▪ Journal of Competitiveness

Comparative analysis of economic development indicators among South American countries based on a novel MCDM model

Hossein Komasi[1], Alireza Nemati[2], Sarfaraz Hashemkhani Zolfani[1,3*], Nigel L Williams[3], Jonas Šaparauskas[4]

Abstract
Given the significance of economic development, this paper undertakes a comparative assessment and analysis of the level of economic development among South American countries. Initially, a modified ITARA method was applied to determine criteria weights through the examination of real data. Subsequently, a modified version of AROMAN was introduced and utilized in conjunction with the RAM method to prioritize the nine countries based on eight economic development indicators. The findings from the modified AROMAN method indicate that Brazil ranks first among the nine studied countries in South America in terms of economic development indicators, while Argentina occupies the last position (ninth). The results obtained from the RAM method for assessing the economic development level of the 9 South American countries based on the eight examined indicators exactly align with the findings calculated from the modified AROMAN method. The RIV method has been used to validate and confirm the findings obtained from the modified AROMAN and RAM methods. The results obtained from the RIV method are consistent with those of the modified AROMAN and RAM methods. Therefore, the findings exhibit a high level of validity and reliability. The research results indicate that economic development among South American countries is not uniform.

Keywords: *Comparative Analysis, Economic Development Indicators, Multiple Criteria Decision Making (MCDM), Modified Indifference Threshold-based Attribute Ratio Analysis (ITARA), Modified Alternative Ranking Order Method Accounting Two-Step Normalization (AROMAN), Root Assessment Method (RAM)*

JEL Classification: O11, O21, P51

Article history: Received: April 2024; Accepted: August 2024; Published: September 2024

1 INTRODUCTION:

Development encompasses various dimensions, e.g., economic, social, cultural, and environmental. The development of each of these dimensions significantly influences the development of other dimensions. As one of the fundamental concepts in economics, economic development holds special importance due to its profound effects on various aspects of people's lives.

Economic development, owing to its effects on increasing national income and consequently individual incomes, leads to the improvement of quality of life, enhanced employment opportunities, access to healthcare and educational services, and overall enhancement of the social well-being of individuals (Song et al., 2023; Erdin & Ozkaya, 2020). Economic development can serve as a solution for the development of marginalized regions and the reduction of poverty (Gao & Hao, 2023). It leads to increased investment in critical infrastructure such as roads, airports, ports, and essential energy infrastructure like electricity

and gas. Consequently, it enhances nations' capabilities and competitiveness. This competitiveness can manifest in various dimensions, including economic, social, environmental, and even security (Komasi et al., 2022). Both natural and human factors influence economic development. However, the depletion of natural resources has a compounded impact on economic development (Huang & He, 2023).

Economic development is recognized as one of the primary goals of sustainable development. In accordance with the definition of sustainable development, which emphasizes meeting the needs of the current generation without compromising the needs of future generations, economic development should also embody sustainability and ensure the economic security of nations (Dong et al., 2023). Economic development in South American countries is a highly significant and complex subject influenced by multiple factors, including economic policies, natural resources, and international issues.

South American economic development can be compared to that of European, Asian, and North American nations, making it an interesting and difficult subject. The E.U.'s economic growth has improved significantly as a result of the creation of a common market and the expansion of sophisticated industries. By advancing industry and technology, these nations have become more knowledge-based economies and improved the well-being of their societies (Bazhan & Pishchik, 2023).

On the other hand, industrial development and export-oriented policies have allowed Asian nations like China, Japan, and South Korea to achieve notable economic revolutions. These countries have successfully grown exports and drawn investments by concentrating on the manufacture of cutting-edge goods and cutting-edge technology (Gao et al., 2024; Kim, 2023). The United States is a prominent example, as it has grown to be one of the largest economies in the world by emphasizing innovation, entrepreneurship, and investment in developing markets. Different approaches and policies for economic development may be used in each of these regions due to cultural, social, and historical distinctions between South American countries and these regions (Hu, 2023; Nebozhenko, 2023).

Extensive studies have been conducted on the significance of economic development in South American countries and the potential impacts that economic development can exert on other dimensions of development, such as social and environmental aspects (Cerda-Suarez et al., 2023; Singh et al., 2024; Acevedo-Ramos et al., 2023; Maffini & Gonzalez, 2023). However, there is a notable absence of in-depth research on the comparative analysis of South American countries among themselves and the positioning of each country relative to others within the region.

The identification of countries' positions in terms of economic development compared to other nations contributes to clarifying their competitive standings. Consequently, by becoming aware of the strengths, weaknesses, opportunities, and threats to their economic development, South American countries can not only enhance their understanding of their own economic landscape but also engage in more targeted political and economic exchanges with regional counterparts. This approach enables them to strategically align their economic development efforts and collaborations with neighboring countries in South America.

The current study attempts to first determine the variables affecting economic development. It compares South American nations according to their degree of economic growth in the second phase. The application of a novel MCDM model is an important part of this study. By doing so,

it informs countries within South America about their economic development positions relative to others and provides a blueprint for countries with advanced economic development to contribute to the long-term improvement of economic development in less developed nations. Therefore, using a novel hybrid MCDM Model, we intend to conduct a more in-depth analysis of this topic to offer effective recommendations for accelerating the economic development process in the region. As an advanced study in economic development and multiple-criteria decision-making, this research can provide valuable insights to policymakers, researchers, and stakeholders in this domain. It can contribute to the economic progress of South American countries and aid in advancing economic development in the region.

2 THEORETICAL BACKGROUND:

In general, economic development refers to the policies, programs, or activities used to achieve improvements in the economic conditions and quality of life within a society (He, 2023). Although some influential factors in economic development, such as the impact of policies on economic development, have not been fully understood, and the existing literature in this field yields conflicting results (Li et al., 2023), economic development, in broad terms, encompasses various dimensions of socio-economic changes along with enhancements in production capacities, physical infrastructure, innovation, technical aspects, and technology (Wang et al., 2023a).

Numerous economic, social, and environmental issues have arisen worldwide, underscoring the necessity for sustainability across all economic, social, and environmental dimensions (Rahman, 2023). Economic development is one of the essential components of sustainable development. It is impossible to separate the concepts of sustainable development and sustainable economic development, as various studies have examined the impacts of natural and human factors on economic development (Yu et al., 2023; Li & Wu, 2023). Different studies have explored economic development from various perspectives and using diverse methodologies.

Dong and Shi (2023) have examined the mutual impact between natural resource efficiency and economic development in China over two decades, concluding that a positive correlation exists between economic growth and resource efficiency. Moreover, they found a positive correlation between increased natural resource utilization and economic growth.

A study by Zhang et al. (2023) on economic growth, natural resource utilization, and sustainability goals, emphasizes the need for resource management for sustainable economic development and environmental conservation.

Ze et al. (2023) have explored the relationship between economic development, financial development, natural resource utilization, trade openness, and greenhouse gas emissions in pursuit of sustainable development. Their findings identify the positive impact of natural resource utilization and the negative impact of financial development on greenhouse gas emissions.

Puska et al. (2023) have proposed a new method for ranking the knowledge economies of European Union (E.U.) countries. The research results provide valuable resources for economic development and policymaking decision-making.

Various studies have examined different economic indicators, and in this present study, 9 indicators related to economic development have been selected based on academic research and the World Bank's focus.

Shu and Xiong (2018) conducted a study in which they utilized the gini coefficient to assess regional development balance in China. They emphasized that in evaluating balanced regional development, one must consider economic and environmental benefits and pay special attention to regional disparities. Hence, the significance of the two indicators, GNI per capita, atlas method (current US$), and terrestrial and marine protected areas (% of the total territorial area), used in the present research, becomes evident.

Urban population growth has been accepted as a development indicator in various studies (Bui Minh et al., 2023; Song et al., 2021; Li et al., 2020; Wang et al., 2023b). However, in today's context of increasing urbanization and the complexities of urban management, it is essential not to focus solely on the urban population growth rate as a development indicator. Instead, factors such as citizens' quality of life, infrastructure, and access to services should also be considered alongside the urban population growth rate.

Gross domestic product (GDP) is one of the most critical factors in the economy, playing a vital role in economic development. Among the reasons that have made this indicator important is that by measuring GDP, one can determine the extent to which a country has utilized its produced goods and services within a specific time frame. Furthermore, an increase or decrease in GDP growth rate can either contribute to the well-being of the population or lead to economic recession. Therefore, in the present study, this indicator has been examined from various angles among South American countries (inflation, GDP deflator (annual %); GDP (current US$); merchandise trade (% of GDP); GDP growth (annual %)), as emphasized by Mbassi et al. (2023) and Hoekman and Shingal (2024).

The personal remittances received (current US$) indicator also plays a crucial role in the economic development of countries. This indicator can contribute to maintaining the exchange rate stability of countries and reducing unstable trade relations, ultimately reducing poverty, particularly in developing countries. Some studies have also emphasized the importance of this indicator in economic development (Basu et al., 2022; Li et al., 2012).

The foreign direct investment, net inflows (BoP, current US$) indicator measures the net amount of foreign investment in a country within a specific period, typically one year. Foreign direct investment can serve various purposes, such as expanding existing trade, establishing new infrastructure, and ultimately improving employment and social welfare in countries. Some studies have also indirectly examined the importance and role of the level of foreign investment in the development of countries (Djokoto & Wongnaa, 2023; Yoo & Woo, 2023).

Systematically assessed the MCDM method to solve economic development problems. Following this, these studies that have used the multiple criteria decision making (MCDM) model methodology are introduced in Table 1.

Tab. 1– Some of the studies that have used the multiple criteria decision making (MCDM) model

Author	Year	MCDM methods	Cause of implementation
Liu et al.	2018	DEMATEL	Evaluation of economic zones

		DANP	
Batur Sir & Caliskan	2019	Fuzzy-PROMETHEE and Fuzzy-MULTIMOORA	Evaluation of development regions for the purpose of allocating funds
Luczak & Just	2020	TOPSIS Mean Excess Function (MEF)	To assess the economic development level of units at different government levels
Yi et al.	2021	Based on the grey relational analysis	Appropriate measurement of city sustainability
Tavana et al.	2022	Best-Worst method (BWM) weighted influence non-linear gauge system (WINGS) the technique of order preference similarity to the ideal solution (TOPSIS)	A private sustainable partner selection model for regional economic development
Pamucar et al.	2023	LMAW (logarithm methodology of additive weights) and MARCOS (measurement of Alternatives and Ranking according to the Compromise Solution)	For the development of smart mobility systems
Zhao et al.	2023	Fuzzy-Delphi anti-entropy weight (AEW) best-worst method (BWM)	Evaluating DE development of 31 provincial-level regions in China ranging from 2015 to 2020
Brodny & Tutak	2023	CODAS and CoCoSo methods and the Laplace criterion Shannon Entropy and CRITIC methods and the aforementioned criterion.	Assessing the level of sustainability in building stable infrastructure, fostering innovation, and promoting sustainable industrialization
Darmian et al.	2023	hybrid multi-criteria decision-making model based on fuzzy SWARA and fuzzy EDAS technique	To assess the current status of businesses operating in high-priority agricultural processing sectors

3 RESEARCH OBJECTIVE, METHODOLOGY AND DATA:

3.1. Research Gap

Numerous studies have delved into various dimensions of development in South American countries. However, significant research gaps persist, with one such gap being the limited exploration of the relative economic positions of these countries concerning each other. By identifying these positions, countries can gain insight into their own standings and work towards reducing weaknesses and improving their economic positions by emulating countries with superior economic performance. This study employs innovative decision-making methods to conduct a comparative analysis of the most critical economic development indicators among South American countries. Therefore, the innovation in this research extends beyond the methodology employed to encompass the selection of economic indicators for comparing South American nations.

3.2. Study area

The total area of South America is approximately 17,840,000 square kilometers (6,890,000 square miles), and more than 422 million people lived there in 2021. South America is the fourth-largest continent by area and the fifth-most populous, after Asia, Africa, Europe, and North America.

The following analyzes the provided data on the population and annual growth rate of South American countries: Bolivia, with an annual growth rate of 1.2%, exhibits one of the highest population growth rates in the region. Ecuador and Paraguay, with an annual growth rate of 1.1%, rank second in population growth. Uruguay, with an annual growth rate of -0.1%, is the only country with a negative growth rate. Brazil, with its large population and a growth rate of 0.5%, is one of the most populous countries in the world. Colombia and Argentina, with annual growth rates of 0.7% and 0.9% respectively, also have significant populations. These data reveal significant differences in population growth rates among Latin American countries, which can have notable impacts on their economic and social development Table 2.

Tab. 2– Development Indicators in South America

Indicators / Countries	Population	Population growth (annual %)	Urban population growth
Brazil	215313498	0.5	0.7
Colombia	51874024.0	0.7	1.1
Argentina	46234830.0	0.9	1.1
Peru	34049588.0	1.0	1.3
Chile	19603733.0	0.6	0.7
Ecuador	18001000.0	1.1	1.5
Bolivia	12224110.0	1.2	1.7
Paraguay	6780744.0	1.1	1.7
Uruguay	3422794.0	-0.1	0.0

Venezuela has been excluded from the comparison process due to the unavailability of data.
Reference: World Bank, 2022

3.3. Development indicators

Economic development indicators reflect a country's economic status and performance, aiding in the analysis and comparison of various economies worldwide. These indicators are among the critical factors used in policymaking and economic research. In general, economic development encompasses a multitude of indices. This study examined eight indicators for South American countries in 2022 based on World Bank data. See Table 3.

Tab. 3 – Development Indicators in South America

Indicators / Countries	Code	GNI per capita, Atlas method (current US$)	Terrestrial and marine protected areas (% of total territorial area)	GDP (current US$)	GDP growth (annual %)	Inflation, GDP deflator (annual %)	Merchandise trade (% of GDP)	Personal remittances received (current US$)	Foreign direct investment, net inflows (BoP, current US$)
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Brazil	A_1	8140.0	29.3	1920095560995.1	2.9	8.3	32.6	4969231432.8	91502.10
Colombia	A_2	6510.0	16.7	343939445259.5	7.5	14.2	39.1	9440138236.9	16868.75
Argentina	A_3	11620.0	9.6	632770284408.5	5.2	69.7	26.9	1258499654.2	15408.35
Peru	A_4	6770.0	16.8	242631549613.3	2.7	4.4	49.3	3707556166.5	10848.49
Chile	A_5	15360.0	37.9	301025249437.9	2.4	6.6	67.1	69392670.4	20864.90
Ecuador	A_6	6310.0	20.0	115049476000.0	2.9	5.3	57.1	4747980446.4	829.04
Bolivia	A_7	3450.0	30.9	43068885672.9	3.1	3.4	62.0	1458776647.5	-11.93
Paraguay	A_8	5920.0	14.3	41722295362.1	0.1	7.6	61.9	592286768.1	473.69
Uruguay	A_9	18030.0	2.4	71177146197.5	4.9	4.4	34.0	124690721.2	9403.62

Venezuela has been excluded from the comparison process due to the unavailability of data.
Reference: World Bank, 2022, Retrieval date (17 November 2023)

3.4. Methodology

This section introduces a novel hybrid multi-criteria decision-making approach to evaluate the economic development indicators among nine South American countries. First, modified ITARA has been implemented to acquire the criteria weights according to real data examination. In the second step, a modified version of AROMAN is introduced and used along with the RAM method to prioritize the nine countries according to eight economic development indicators. Figure 1 shows the methodology procedure.

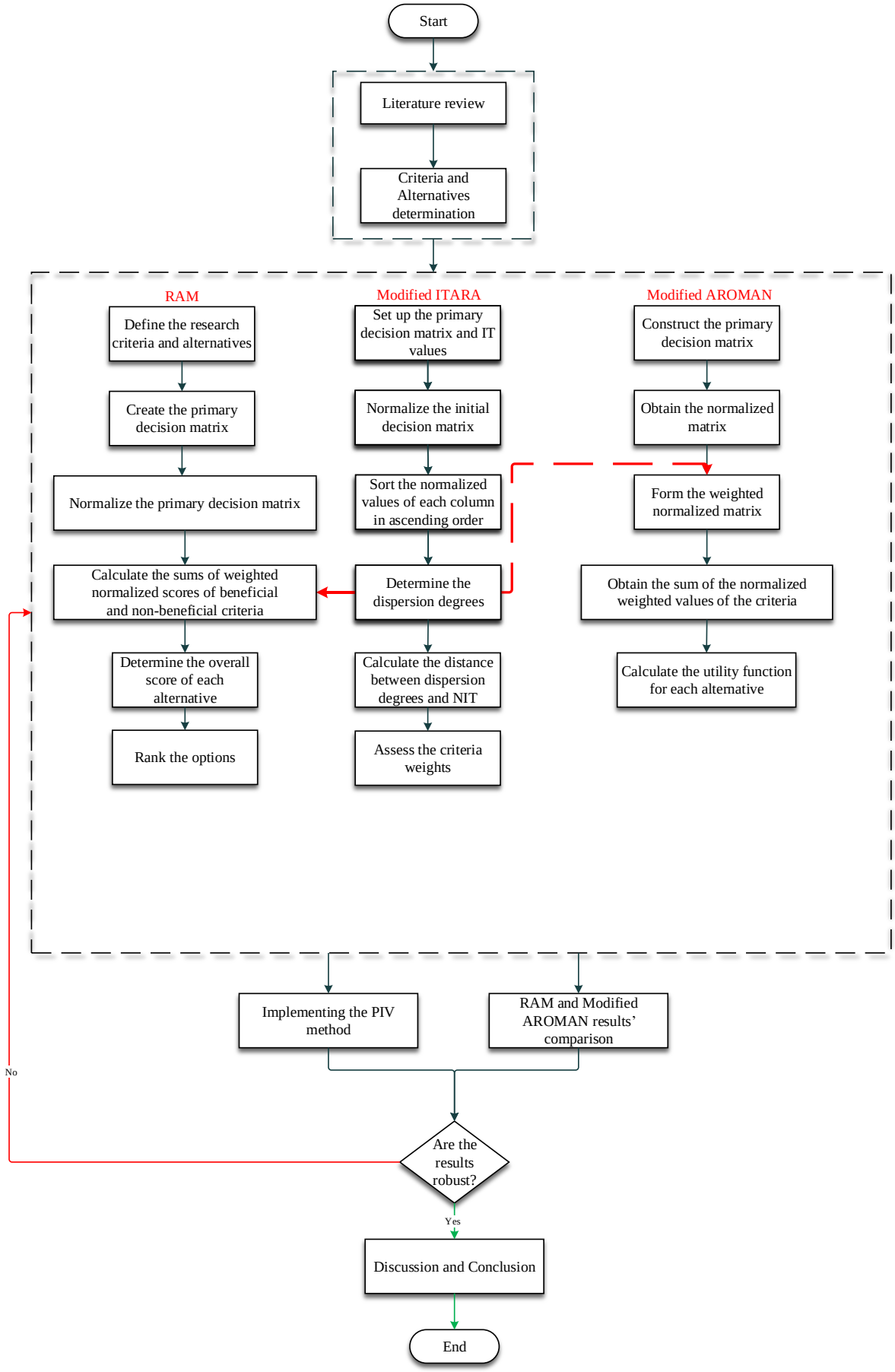


Fig. 1– Flow diagram of introduced MCDM model

3.5. Modified ITARA

As a resolution to murkiness in expert information on criteria, Hatefi (2019) proposed an indifference threshold-based attribute ratio analysis (ITARA). Criteria with near-identical attributed values receive smaller weightings in ITARA. This technique, however, does not consider the distance between options and their highest ratings, nor does it analyze their dispersion. Therefore, Lo et al. (2021; see also Komasi et al., 2024) introduced a modified version of ITARA that contains aspiration level and the increase of the coefficient of variation to overcome the mentioned imperfections. Modified ITARA steps are as follows:

Step 1. Set up the initial decision matrix and determine the indifference threshold values (IT_j).

Consider the problem that includes N ($c_n, n = 1, 2, \dots, N$) criteria and M ($a_m, m = 1, 2, \dots, M$) alternative elements and a_{ij} represent the performance of the ith alternatives under jth criterion. Then, each criterion is assigned an indifference threshold to make the evaluation more efficient ($IT_j, j \in n = \{1, 2, \dots, N\}$).

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \\ a_{aspire,1} & a_{aspire,2} & \cdots & a_{aspire,n} \end{bmatrix} a_{ij}, i = 1,2, \dots, m;\ j = 1,2, \dots, n \quad (1)$$

It is suggested that indifference threshold values should be less than the standard deviation of criteria ($\sigma_n = \sqrt{1/N \sum_{n=1}^{N} (a_{ij} - \overline{a_n})^2}$).

Step 2. Normalize the initial decision matrix and indifference threshold values (IT_j) .

Equations (2) and (3) are implemented to obtain the normalized values.

$$n_{ij} = \frac{a_{ij}}{\sum_{i=1}^{M} a_{ij}} \quad (2)$$

$$NIT_j = \frac{IT_j}{\sum_{i=1}^{M} a_{ij}} \quad (3)$$

Step 3. Sorting the normalized values

The elements of each column are sorted in ascending order using equation (4).

$$\beta_{ij} \leq \beta_{i+1,j}, \forall i \in \{1, \dots, m-1\} \quad (4)$$

Step 4. Evaluate the ordered distances

Ordered distances between sorted values are calculated using the following equation:

$$\gamma_{ij} = \beta_{i+1,j} - \beta_{ij}, \forall i \in \{1, \dots, m-1\} \quad (5)$$

Step 5. Calculate the distance between γ_{ij} and NIT_j.

Considerable distances are evaluated by implementing equation (6).

$$\delta_{ij} = \begin{cases} \gamma_{ij} - NIT_j \; for \; \gamma_{ij} > NIT_j \\ 0 \; for \; \gamma_{ij} \leq NIT_j \end{cases} \quad (6)$$

Step 6. Evaluate the criteria weights.

Criteria weights are assessed by utilizing equation (7) where $\alpha = 0.6$ according to decision makers in this research.

$$w_j = \alpha \times \left(\frac{v_j}{\sum_{j=1}^{N} v_j}\right) + (1 - \alpha) \times \left(\frac{cv_j}{\sum_{j=1}^{N} cv_j}\right), j = 1, 2, \ldots, N \quad (7)$$

Where $v_j = \left(\sum_{j=1}^{N} \delta_{ij}^2\right)^{\frac{1}{2}}$, $cv_j = \frac{\sigma_j}{\bar{a}_j}$, $\sigma_j = \sqrt{1/N \sum_{j=1}^{N} (a_{ij} - \bar{a}_j)^2}$) and $\bar{a}_n = \frac{\sum_{i=1}^{M} a_{ij}}{M}$.

3.6. Modified AROMAN

This research benefits from a modified version of the alternative ranking order method accounting for two-step normalization (AROMAN). This method was originally developed by Bošković et al. (2023). The method can be described through the six steps:

Step 1. Define the initial input data decision-making matrix.

Formulating the initial input data decision-making matrix is essential. The input data regarding the alternatives and criteria are mostly collected in advance. In that sense, let us suppose we have a decision matrix *X* with the input datax_{11},…, x_{2j}, …, x_{mn}, Eq. (8):

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{21} & \cdots & x_{2j} & \cdots & x_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}, i = 1,2, \ldots, m, j = 1,2, \ldots, \text{n}. \quad (8)$$

Step 2. Normalize the primary data.

The second step of the AROMAN method is to normalize the input data. In other words, the input data should be restructured in intervals between 0 and 1. Instead of integrating two types of normalization techniques, which may be difficult to implement in big data sets, sum-based linear normalization has been utilized:

$$u_{ij}^{norm} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}; \; i = 1, 2, \ldots, m, j = 1, 2, \ldots, n. \quad (9)$$

Step 3. Multiply the aggregated averaged normalized decision-making matrix with the criteria weights to obtain a weighted DM matrix.

$$\widehat{u_{ij}} = W_{ij} \cdot u_{ij}^{norm}; \; i = 1,2, \ldots, m; \; j = 1, 2, \ldots, n. \quad (10)$$

Step 4. Summarize the normalized weighted values of the criteria type min (K_i) and the normalized weighted values of the max type (O_i).

This can be calculated by applying Eq. (6) and Eq. (7):

$$K_i=\sum_{j=1}^{n} \widehat{u_{ij}}^{(min)}; i = 1,2,\dots,m;\ j = 1,2,\dots,n; \quad (11)$$

$$O_i=\sum_{j=1}^{n} \widehat{u_{ij}}^{(max)}; i = 1,2,\dots,m;\ j = 1,2,\dots,n. \quad (12)$$

Step 5. Raise the obtained sum of O_i and K_i values to the degree of λ.

$$\hat{K_i} = K_i^{\lambda} = \left(\sum_{j=1}^{n} \widehat{u_{ij}}^{(min)}\right)^{\lambda}; \quad (13)$$

$$\hat{O_i} = O_i^{1-\lambda} = \left(\sum_{j=1}^{n} \widehat{u_{ij}}^{(max)}\right)^{1-\lambda}. \quad (14)$$

λ denotes the coefficient degree of the criterion type. In our case, λ is 0.5. However, variations of the parameter λ when considering the criteria type are used in the sensitivity analysis.

Step 6. Calculate the difference between the values $K_i\hat{}$ and $O_i\hat{}$ and finally, rank alternatives (T_i).

$$T_i = e^{(\hat{O_i}-\hat{K_i})} \quad (15)$$

Where: T_i denotes the final rank.

3.7. RAM

Root assessment method (RAM) was introduced by Sotoudeh-Anvari (2023) to provide a different compensation degree between beneficial and non-beneficial criteria, which is rare in existing MCDM methods. As one of the advantages of RAM, the ranking result is not influenced by additional parameters, beneficial and non-beneficial criteria can be simultaneously considered without any transformation, and pairwise comparisons are not used. The steps of the RAM method are as follows:

Step 1. Set up the initial decision matrix.

Consider a problem that contains N ($c_n, n = 1,2,\dots,N$) criteria and M ($a_m, m = 1,2,\dots,M$) alternatives and a_{ij} represent the performance of the ith alternatives under jth criterion. The primary decision matrix of A is as follows:

$$\mathrm{A} = \begin{array}{c} \\ \mathrm{A}_1 \\ \mathrm{A}_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \end{array} a_{ij}, i = 1,2,\dots,m;\ j = 1,2,\dots,n \quad (16)$$

Step 2. Normalize the primary decision matrix.

The normalization is done using sum-based normalization formula.

$$r_{ij}=\frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}};\ i=1,2,\dots,m, j=1,2,\dots,n. \quad (17)$$

Step 3. Obtain the weighted normalized decision matrix.

The weighted normalized decision matrix is calculated using the following equation:

$$y_{ij}=r_{ij}\times w_j\ ;\ i=1,2,\dots,m, j=1,2,\dots,n. \quad (18)$$

Step 4. Calculate the sums of weighted normalized scores.

The sums of weighted normalized scores of beneficial and non-beneficial criteria of *i*th alternative is evaluated by utilizing the following equations:

$$S_{+i}=\sum_{j=1}^{n} y_{+ij} \quad (19)$$

$$S_{-i}=\sum_{j=1}^{n} y_{-ij} \quad (20)$$

Step 5. Determine the overall score of each alternative.

The overall score of each alternative is obtained using the following aggregating function:

$$RI_i=\sqrt[S_{-i}+2]{2+S_{+i}} \quad (21)$$

Step 6. Rank the options according to RI_i values.

A larger RI_i implies the higher the priority of A_i. On the other words, the better option has a larger value of RI_i.

4 RESULTS AND DISCUSSION:

This section illustrates the outcomes of our novel hybrid MCDM model. In the first step, the criteria weights are calculated using modified ITARA, and then nine South American countries are assessed using RAM and modified AROMAN.

4.1 Modified ITARA results

This subsection assesses eight economic development indicators to determine their weights according to actual data evaluation. Table 4 shows the primary decision matrix along with indifference threshold values.

Tab. 4 – Primary decision matrix for modified ITARA

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	8140.00	29.30	1920095560995.10	2.90	8.30	32.60	4969231432.80	91502.10
A_2	6510.00	16.70	343939445259.50	7.50	14.20	39.10	9440138236.90	16868.75
A_3	11620.00	9.60	632770284408.50	5.20	69.70	26.90	1258499654.20	15408.35
A_4	6770.00	16.80	242631549613.30	2.70	4.40	49.30	3707556166.50	10848.49
A_5	15360.00	37.90	301025249437.90	2.40	6.60	67.10	69392670.40	20864.90

A_6	6310.00	20.00	115049476000.00	2.90	5.30	57.10	4747980446.40	829.04
A_7	3450.00	30.90	43068885672.90	3.10	3.40	62.00	1458776647.50	-11.93
A_8	5920.00	14.30	41722295362.10	0.10	7.60	61.90	592286768.10	473.69
A_9	18030.00	2.40	71177146197.50	4.90	4.40	34.00	124690721.20	9403.62
Average Value	9123.33	19.77	412386654771.87	3.52	13.77	47.78	2929839193.78	18465.22
Standard deviation	4849.69	11.16	596477082277.95	2.10	21.22	14.98	3100930507.93	28434.79
IT	0.60	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Sum	82110.00	177.90	3711479892946.80	31.70	123.90	430.00	26368552744.00	166187.01

Moreover, Table 5 illustrates the final results of modified ITARA implementation.

Tab. 5 – Modified ITARA final results

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
V_j	0.421	0.433	0.711	0.417	0.720	0.297	0.596	0.742
W_j	0.086	0.090	0.175	0.089	0.181	0.058	0.138	0.184

4.2 Modified AROMAN results

In order to assess nine South American countries according to eight economic development indicators, a modified AROMAN is implemented. Table 6 shows modified AROMAN results.

Tab. 6 – Modified AROMAN results

	K_i	O_i	$K_i\hat{}$	$O_i\hat{}$	$K_i\hat{} - O_i\hat{}$	T_i	Rank
Brazil	0.012	0.253	0.110	0.503	0.393	1.482	1
Colombia	0.021	0.126	0.144	0.355	0.211	1.235	2
Argentina	0.102	0.089	0.319	0.298	-0.021	0.979	9
Peru	0.006	0.073	0.080	0.269	0.189	1.208	4
Chile	0.010	0.089	0.098	0.298	0.199	1.221	3
Ecuador	0.008	0.064	0.088	0.252	0.164	1.179	5
Bolivia	0.005	0.046	0.070	0.214	0.144	1.155	7
Paraguay	0.011	0.028	0.105	0.166	0.061	1.063	8
Uruguay	0.006	0.053	0.080	0.230	0.150	1.162	6

4.3 RAM results

This subsection includes the utilization of the RAM method to assess nine South American countries according to eight economic development indicators of research. Table 7 shows RAM results.

Tab. 7– RAM result

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	S_{i+}	S_{i-}	T_i	Rank
Brazil	0.009	0.015	0.090	0.008	0.012	0.004	0.026	0.101	0.253	0.012	1.497	1
Colombia	0.007	0.008	0.016	0.021	0.021	0.005	0.049	0.019	0.126	0.021	1.452	2
Argentina	0.012	0.005	0.030	0.015	0.102	0.004	0.007	0.017	0.089	0.102	1.420	9
Peru	0.007	0.008	0.011	0.008	0.006	0.007	0.019	0.012	0.073	0.006	1.438	4
Chile	0.016	0.019	0.014	0.007	0.010	0.009	0.000	0.023	0.089	0.010	1.443	3
Ecuador	0.007	0.010	0.005	0.008	0.008	0.008	0.025	0.001	0.064	0.008	1.435	5
Bolivia	0.004	0.016	0.002	0.009	0.005	0.008	0.008	0.000	0.046	0.005	1.429	7
Paraguay	0.006	0.007	0.002	0.000	0.011	0.008	0.003	0.001	0.028	0.011	1.421	8
Uruguay	0.019	0.001	0.003	0.014	0.006	0.005	0.001	0.010	0.053	0.006	1.431	6

4.4 Sensitivity analysis

The robustness of the research methodology will be evaluated through two experiments. For modified AROMAN and RAM outcomes, the Pearson correlation coefficient test is implemented in the first step. Then, the PIV method is applied to assess the final results from proximity indexed value for minimizing rank reversals perspective.

Results comparison

We constructed our research methodology based on two newly developed MCDM methods: modified AROMAN and RAM.

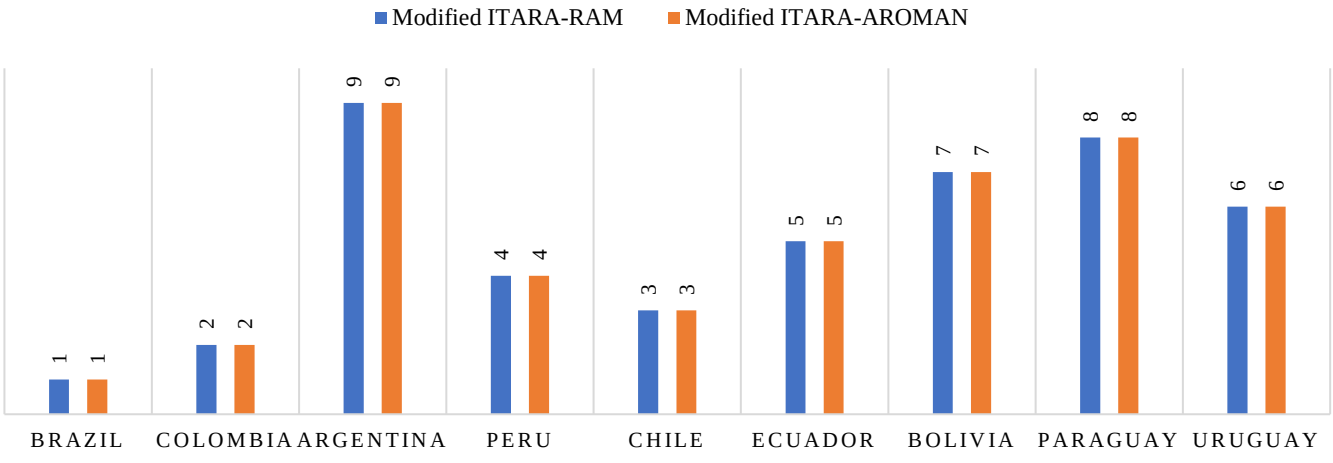


Fig. 2 – RAM and modified AROMAN results. South American countries from an economic perspective.

Additionally, RAM and modified Pearson correlation coefficients analyze AROMAN results. The outcomes are shown in Table 8.

Tab. 8 – Pearson correlation coefficient test outcome

	Modified AROMAN	RAM
Modified AROMAN	1	1
RAM	1	1

This test indicates a robust experimental design and a high degree of correlation between the modified AROMAN and RAM outcomes. For this reason, the results obtained are highly trustworthy. Under these conditions, policymakers and planners can make more confident plans for developing national economies. Further confidence can be provided by using additional techniques or by analyzing the results of each technique independently if the ranking nations yield differing conclusions.

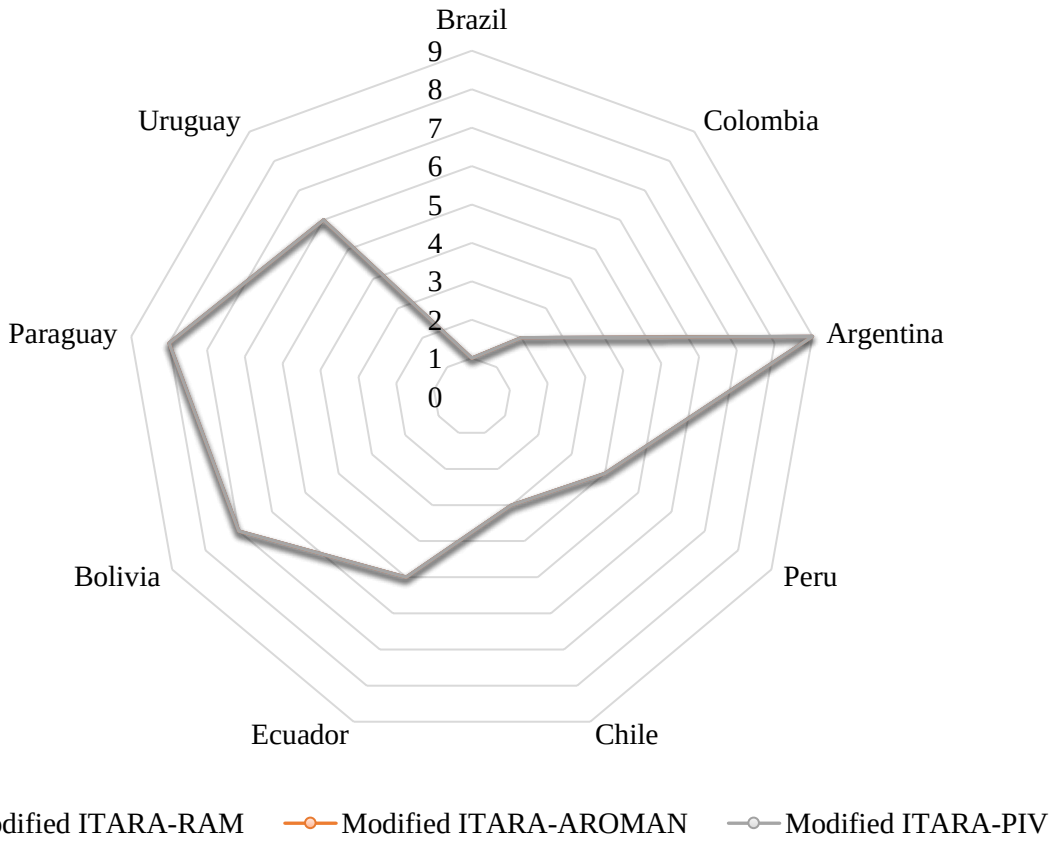
PIV implementation

PIV method was introduced in 2018 to minimize the rank reversal problem (Mufazzal & Muzakkir, 2018). Therefore, it is a strong method for results' validation. Table 9 shows PIV, RAM, and modified AROMAN outcomes.

Tab. 9 – Three MCDM techniques results

	PIV	RAM	Modified AROMAN
Brazil	1	1	1
Colombia	2	2	2
Argentina	9	9	9
Peru	4	4	4
Chile	3	3	3
Ecuador	5	5	5
Bolivia	7	7	7
Paraguay	8	8	8
Uruguay	6	6	6

Furthermore, Figure 3 shows the final results comparison of 3 MCDM methods.



The comparison indicates that research results are fully trustworthy, and that the prioritization of South American countries according to economic indicators is accurate.

4.5 Discussion

Eight crucial economic development indicators have been utilized to compare and evaluate economic development indicators among the 9 South American countries. These indicators were selected based on research literature in the field of economic development and are derived from World Bank data. Although all chosen indicators are significant and directly or indirectly impact countries' economic development (and other aspects of development such as social and environmental development), they do not share equal importance. Some indicators hold greater significance than others, and correspondingly, they play a more substantial role in the economic development of countries.

Various methods exist for weighting indicators based on their importance. Researchers choose the optimal weighting method considering factors such as the research topic, data type, and the nature of the subject's diversity. Given the research topic and data type, the Modified ITARA method has been employed to weigh the research indicators in this study.

The findings resulting from the weighting of the economic development indicators among the 9 South American countries based on the Modified ITARA method are presented in Table 5. According to the Modified ITARA method, indicator "foreign direct investment, net inflows (BoP, current US$) (C8)" with a weight of 0.184, holds the highest weight and significance among the examined economic development indicators in South American countries, securing the first position. On the other hand, the indicator "merchandise trade (% of GDP) (C6)" with

a weight of 0.058, carries the least weight and importance compared to the other investigated indicators of economic development in South American countries, positioning itself in the eighth place. The weights and significance of the other examined indicators are arranged as follows, with the indicator foreign direct investment, net inflows (BoP, current US$) (C8) having the highest weight and significance, and the indicator "merchandise trade (% of GDP) (C6)" having the least weight and importance: indicator "inflation, GDP deflator (annual %) (C5)" with a weight of 0.181 in the second position; indicator "GDP (current US$) (C3)" with a weight of 0.175 in the third position; indicator "personal remittances, received (current US$) (C7)" with a weight of 0.138 in the fourth position; indicator "terrestrial and marine protected areas (% of the total territorial area) (C2)" with a weight of 0.090 in the fifth position; indicator "GDP growth (annual %) (C4)" with a weight of 0.089 in the sixth position, and indicator "GNI per capita, Atlas method (current US$) (C1)" with a weight of 0.086 in the seventh position.

For the ranking and comparison of the economic development level among the 9 studied countries in South America, based on the obtained weights for each of the eight examined indicators, modified AROMAN and RAM methods were employed.

The findings from the modified AROMAN method indicate that Brazil has secured the first rank among the nine studied countries in South America in terms of economic development indicators. According to the data in Table (6), Brazil outperforms the average of these indicators in four indices: "terrestrial and marine protected areas (% of total territorial area) (C2)", "inflation, GDP deflator (annual %) (C5)", "personal remittances, received (current US$) (C7)" and "foreign direct investment, net inflows (BoP, current US$) (C8)".

In the remaining four indices, including "GNI per capita, atlas method (current US$) (C1), GDP (current US$) (C3), GDP growth (annual %) (C4), and merchandise trade (% of GDP) (C6)", Brazil, with a slight difference, performs below the average of these indicators in the 9 studied countries in South America. In other words, in the planning and economic development policies, Brazil has performed significantly better than other countries in South America in the four indices "terrestrial and marine protected areas (% of total territorial area) (C2), inflation, GDP deflator (annual %) (C5), personal remittances, received (current US$) (C7), and foreign direct investment, net inflows (BoP, current US$) (C8)", while its performance is notably weaker in the four indices "GNI per capita, atlas method (current US$) (C1), GDP (current US$) (C3), GDP growth (annual %) (C4) and merchandise trade (% of GDP) (C6)". Therefore, Brazilian managers and policymakers should pay special attention to planning and policymaking in economic development in those indices where their performance has been weaker. This is crucial to maintaining Brazil's leading position in economic development among the countries in South America.

Based on the modified AROMAN method findings, Argentina, in terms of the economic development indicators examined in this research, ranks last (ninth) among the nine studied countries in South America. This is noteworthy, considering that Argentina performs even higher than the average in three indices: GNI per capita, atlas method (current US$) (C1), GDP (current US$) (C3), and GDP growth (annual %) (C4)" among the 9 South American countries. In the remaining indices, terrestrial and marine protected areas (% of total territorial area) (C2), inflation, GDP deflator (annual %) (C5), merchandise trade (% of GDP) (C6), personal remittances, received (current US$) (C7) and foreign direct investment, net inflows (BoP, current US$) (C8), Argentina also performs below the average of these indicators among the 9 South American countries.

One of the most influential indicators contributing to Argentina's current position (ninth place) in terms of economic development among the 9 South American countries is the indicator "inflation, GDP deflator (annual %) (C5)". In this indicator, Argentina exhibits a significant deviation from the average of the nine countries, with a statistic of (69.7), compared to the overall average of (13.76).

The rankings of the other countries are as follows: Colombia, with two indicators performing better than the average of the nine countries, (GDP growth (annual %) C4, personal remittances, received (current US$) C7), secures the second position. Chile, with six indicators performing better than the average of the 9 countries, (GNI per capita, atlas method (current US$) C1, terrestrial and marine protected areas (% of total territorial area) C2, inflation, GDP deflator (annual %) C5, merchandise trade (% of GDP) C6, personal remittances, received (current US$) C7, foreign direct investment, net inflows (BoP, current US$) C8)", holds the third position. Peru, with three indicators performing better than the average of the 9 countries, (inflation, GDP deflator (annual %) C5, merchandise trade (% of GDP) C6, personal remittances, received (current US$) C7), is in the fourth position. Ecuador, with four indicators performing better than the average of the 9 countries, (terrestrial and marine protected areas (% of total territorial area) C2, inflation, GDP deflator (annual %) C5, merchandise trade (% of GDP) C6, personal remittances, received (current US$) C7), is in the fifth position. Uruguay, with four indicators performing better than the average of the 9 countries, (GNI per capita, atlas method (current US$) C1, GDP (current US$) C3, GDP growth (annual %) C4, inflation, GDP deflator (annual %) C5), holds the sixth position. Bolivia, with four indicators performing better than the average of the 9 countries, (terrestrial and marine protected areas (% of total territorial area) C2, GDP (current US$) C3, inflation, GDP deflator (annual %) C5, merchandise trade (% of GDP) C6), is in the seventh position. Paraguay, with four indicators performing better than the average of the 9 countries, (GDP (current US$) C3, inflation, GDP deflator (annual %) C5, merchandise trade (% of GDP) C6, personal remittances, received (current US$) C7), is in the eighth position.

The findings obtained from the RAM method for assessing the level of economic development among the 9 South American countries based on the eight examined indicators are exactly consistent with the results calculated from the modified AROMAN method table (7). In other words, according to the RAM method, Brazil is positioned first among the South American countries in terms of economic development indicators, and Argentina is in last place (ninth). The other countries also, similar to the findings obtained from the modified AROMAN method, are ranked from second to eighth accordingly.

The RIV method has been used to validate and confirm the findings obtained from the modified AROMAN and RAM methods. The results obtained from the RIV method, similar to those from the modified AROMAN and RAM methods, have demonstrated high credibility and reliability. In general, the ranking of South American countries in terms of economic development is not uniformly distributed, and some countries, such as Brazil, Colombia, and Chile, securing the first to third positions, exhibit superior performance in terms of economic development compared to other countries.

5 CONCLUSION

The economic development of countries is influenced by various natural and human factors. In this study, the economic development of nine South America countries is examined based on

eight key indicators of economic development. The results indicate that despite abundant natural and human resources, some South American countries have been unable to attain a favorable position in terms of economic development indicators among their regional counterparts.

For instance, Argentina, despite possessing high potential in certain economic development indicators such as GNI per capita, atlas method (current US$) C1, GDP growth (annual %) C4, finds itself at the bottom rank among the nine South American countries considered in terms of economic development indicators. This highlights the discrepancy between the country's potential and its actual economic development performance.

The identification of the economic development status of countries assists planners and policymakers in becoming aware of their performance in economic development. This awareness enables them to identify weaknesses and potential threats to their country's development. In turn, this knowledge empowers planners and policymakers to strategically plan and implement measures to address and mitigate these challenges, fostering a more effective and sustainable path toward economic development.

Comparing the level of economic development among the countries in South America serves as an indicator of the economic competitiveness of these nations relative to their counterparts. Through such comparisons, countries can identify their position and enhance their economic competitiveness by emulating successful models tailored to their own natural and human conditions. This process allows nations to strategically improve their economic competitiveness by learning from the successes of others within the region, considering the specific characteristics and circumstances unique to each country.

Development, in general, encompasses economic, social, and environmental aspects. Improvement in any of these dimensions can have ripple effects on the others. Awareness of the economic development status leads to identifying strengths, weaknesses, opportunities, and threats that can influence economic development. This understanding lays the foundation for further studies to assess the impacts and relationships between economic development and other developmental sectors such as social and environmental development.

In the event of negligence and a lack of effective management and precise planning for the improvement of the economic development position and ranking, not only are economic development opportunities lost, but there is also the risk of destroying these opportunities permanently. Consequently, this can lead to irreparable social and, especially, environmental repercussions. The failure to capitalize on economic development opportunities, due to inattention and inadequate planning, may result in long-lasting and adverse effects on both the social and environmental aspects of a region.

In this study, Brazil has secured the top position in economic development among the nine South American countries based on the eight indicators under examination. Brazil demonstrates a favorable status in fifty percent of the indicators compared to the average of the nine countries, and in the remaining fifty percent of the indicators, it is slightly below the average. The implication is that even though Brazil holds the top position, the absence of planning to address the specific indicators where it lags behind may potentially lead to a decline in its economic development standing in the future. This highlights the importance of strategic planning and targeted interventions to sustain and enhance economic development, even for countries that are currently leading in certain aspects.

The utilization of various methods for assessing the ranking of countries in terms of economic development contributes to confidence in the findings. In this study, two methods, modified AROMAN and RAM, were employed to compare economic development among the nine South American countries based on eight economic development indicators. Additionally, the RIV method was utilized to ensure further confidence. The results obtained from all three methods were consistent, indicating that these models are suitable for calculating the economic development of countries. This multi-method approach enhances the robustness and reliability of the assessment, providing a comprehensive understanding of the economic development landscape among the considered nations.

The findings of this study align with the research conducted by Yin et al. (2023) regarding the impact of foreign direct investment on economic development in a coherent manner. The results obtained are consistent with the findings of the study by Zhang et al. (2023) regarding the correlation between economic growth, the utilization of natural resources, and sustainable objectives. Furthermore, the present research corroborates the results of the study by Li and Huang (2023) on the complex interplay between resource availability, economic growth, and sustainable behaviors.

Research limitations:

- Limited access to statistical data for all South American countries and all indicators. The availability of more data and additional indicators would undoubtedly contribute to a more comprehensive study.
- Constraints in simultaneously investigating all three dimensions of development, including social and environmental aspects alongside the economic dimension.
- Limitations in accessing expert opinions to weigh the research indicators.
- These limitations underscore the potential for further enhancement and refinement of the study through expanded data access, a more holistic examination of development dimensions, and consultation with subject matter experts for indicator weighting.

Suggestions for future studies:

- Simultaneous examination of the triple dimensions of development, including economic, social, and environmental aspects.
- Investigation of the relationship and impacts of economic development with other dimensions of development, particularly environmental development.
- Scenario-based planning and exploration of strategies to improve countries' economic development status, tailored to each nation's natural and human capacities.
- The utilization of diverse methodologies alongside those employed in this study is needed to investigate economic development in South American countries and compare the results with those obtained in this study.

References

Acevedo-Ramos, J. A., Valencia, C. F., & Valencia, C. D. (2023). The environmental Kuznets curve hypothesis for Colombia: Impact of economic development on greenhouse gas emissions and ecological footprint. *Sustainability*, *15*(4), 3738. https://doi.org/10.3390/su15043738

Basu, R., Paul, J., & Singh, K. (2022). Visual merchandising and store atmospherics: An integrated review and future research directions. *Journal of Business Research*, *151*, 397–408. https://doi.org/10.1016/j.jbusres.2022.07.019

Batur Sir, G. D., & Çalışkan, E. (2019). Assessment of development regions for financial support allocation with fuzzy decision making: A case of Turkey. *Socio-Economic Planning Sciences*, *66*, 161–169. https://doi.org/10.1016/j.seps.2019.02.005

Bazhan, A. I., & Pishchik, V. Y. (2023). Evolution of EU economic and monetary union, *Sovremennaya Evropa*, *1*, 59–73.

Bošković, S., et al. (2023). An alternative ranking order method accounting for two-step normalization (AROMAN)—A case study of the electric vehicle selection problem. *IEEE Access*, *11*, 39496-39507. doi: https://doi.org/10.1109/ACCESS.2023.3265818

Brodny, J., & Tutak, M. (2023). Assessing regional implementation of sustainable development goal 9 "build resilient infrastructure, promote sustainable industrialization and foster innovation" in Poland. *Technological Forecasting and Social Change*, *195* (122773). https://doi.org/10.1016/j.techfore.2023.122773

Bui Minh, T., Nguyen Ngoc, T., & Bui Van, H. (2023). Relationship between carbon emissions, economic growth, renewable energy consumption, foreign direct investment, and urban population in Vietnam. *Heliyon*, *9*(6), e17544. https://doi.org/10.1016/j.heliyon.2023.e17544

Cerdá-Suárez, L. M., Espinosa-Cristia, J. F., Núñez-Valdés, K., & Núñez-Valdés, G. (2023). Detecting circular economy strategies in the fourth sector: Overview of the Chilean construction sector as evidence of a sustainable business model. *Sustainability*, *15*(11), 8559. https://doi.org/10.3390/su15118559

Darmian, S. M., Afrasiabi, A., & Yazdani, M. (2023). Multi-criteria evaluation of agro-processing industries for sustainable local economic development in east of Iran. *Expert Systems with Applications*, *230*, 120607. https://doi.org/10.1016/j.eswa.2023.120607

Djokoto, J. G., & Wongnaa, C. A. (2023). Does the level of development distinguish the impacts of foreign direct investment on the stages of human development? *Sustainable Futures*, *5*, 100111. https://doi.org/10.1016/j.sftr.2023.100111

Dong, Y., et al. (2023). Do natural resources utilization and economic development reduce greenhouse gas emissions through consuming renewable and Clean Technology? A case study of China towards sustainable development goals. *Resources Policy*, *85*(B),103921.
https://doi.org/10.1016/j.resourpol.2023.103921

Dong, Z., & Shi, H. (2023). Does natural resources efficiency provide roadmap for economic development in China? Evidence from econometric analysis. *Resources Policy*, 86, 104127. https://doi.org/10.1016/j.resourpol.2023.104127

Erdin, C., & Ozkaya, G. (2020). Contribution of small and medium enterprises to economic development and quality of life in Turkey. *Heliyon*, *6*(2), e03215.
https://doi.org/10.1016/j.heliyon.2020.e03215

Gao, Z., Li, L., & Hao, Y. (2024). Resource industry dependence and high-quality economic development of Chinese style: Reexamining the effect of the "resource curse." *Structural Change and Economic Dynamics*, 68, 1–16. https://doi.org/10.1016/j.strueco.2023.09.013

Hatefi, M. A. (2019). Indifference threshold-based attribute ratio analysis: A method for assigning the weights to the attributes in multiple attribute decision making. *Applied Soft Computing*, *74*, 643–651.

He, X. (2023). Dams, cropland productivity, and economic development in China. *China Economic Review*, *81*, 102046. https://doi.org/10.1016/j.chieco.2023.102046

Hoekman, B., & Shingal, A. (2024). Development goals, commercial interest and EU aid-for-trade. *World Development*, *173*, 106389. https://doi.org/10.1016/j.worlddev.2023.106389

Hu, J. (2023). The international spillover effect of American economy on China's macro-economy based on MCMC-Gibbs sampling algorithm. *PLOS ONE*, *18*(11). e0293909. https://doi.org/10.1371/journal.pone.0293909

Huang, W., & He, J. (2023). Impact of energy intensity, green economy, and natural resources development to achieve sustainable economic growth in Asian countries. *Resources Policy*, *84*, 103726. https://doi.org/10.1016/j.resourpol.2023.103726

Kim, K. S. (2023). Development of industrial policy in South Korea: The case of from rags to riches with lessons for newly emerging nations. In Diederik de Boer et al. (Eds.), *Private sector development in an emerging world* (pp. 69–76). De Gruyter. https://doi.org/10.1515/9783111071251-006

Komasi, H., Hashemkhani Zolfani, S., Prentkovskis, O., & Skačkauskas, P. (2022). Urban competitiveness: Identification and analysis of sustainable key drivers (A case study in Iran). *Sustainability*, *14*(13),7844. https://doi.org/10.3390/su14137844

Komasi, H., Nemati, A., Hashemkhani Zolfani, S., & Mehtari Taheri, H. (2024). Road safety evaluation in inner-city roads and suburban roads based on a novel-hybrid MCDM model. *Ain Shams Engineering Journal*, 102796. https://doi.org/10.1016/j.asej.2024.102796

Li, J., Fan, Z., & Han, X. (2023). Strict party governance and economic development: Evidence from China. *Finance Research Letters*, 58, 104023. https://doi.org/10.1016/j.frl.2023.104023

Li, L., Dunford, M., & Yeung, G. (2012). International trade and industrial dynamics: Geographical and structural dimensions of Chinese and Sino-EU merchandise trade. *Applied Geography*, *32*(1), 130–142. https://doi.org/10.1016/j.apgeog.2010.10.017

Li, N., & Wu, D. (2023). Nexus between natural resource and economic development: How green innovation and financial inclusion create sustainable growth in BRICS region? *Resources Policy*, *85*, 103883. https://doi.org/10.1016/j.resourpol.2023.103883

Li, Y., & Huang, Y. (2023). Enhancing resources efficiency: Studying economic development in resource-rich regions for long-term sustainability of China. *Resources Policy*, *86*, 104234. https://doi.org/10.1016/j.resourpol.2023.104234

Li, Z., Luan, W., Zhang, Z., & Su, M. (2020). Relationship between urban construction land expansion and population/economic growth in Liaoning Province, China. *Land Use Policy*, *99*, 105022. https://doi.org/10.1016/j.landusepol.2020.105022

Liu, W., et al. (2018). The development evaluation of economic zones in China. *International Journal of Environmental Research and Public Health*, *15*(1), 56. https://doi.org/10.3390/ijerph15010056

Lo, H. W., Liaw, C. F., Gul, M., & Lin, K. Y. (2021). Sustainable supplier evaluation and transportation planning in multi-level supply chain networks using multi-attribute-and multi-objective decision making. *Computers & Industrial Engineering*, *162*, 107756.

Łuczak, A., & Just, M. (2020). A complex MCDM procedure for the assessment of economic development of units at different government levels. *Mathematics*, *8*(7), 1067. https://doi.org/10.3390/math8071067

Maffini, N. D., & González, F. A. I. (2023). International borders, integration and economic development: Evidence from Argentina. *Journal of Economic Integration*, *38*(4), 545–570. https://doi.org/10.11130/jei.2023.38.4.545

Mbassi, C. M., & Messono, O. O. (2023). Historical technology and current economic development: Reassessing the nature of the relationship. *Technological Forecasting and Social Change*, *195*, 122803. https://doi.org/10.1016/j.techfore.2023.122803

Mufazzal, S., & Muzakkir, S. M. (2018). A new multi-criterion decision-making (MCDM) method based on proximity indexed value for minimizing rank reversals. *Computers & Industrial Engineering*, *119*, 427–443. https://doi.org/10.1016/j.cie.2018.03.045.

Nebozhenko, T. (2023). Economic development of countries and formation of international business relations under the influence of globalization. *Economic Affairs*, *68*(3), 1577–1588. https://doi.org/10.46852/0424-2513.3.2023.24

Pamučar, D., Durán-Romero, G., Yazdani, M., & López, A. M. (2023). A decision analysis model for smart mobility system development under circular economy approach. *Socio-Economic Planning Sciences*, *86*, 101474. https://doi.org/10.1016/j.seps.2022.101474

Puška, A., Hodžić, I., & Štilić, A. (2023). Evaluating the knowledge economies within the European Union: A global knowledge index ranking via entropy and CRADIS methodologies. *International Journal of Knowledge and Innovation Studies*, *1*(2), 103–115. https://doi.org/10.56578/ijkis010203

Rahman, M. (2023). Impact of taxes on the 2030 agenda for sustainable development: Evidence from organization for economic co-operation and development (OECD) countries. *Regional Sustainability*, *4*(3), 235–248. https://doi.org/10.1016/j.regsus.2023.07.001

Shu, H., & Xiong, P. (2018). The gini coefficient structure and its application for the evaluation of regional balance development in China. *Cleaner Production*, *199*, 668–686. https://doi.org/10.1016/j.jclepro.2018.07.224

Singh, S., et al. (2024). Exploring economic development and mineral rents nexus across BRICS nations: Fresh insights from multiple threshold panel analysis. *Resources Policy*, *88*, 104537. https://doi.org/10.1016/j.resourpol.2023.104537

Song, X., et al. (2021). Impacts of changing urban land-use structure on sustainable city growth in China: A population-density dynamics perspective. *Habitat International*, *107*, 102296. https://doi.org/10.1016/j.habitatint.2020.102296

Song, Y., Gao, J., & Zhang, M. (2023). Study on the impact of energy poverty on income inequality at different stages of economic development: Evidence from 77 countries around the world. *Energy*, *282*, 128816. https://doi.org/10.1016/j.energy.2023.128816

Sotoudeh-Anvari, A. (2023). Root assessment method (RAM): A novel multi-criteria decision making method and its applications in sustainability challenges. *Journal of Cleaner Production*, *423*, 138695.

Tavana, M., Khalili Nasr, A., Mina, H., & Michnik, J. (2022). A private sustainable partner selection model for green public-private partnerships and regional economic development. *Socio-Economic Planning Sciences*, *83*, 101189. https://doi.org/10.1016/j.seps.2021.101189

Wang, F., et al. (2023a). Emerging pathways to sustainable economic development: An interdisciplinary exploration of resource efficiency, technological innovation, and ecosystem resilience in resource-rich regions. *Resources Policy*, *85*, 103747. https://doi.org/10.1016/j.resourpol.2023.103747

Wang, J., et al. (2023b). Spatio-temporal changes in ecosystem service value: Evidence from the economic development of urbanised regions. *Technological Forecasting and Social Change*, *193*, 122626. https://doi.org/10.1016/j.techfore.2023.122626

World Bank (2022). Foreign direct investment, net inflows (BoP, current US$), International Monetary Fund, Balance of Payments database, supplemented by data from the United

Nations Conference on Trade and Development and official national sources. https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD?name_desc=false

Yi, P., Dong, Q., Li, W., & Wang, L. (2021). Measurement of city sustainability based on the grey relational analysis: The case of 15 sub-provincial cities in China. *Sustainable Cities and Society*, *73*, 103143. https://doi.org/10.1016/j.scs.2021.103143

Yin, K., Han, R., & Huang, C. (2023). Effect on high-quality economic development of foreign direct investment in China from the triple perspectives of financial development. *Journal of Cleaner Production*, *427*, 139251. https://doi.org/10.1016/j.jclepro.2023.139251

Yoo, S. H., & Woo, B. (2023). Types of foreign finance and slum upgrading: How do official development assistance, foreign direct investment, and foreign remittances affect slum upgrading across regime types in developing countries?. *Habitat International*, *139*, 102898. https://doi.org/10.1016/j.habitatint.2023.102898

Yu, J., et al. (2023). Spatiotemporal dynamic impacts of Lake Victoria water volume variations on sustainable economic development. *International Journal of Applied Earth Observation and Geoinformation*, *123*, 103475. https://doi.org/10.1016/j.jag.2023.103475

Ze, F., et al. (2023). Economic development, natural resource utilization, GHG emissions and sustainable development: A case study of China. *Resources Policy*, *83*, 103596. https://doi.org/10.1016/j.resourpol.2023.103596

Zhang, R., et al. (2023). How economic development promotes the sustainability targets? Role of natural resources utilization. *Resources Policy*, *85*, 103998. https://doi.org/10.1016/j.resourpol.2023.103998

Zhao, H., Wang, Y., & Guo, S. (2023). A hybrid MCDM model combining fuzzy-delphi, AEW, BWM, and MARCOS for digital economy development comprehensive evaluation of 31 provincial level regions in China. *PLOS ONE*, *18*(4), e0283655. https://doi.org/10.1371/journal.pone.0283655

Contact information
Hossein Komasi, Ph.D.
Universidad Catolica del Norte
School of Engineering
Chile
E-mail: hossein.komasi@ucn.cl
ORCID: https://orcid.org/0000-0002-7465-3990

Alireza Nemati, MS.c
Amirkabir University of Technology
Department of Industrial Engineering and Management Systems
Iran
E-mail: alirezanemati@aut.ac.ir
ORCID: https://orcid.org/0000-0002-7735-1509

Associate Professor Sarfaraz Hashemkhani Zolfani, Ph.D.
Universidad Catolica del Norte
School of Engineering
Chile
University of Portsmouth
Faculty of Business and Law

Portsmouth, U.K.
E-mail: sa.hashemkhani@gmail.com; sarfaraz.hashemkhani@ucn.cl
ORCID: https://orcid.org/0000-0002-2602-3986

Professor Nigel L Williams, Ph.D.
University of Portsmouth,
Faculty of Business and Law
Portsmouth, U.K.
E-mail: nigel.williams@port.ac.uk
ORCID: https://orcid.org/0000-0001-6414-7085

Associate Professor Jonas Šaparauskas, Ph.D.
Vilnius Gediminas Technical University
Faculty of Civil Engineering
Department of Construction Management and Real Estate
Lithuania
Email: jonas.saparauskas@vilniustech.lt
ORCID: 0000-0003-3685-7754