots & \ddots & \vdots \\ t_{m1} & \cdots & t_{mn} \end{bmatrix}$$

The elements t_{ij} of the theoretical ranking matrix are equal for all alternatives across each specific criterion and are defined as:

$$t_{ij} = P_{ai} * w_j$$

Step 4: Construction of the Real Ranking Matrix

To calculate the real ranking matrix, the initial decision matrix elements are normalized according to their criterion types (benefit or cost) and then multiplied with the theoretical matrix elements.

For benefit (maximum) criteria, the transformation formula is applied as:

$$t_{r_{ij}} = t_{ij} * \left(\frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \right)$$

For cost (minimum) criteria, the transformation formula is applied as:

$$t_{r_{ij}} = t_{ij} * \left(\frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \right)$$

Where x_j^{max} and x_j^{min} denote the maximum and minimum values in the initial decision matrix for the j-th criterion, respectively.

Step 5: Construction of the Total Gap Matrix

The total gap matrix represents the difference between the absolute ideal performance and the actual performance achieved. The gap elements are calculated using the following subtraction formula:

$$G = T_p - T_r$$
$$g_{ij} = t_{ij} - t_{r_{ij}}$$

if an alternative achieves the maximum possible ideal value for a benefit criterion, its gap value g_{ij} will equal 0.

Step 6: Calculation of Final Gap Scores and Ranking

The final empirical score Q_i for each alternative is computed by summing the individual gap values across all n criteria:

$$Q_i = \sum_{j=1}^{n} g_{ij}$$

The alternatives are sorted based on their Q_i values in ascending order.

MULTIMOORA

MULTIMOORA (Multi-Objective Optimization on the basis of the Ratio Analysis plus Full Multiplicative Form) is a MCDM technique that determines a composite ranking by aggregating the results of three different connected sub-models. This technique evaluates decision alternatives by integrating the Ratio System, the Reference Point Approach, and the Full Multiplicative Form. MULTIMOORA method consists of six steps:

Step 1: Vector Normalization

The normalized values are calculated using the formula below:

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} {x_{ij}}^2}}$$

where x_{ij} represents the raw score of alternative i (i = 1, 2, …, m) under criterion j (j = 1, 2, …, n).

Step 2: Integration of Criterion Weights

To reflect the relative importance of each indicator, the normalized decision matrix elements are multiplied by the objective weights from the CRITIC method:

$$v_{ij} = x_{ij}^{*} * w_j$$

where v_{ij} represents the weighted normalized performance score.

Step 3: The Ratio System

The Ratio System measures the cumulative success of each alternative based on linear arithmetic aggregation. For each alternative, the sum of the weighted normalized values of the cost criteria is subtracted from the sum of the benefit criteria:

$$y_i = \sum_{j=1}^{g} v_{ij} - \sum_{j=g+1}^{n} v_{ij}$$

where g denotes the number of benefit criteria, and (n - g) represents the number of cost criteria. Alternatives are sorted based on their y_i scores in descending order; the alternative with the highest y_i value represents the optimal choice.

Step 4: The Reference Point Approach

The Reference Point Approach is a conservative assessment tool that evaluates alternatives based on their maximal single-criterion deviation from an ideal point.

Calculate maximal ideal reference point for each criterion:

$$r_j = \max_i v_{ij} \text{(if criterion j is a benefit criterion)}$$
$$r_j = \min_i v_{ij} \text{(if criterion j is a cost criterion)}$$

The absolute distance between the performance of each alternative and the ideal reference point is calculated, and only the maximum deviation is selected as the final score for that alternative:

$$z_i = \max_j |r_j - v_{ij}|$$

Alternatives are sorted based on their z_i values in ascending order; the alternative with the minimum z_i value is designated as the optimal choice, as it minimizes the maximum risk of underperformance.

Step 5: The Full Multiplicative Form

The Full Multiplicative Form calculates the geometric utility of the alternatives, where the criterion weights are integrated as exponents. The overall utility score is computed using the following formula:

$$U_i = \frac{\Pi_{j=1}^{g} (x_{ij}^{*})^{wj}}{\Pi_{j=g+1}^{n} (x_{ij}^{*})^{wj}}$$

where the numerator represents the product of the weighted normalized benefit criteria, and the denominator represents the product of the cost criteria. Alternatives are sorted based on their U_i scores in descending order; the alternative with the highest U_i value represents the optimal choice.

Step 6: Integration via Dominance Theory

Three independent ranking lists are generated for the alternatives via step 3-5. Dominance Theory is applied to obtain a single and integrated multi-criteria evaluation, This theory employs a ranking logic based on majority rule and pairwise comparisons. An alternative is deemed superior if it dominates other options across at least two out of the three sub-systems. In cases of circular ties (transitivity violations), the final order is determined by evaluating the cumulative rank sums to ensure absolute transitivity.

RESULTS

Analysis of Criterion Weights via the CRITIC Method

The criterion weights calculated using four steps of the CRITIC method -normalization, contrast intensity, correlation and conflict- to obtain the intrinsic information contained in the dataset and determine the weights are presented in Table 2.

Table 2. Objective Weights and Rankings of Digitalization Criteria

Evaluation Criteria	Weight
Individuals using the Internet	9.65%
Secure Internet Servers	10.29%
Mobile cellular subscriptions	13.18%
Fixed broadband subscriptions	9.90%
Ict goods exports	9.85%
High-technology exports	8.42%
R&D expenditure	7.41%
Ict service exports	11.89%
National cyber security index	9.67%
Average cost of broadband per month	9.73%

The weights of the ten criteria are examined, and no criterion was found to be more or less important than the others (see Table 2.) The weights are relatively evenly distributed across the criteria, mobile cellular subscriptions has the highest weight (13.18%), followed by ICT service exports (11.89%), whereas R&D expenditure has the lowest weight (7.41%). The relatively close distribution of the criterion weights can be explained by the structure of CRITIC method, which determines objective weights by jointly considering the contrast intensity of each criterion and its correlation with the other criteria. Afterwards both the degree of variation across countries and the extent to which each criterion provides distinct information from the other criteria contribute the final weight. The relatively similar weights obtained in this study may suggest that the criteria do not differ significantly in terms of overall discriminatory power.

Analysis of Digitalization Performance via the MAIRCA Method

The digital transformation performance of the 19 G20 member countries, calculated using the four steps of MAIRCA method- preference determination, theoretical gap matrix, real gap matrix and total gap matrix- is presented in Table 3.

The MAIRCA method evaluates digitalization performance by linearly measuring the mathematical distance between each country's actual data and the ideal performance, preventing alternative rankings from being masked by single-criterion successes.

Table 3. MAIRCA Results and Final Rankings of G20 Countries

	Q	Rank		Q	Rank
South Korea	0.0139	1	**Saudi Arabia**	0.029	10
Germany	0.0215	2	**Canada**	0.0299	11
U.S.	0.022	3	**Italy**	0.0306	12
China	0.0225	4	**India**	0.0354	13
Japan	0.0242	5	**Brazil**	0.0361	14
U.K.	0.0251	6	**Türkiye**	0.037	15
France	0.0263	7	**Mexico**	0.0372	16
Russia	0.0286	8	**South Africa**	0.0376	17
Australia	0.0289	9	**Argentina**	0.0385	18
			Indonesia	0.0414	19

Analysis of Digitalization Performance via the MULTIMOORA Method

The results obtained by evaluating the MULTIMOORA method together with its three sub-models are presented in Table 4. An overall MULTIMOORA ranking was obtained by combining the outputs of Ratio System, Reference Point and Full Multiplicative Form methods using Dominance Theory.

Table 4. MULTIMOORA Sub-Systems and Final Integrated Rankings

	Ratio System Ranking	Reference Point Ranking	Full Multiplicative Ranking	MULTIMOORA
South Korea	1	1	1	1
U.S.	3	2	2	2
Germany	5	4	3	3*
China	2	6	5	4*
Japan	4	3	6	5*
U.K.	6	5	4	6
France	7	7	7	7
Canada	9	9	8	8
Australia	10	8	10	9
Italy	11	10	9	10
Brazil	12	12	12	11
India	8	14	13	12
Türkiye	14	11	14	13
Russia	15	13	11	14
South Africa	16	15	15	15
Mexico	13	19	16	16
Saudi Arabia	18	16	18	17
Argentina	17	17	19	18
Indonesia	19	18	17	19

**: Countries have circular ties according to Dominance Theory.*

The occurrence of identical rankings for certain countries (Germany, China and Japan, all ranked 3rd) stems from the integration of its three underlying sub-models of MULTIMOORA. Because this method synthesizes these distinct models based on Dominance Theory, it may yield tied ranks when none of the sub-model establishes a definitive superiority over the others. In such cases of circular ties, the final order is determined by evaluating the cumulative rank sums to ensure absolute transitivity. Accordingly Germany (sum=12) is found to have a superiority over China and Japan (both sum=13). These two countries are then evaluated again with dominance, China is found to perform better than Japan.

The comparison of the rankings obtained from MAIRCA and MULTIMOORA used in this study is presented in Table 5. Overall, the rankings produced by MAIRCA and MULTIMOORA show high level of consistency, although some differences can be observed for specific countries. Both methods yield similar results in terms of best and worst performing countries. South Korea ranks first in both methods, while Germany and United States exchange the second and third positions. In addition, the United States, Germany, China, Japan, the U.K., and France are among the top ranked countries in both methods. Similarly, Argentina and Indonesia occupy similar positions among lowest ranked countries.

Table 5. Comparative Ranking Results of MAIRCA and MULTIMOORA Methods

	MULTIMOORA	**MAIRCA**
Argentina	18	18
Australia	9	9
Brazil	11	14
Canada	8	11
China	4	4
France	7	7
Germany	3	2
India	12	13
Indonesia	19	19
Italy	10	12
Japan	5	5
Mexico	16	16
Russia	14	8
Saudi Arabia	17	10
South Africa	15	17
South Korea	1	1
Türkiye	13	15
U.K.	6	6
U.S.	2	3

The largest ranking variations were observed for Russia and Saudi Arabia, which ranked 8th and 10th in MAIRCA, but dropped to 14th and 17th in MULTIMOORA, respectively. There found to be minor position shifts for countries such as Türkiye, which ranks 15th in MAIRCA and 13th in MULTIMOORA, and Brazil which ranks 14th and 11th, respectively. These variations may be attributed to the mathematical differences in the way the two methods handle criterion variations.

In order to formally test the statistical difference and agreement between these rankings, two rank correlation analyses were conducted. The Spearman's rank correlation, which evaluates association between the ranks, and Kendall's Tau-b, which accounts for concordant and discordant pairs, were both calculated.

The analysis revealed a strong positive relationship between the results of MAIRCA and MULTIMOORA. Spearman coefficient (ρ=0.896) and Kendall's Tau-b coefficient (τ_b=.801) were both statistically significant ($p<.001$). These findings indicate that two methods produce consistent results and cross-validate each other. The high level of statistical agreement between the two methods suggests that the resulting country rankings are relatively robust and independent to the choice of the MCDM method.

CONCLUSION

The main objective of this study is to examine the digital transformation performance of the G20 countries, which constitute the majority of global trade and GDP and shape the world both economically and politically within rapidly digitizing new world system. In this context, the digital transformation performances of 19 G20 member countries were evaluated using ten indicators: eight obtained from World Bank's World Development Indicators (WDI) database, one from the National Cyber Security Index (NSCI) and one from the World Population Review. The indicators utilized to measure digital performance include Individuals using the Internet, Secure Internet servers, Mobile cellular subscriptions, fixed broadband subscriptions, ICT goods exports, High technology exports, R&D expenditure, ICT service export, National cyber security Index, Average cost of broadband. These indicators can be categorized under four main dimensions as infrastructure, economy & trade, innovation & security and accessibility.

In the first stage of the study, the CRITIC method was employed to objectively determine the weights and relative importance of the ten selected criteria. Subsequently, considering these criteria weights, the digital transformation performance of the G20 countries were analyzed using the MAIRCA and MULTIMOORA methods.

The empirical findings reveal that the criteria weights do not vary significantly, which can be attributed to the mathematical structure of the CRITIC method. Countries yielded consistent rankings in both performance evaluation methods. Countries that stand out with technology in both the literature and real world application achieved similar high scores in this study. Accordingly, South Korea emerged as the top performing country in both the MAIRCA and MULTIMOORA rankings. Except for Germany and the U.S. swapping the 2nd and 3rd positions depending on the method, the top seven countries remained identical, with China, Japan, the U.K., and France identified as other high performing countries. Conversely, countries whose digitalization performance remains relatively open to development compared to other G20 members, such as Argentina and Indonesia, yielded strong alignment across both methods.

Leading countries at the top of the ranking, such as South Korea, the U.S., Germany, China, and Japan, effectively driving digital transformation compared to other G20 nations, dominate the market with high values in R&D expenditure (South Korea at 5.21%, U.S. at 3.59%), high technology exports (South Korea at 36%, China at 26%), and ICT goods exports (South Korea at 27.7%, China at 22.6%). Furthermore, a robust infrastructure and security capacity represent critical factors that cannot be ignored. Regarding secure internet servers, the U.S. (196,554) and Germany (152,114) lead the ranking, while Germany (90.83%) and Japan (82.50%) secure digital ecosystems with relatively high cybersecurity index scores.

An analysis of countries needing improvement indicates that Argentina's disproportionately high average cost of broadband ($149.12) serves as a major barrier to its digitalization process, alongside R&D expenditure. Similarly, Indonesia has one of the lowest R&D expenditure levels (0.28%) among G20 countries, together with a low national cyber security index score (47.50%) and fixed broadband subscriptions (4.82).

Türkiye is ranked 13th in MULTIMOORA and 15th in MAIRCA models. Some of its indicators are around G20 median values, such as national cyber security index (71.67%), individuals using the internet (87%), and average cost of broadband ($43.02). Türkiye can strengthen its digitalization capacity and achieve higher positions in the rankings by focusing on ICT goods exports (0.7%). Policy efforts can prioritize high value added production through techno parks and R&D centers instead of assembly based or medium-tech manufacturing. Even though R&D expenditure rate (1.32%) is relatively promising, further focus in this area is required to achieve higher ranks.

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