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ORIGINAL ARTICLE

Comparison of countries in the WHO European Region according to noncommunicable disease indicators by multi-criteria decision making methods

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ABSTRACT

Objective: The aim of this study is to compare the relative risk prevalence of noncommunicable diseases (NCDs) in the countries of the European Region as defined by WHO (World Health Organization) using WASPAS (Weighted Aggregated Sum Product Assessment) and MULTIMOORA (Multi-Objective Optimization by Ratio Analysis plus the full Multiplicative Form) multi-criteria decision-making (MCDM) methods.

Materials and Methods: The cross-sectional study's target population consisted of 50 countries in the WHO European Region with complete observations. The study utilizes NCDs data that the WHO publicly released. Analysis was performed using the R programming language and Microsoft Excel.

Results: Based on the CRITIC (CRiteria Importance Through Intercorrelated Corrected) weighted WASPAS analysis, it was observed that 24 European countries exhibited Q scores above the average, while 26 countries displayed Q scores below the average. Finland, Cyprus, Switzerland, Spain, Iceland, Iceland, Sweden, Slovenia, Italy, Norway, Latvia, Portugal, Luxembourg, Belgium, France, Greece, the Netherlands, Germany, Malta, Austria, Ireland, Israel, Lithuania, Israel, Lithuania and Estonia have the highest Q scores. Twenty-four countries with above-average Q scores have lower NCD prevalence than twenty-six European countries. In Türkiye, the prevalence of NCDs is above the European average. However, Switzerland, Finland, Iceland, Spain, Cyprus, Slovenia, Sweden, Portugal, Norway, and Luxembourg are among the top 10 European countries with the lowest NCD prevalence in the overall MULTIMOORA ranking. According to the overall ranking, Turkmenistan, Tajikistan, and Kyrgyzstan have the highest NCD prevalence.

Conclusions: The findings from the CRITIC based WASPAS method and the CRITIC based MULTIMOORA indicate that the prevalence of NCDs generally varies according to income level. Higher-income countries note a lower prevalence of NCDs compared to those with lower income levels. Nonetheless, the prevalence of NCDs may differ among various socioeconomic groups.

Keywords: NCDs, CRITIC, MCDM, WASPAS, MULTIMOORA

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INTRODUCTION

Examining global mortality trends, data indicate a progressive rise in the proportion of deaths related to noncommunicable diseases (NCDs), which reached 73.9% of all fatalities in 2019. In contrast, the proportion of deaths linked to communicable diseases has progressively declined, accounting for just 18.2% of total deaths by 2019. In 2020 and 2021, communicable diseases accounted for 23.0% and 28.1% of all deaths, respectively, marking a reversion to the proportions seen in 2005. As a result, the proportion of deaths caused by non-communicable diseases decreased to 70.0% in 2020 and 65.3% in 2021 [1]. Nevertheless, the advancement in the prevention and management of NCDs and their primary risk factors has been inadequate and inconsistent. Only a small number of countries are making sufficient progress towards achieving Sustainable Development Goal (SDG) goal 3.4, which requires a one third reduction in premature death from NCDs by 2030 [2].

The four main risk factors for NCDs with economic transition, fast urbanization, and 21st-century lifestyles are tobacco use, poor diet, insufficient physical exercise, and problematic alcohol consumption. Like socioeconomic determinants, these risk variables have a greater impact on low- and middle-income countries and poorer persons in all countries. In these communities, poverty exposes people to behavioural risk factors for NCDs, which may then promote the downward circle that drives families to poverty. Unless the NCD epidemic is actively challenged in the most highly impacted countries and communities, NCDs will continue to worsen and the global goal of decreasing poverty will be weakened [3].

By comparing the countries in the WHO European Region according to NCD indicators with WASPAS (Weighted Aggregated Sum Product Assessment) and MULTIMOORA (Multi-Objective Optimization by Ratio Analysis plus the full Multiplicative Form) multi-criteria decision-making (MCDM) methods, this study aims to reveal the relative risk prevalence of the countries in the region in terms of NCDs. The study employs the CRITIC (CRiteria Importance Through Intercriteria Correlation) method to determine the weights of decision criteria prior to applying the MULTIMOORA and WASPAS MCDM techniques.

MATERIALS AND METHODS

The study's population, which is cross-sectional, includes 53 European Region countries identified by WHO. However, the decision criteria used for evaluating the countries include complete observations in 50 of these countries. These countries represent the study's target population. The study utilizes NCDs data that the WHO publicly released. This dataset is accessible on the "Noncommunicable Diseases Data Portal" web page at https://ncdportal.org/ [4]. Analyses were performed using the R programming language [5] and Microsoft Excel [6].

The study identified NCD indicators as decision criteria and identified countries defined by the WHO in the European Region as decision alternatives. The CRITIC method, one of the objective weighting methods. It was compared the countries in the European Region using the WASPAS and MULTIMOORA methods from MCDM, which revealed the prevalence of NCDs in the region. Based on the study's scope, Table 1 shows the NCD decision criteria and their direction.

This study used the CRITIC method, a well-known objective weighting method, to calculate the weights of the decision criteria. An R application algorithm that had been published before and was then changed for this study's needs was used. The following R code block presents the application algorithm for the CRITIC method [7]. This critic() function can be directly executed in the R console after being pasted into the R environment. The execution of the critic() function yields results corresponding to each step of the CRITIC method's implementation.

Table 1. Decision Criteria and Direction of Decision Criteria

Category	Decision Criteria	Code	Direction of Criteria	Year
Cancer	Cancer age-standardized death rate	c1	Minimum	2019
	Percentage of cancer deaths occurring under 70 years	c2	Minimum	2019
Chronic respiratory diseases (CRDs)	CRD age-standardized death rate	c3	Minimum	2019
	Percentage of CRD deaths occurring under 70 years	c4	Minimum	2019
	Percentage of asthma deaths occurring under 70 years	c5	Minimum	2019
	Percentage of asthma deaths occurring under 30 years	c6	Minimum	2019
	Exceedance of WHO PM guidelines (by a multiple of)	c7	Minimum	2019
Cardiovascular diseases (CVDs)	CVD age-standardized death rate	c9	Minimum	2019
	Percentage of CVD deaths occurring under 70 years	c10	Minimum	2019
	Hypertension, adults aged 30–79	c11	Minimum	2019
	Diagnosed hypertension, adults aged 30–79 with hypertension	c12	Minimum	2019
	Treated hypertension, adults aged 30–79 with hypertension	c13	Maximum	2019
	Controlled hypertension, adults aged 30–79 with hypertension	c14	Maximum	2019
Diabetes	Diabetes age-standardized death rate	c15	Minimum	2019
	Percentage of diabetes deaths occurring under 70 years	c16	Minimum	2019
	Raised fasting blood glucose, adults aged 18+	c17	Minimum	2014

```
critic <- function(dm = NULL, dc = NULL, nd = NULL) {
  # Step 1: Check Input Variables and Assign Values
  dm2 <- dm
  dc1 <- ifelse(dc == "max", 1, 0) # Assign 1 if the criteria should be maximized, 0 otherwise

  # Step 2: Normalization Process
  for (r in 1:nrow(dm))
    for (c in 1:ncol(dm))
      if (dc1[c]) { # If the criteria should be maximized
        dm2[r,c] <- (dm[r,c] - min(dm[,c])) / (max(dm[,c]) - min(dm[,c])) # Normalize to [0, 1]
      } else { # If the criteria should be minimized
        dm2[r,c] <- (max(dm[,c]) - dm[r,c]) / (max(dm[,c]) - min(dm[,c])) # Normalize to [0, 1]
      }
  ndm <- dm2 # Assign the normalized decision matrix

  # Step 3: Creating the Correlation Matrix
  if (nd == TRUE) { # Use Pearson correlation
    rcm <- cor(ndm)
    rownames(rcm) <- NULL # Remove row names for cleaner output
  } else if (nd == FALSE) { # Use Spearman's rank correlation
    rcm <- cor(ndm, method = "spearman")
    rownames(rcm) <- NULL # Remove row names for cleaner output
  }

  # Step 4: Calculating Information Amount (Cj) and Weight (wj) Values
  rcm1 <- 1 - rcm # Calculate the difference between 1 and the correlation matrix
  rownames(rcm1) <- NULL # Remove row names for cleaner output
  qj <- apply(ndm, 2, sd) # Calculate the standard deviation of each column in the normalized decision matrix
  cj <- qj * apply(rcm1, 2, sum) # Calculate the information amount (Cj)
  wj <- cj / sum(cj) # Calculate the weights (wj)

  # Step 5: Return Results as a List
  return(list(
    dm = as.matrix(dm), # Original decision matrix
    ndm = as.matrix(ndm), # Normalized decision matrix
    rcm = as.matrix(rcm), # Correlation matrix
    cj = round(cj, 4),    # Information amount (Cj), rounded to 4 decimal places
    wj = round(wj, 4)     # Weights (wj), rounded to 4 decimal places
  ))
}
```

In the R programming language, the critic() function, developed to implement the CRITIC method, accepts the following arguments as input [7]:

- dm: Represents the decision matrix, where alternatives are arranged in rows and criteria in columns. This matrix contains the performance values of the alternatives being evaluated in the decision-making process.

- dc: A vector used to specify the direction of the criteria. This vector contains numerical values (1: maximization, 0: minimization) indicating whether each criterion should be maximized or minimized.
- nd: A logical value that determines the method used to calculate the correlation between criteria. A value of TRUE indicates the use of the Pearson correlation coefficient, while a value of FALSE indicates the use of Spearman's rank correlation coefficient.

The "MCDM" package [8], which can be found in the R environment, was used to analyze countries in the WHO European Region based on NCD indicators using the WASPAS and MULTIMOORA methods, which are well-known MCDM approaches. The "ggpubr" package [9], which is also available in the R environment, was used to make the graph showing the relationship between the CRITIC based WASPAS and CRITIC based MULTIMOORA methods.

It was used the energy test [10], a multivariate normality test, to determine whether the decision criteria exhibit a multivariate normal distribution. In the R programming language, "energy" package was utilized for this [11]. In the third step of the CRITIC weighting method, an energy test was performed to determine whether the decision criteria show a multivariate normal distribution. This process led to the selection of the CRITIC approach's correlation test method. If the decision criteria demonstrate a normal distribution, it will be the Pearson correlation test, a parametric correlation test; if not, it will be Spearman's rank correlation test, a nonparametric correlation test. In the multivariate normality test, the following are the null (H_0) and alternative (H_A) hypotheses:

- H_0: The decision criteria display a multivariate normal distribution.
- H_A: The decision criteria do not display a multivariate normal distribution.

Spearman's rank correlation test, one of nonparametric statistical tests, is commonly used to determine whether two rankings are statistically distinct from one another [12]. Spearman's rank correlation test was performed to assess the monotonic relationship between the score rankings generated from WASPAS and MULTIMOORA techniques, which is based on CRITIC weighting method. The nonparametric Spearman's rank correlation test, which is used to determine whether two rankings are statistically different, is also commonly used to compare MCDM rankings [13-16]. The null hypothesis (H_0) and alternative hypothesis (H_A) established in correlation tests are as follows:

- H_0: There is no monotonic relationship between the rankings of CRITIC based WASPAS method and CRITIC based MULTIMOORA method.
- H_A: There is a monotonic relationship between the rankings of CRITIC based WASPAS method and CRITIC based MULTIMOORA method.

The decision matrix used for weighting the decision criteria and comparing the countries of the European Region (N=50) according to NCD indicators is presented in Table 2.

CRITIC weighting method

One of the objective weighing approaches [17-20], the CRITIC (CRiteria Importance Through Intercorrelated Corrected) method, has the following application steps [17]:

Step 1. Making decision matrix: A decision matrix (X_{ij}) in equation (1), with decision alternatives in rows and decision criteria in columns, is created. In the decision matrix, m is the number of decision alternatives, and n is the number of decision criteria.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \text{ where } i = (1,2,\ldots,m) \text{ and } j = (1,\ldots,n) \quad (1)$$

Step 2. Normalizing decision matrix: Direction of decision criteria, that is, benefit and cost criteria, is taken into account while normalizing decision matrix. In this instance, benefit criteria are determined by Equation (2), and cost criteria are determined by Equation (3).

$$r_{ij} = \frac{x_{ij-x_j^{min}}}{x_j^{max} - x_j^{min}} \quad (2)$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \quad (3)$$

Table 2. Decision Matrix

Country	**c1**	**c2**	**c3**	**c4**	**c5**	**c6**	**c7**	**…**	**c15**	**c16**
Albania	100.1	45.6	23.1	9.5	11.6	0.3	3.2	…	21.0	**7.4**
Armenia	126.9	54.7	21.1	23.7	34.8	0.2	6.8	…	46.7	**11.5**
Austria	108.3	33.1	19.8	16.7	27.9	3.0	2.3	…	12.7	**4.3**
Azerbaijan	84.0	72.8	28.1	40.7	47.1	0.8	4.8	…	66.9	12.3
Belarus	119.0	62.4	13.2	32.6	43.2	0.6	3.0	…	45.6	7.8
Belgium	114.1	34.4	27.4	16.8	27.0	1.0	2.3	…	18.4	4.6
Bosnia and Herzegovina	136.0	53.0	18.7	24.0	20.6	0.4	5.4	…	28.8	7.4
Bulgaria	120.1	49.5	37.7	28.1	34.2	4.4	3.4	…	31.1	7.6
Croatia	147.9	40.5	19.2	15.2	14.4	0.4	7.3	…	13.8	7.3
Cyprus	81.8	37.0	27.4	8.9	10.8	0.0	2.3	…	13.6	7.0
Czechia	128.8	38.5	20.6	26.2	24.5	1.3	2.9	…	17.0	7.5
Denmark	125.5	29.6	35.0	15.9	20.3	1.4	1.9	…	19.9	4.3
Estonia	130.5	34.8	9.4	22.8	20.0	7.3	1.2	…	24.4	7.1
Finland	95.0	30.7	11.9	17.9	10.4	0.1	1.1	…	29.6	5.3
France	123.7	35.7	16.9	13.1	25.5	2.1	2.1	…	16.5	5.9
Georgia	98.9	58.2	19.8	31.8	37.1	3.8	3.8	…	48.7	12.6
Germany	114.2	36.0	22.7	21.4	34.0	1.3	2.1	…	19.0	5.0
Greece	118.4	32.1	23.5	7.5	18.8	2.2	3.0	…	20.6	6.6
Hungary	162.4	48.9	33.3	36.7	35.0	1.7	2.8	…	27.5	7.7
Iceland	104.7	32.6	20.9	11.9	36.7	0.3	1.1	…	16.5	5.9
Ireland	114.1	36.8	32.0	12.6	23.9	3.8	1.6	…	13.4	6.2
Israel	101.4	36.5	21.0	16.5	20.4	1.3	3.9	…	20.1	6.4
Italy	105.7	28.3	19.3	7.7	18.1	1.6	2.7	…	12.1	5.8
Kazakhstan	117.0	71.1	51.0	35.9	38.6	0.7	4.9	…	50.4	11.8
Kyrgyzstan	96.0	75.3	31.8	37.5	62.9	4.4	7.1	…	75.0	10.4
Latvia	144.3	40.9	10.0	34.6	28.8	0.0	2.3	…	25.4	7.2
Lithuania	141.5	41.5	9.5	27.5	24.7	0.0	2.0	…	29.5	7.9
Luxembourg	109.0	36.5	23.4	15.9	33.7	0.3	1.8	…	18.4	5.4
Malta	103.8	36.4	19.0	12.4	21.1	1.8	2.5	…	20.8	7.7
Montenegro	123.5	56.9	8.4	21.9	33.7	1.4	3.7	…	38.4	7.1
Netherlands	125.4	34.6	26.0	17.8	17.8	1.8	2.1	…	20.7	4.3
Republic of North Macedonia	149.0	56.0	35.6	27.4	14.8	0.1	4.9	…	30.8	7.2
Norway	105.4	31.4	25.9	15.5	12.8	0.9	1.3	…	22.3	5.1
Poland	147.8	45.6	20.1	27.3	33.9	1.0	3.7	…	28.7	7.7
Portugal	116.2	34.9	22.9	8.9	17.8	1.6	1.5	…	12.0	6.8
Moldova	119.5	71.0	14.6	40.4	48.7	0.1	2.4	…	60.9	8.1
Romania	141.1	52.0	23.3	31.8	26.5	1.1	2.6	…	34.4	6.8
Russian Federation	129.2	58.0	14.7	34.9	47.4	1.6	1.7	…	42.4	7.7
…	…	…	…	…	…	…	…	…	…	…
Türkiye	138.2	56.2	32.0	22.9	22.3	1.4	4.6	…	31.1	13.6
Turkmenistan	95.5	80.9	10.3	53.0	68.1	8.2	4.9	…	79.2	12.2
Ukraine	128.0	62.2	11.9	34.3	41.4	2.3	2.6	…	54.3	7.3
United Kingdom	113.2	29.8	28.0	17.3	23.7	3.6	1.9	…	18.6	5.8
Uzbekistan	65.0	83.1	15.8	52.9	61.2	2.2	7.8	…	78.7	10.6

Step 3. Creating correlation matrix: Equation (4) calculates correlation of normalizing decision matrix. Pearson correlation coefficient is calculated if decision criteria shows normal distribution, if not, Spearman's rank correlation coefficient is computed.

$$P_{jk} = \frac{\sum_{i=1}^{m}(r_{ij-}\bar{r}_j)^2(r_{ik-}\bar{r}_k)^2}{\sqrt{\sum_{i=1}^{m}(r_{ij-}r_j)^2\sum_{i=1}^{m}(r_{ik-}r_k)^2}} \quad (4)$$

Step 4. Information quantity calculation: Equation (5) uses C_j to represent information quantity and σ_j to represent standard deviation of decision criteria. Here, the correlation matrix is used to compute amount of information.

$$C_j = \sigma_j \times \sum_{k=1}^{m}(1 - r_{jk}) \quad (5)$$

Step 5. Calculating weights of decision criteria: Equation (6) computes weights of decision criteria (w_j) by dividing information amount (C_j) for each criterion by total information amounts of criteria.

$$w_j = \frac{c_j}{\sum_{k=1}^{m} c_k)} \quad (6)$$

WASPAS MCDM method

Weighted Sum Model (WSM) and Weighted Product Model (WPM) are combined in a unique way in the Weighted Aggregated Sum Product Assessment (WASPAS) method. The application steps in the WASPAS method are as follows [21]:

Step 1. Creation of the decision matrix: In the first step, the mxn-dimensional decision matrix X_{ij} given in equation (7) is created. In the matrix, m is the number of decision alternatives, and n is the number of decision criteria.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (7)$$

Step 2. Normalizing the decision matrix: In this step, the matrix X_{ij} is normalized to the cost and benefit criteria. It is used Equation (8) to normalize the decision matrix according to the cost criterion and Equation (9) to normalize it according to the benefit criterion.

$$\bar{x}_{ij} = \frac{min_i X_{ij}}{X_{ij}} \quad (8)$$

$$\bar{x}_{ij} = \frac{X_{ij}}{max_i X_{ij}} \quad (9)$$

Step 3. Calculation of the relative weights: First, we calculate the relative weight of the alternatives using the Weighted Sum Model (WSM). We use Equation (10) for this operation.

$$Q_{\mathrm{i}}^{(1)} = \sum_{j=1}^{n} \bar{x}_{ij} w_j \quad (10)$$

Conversely, the Weighted Product Model (WPM) approach determines the relative weights of the alternatives by applying equation (11).

$$Q_{\mathrm{i}}^{(2)} = \prod_{j=1}^{n} (\bar{x}_{ij})^{w_j} \quad (11)$$

The study used the CRITIC method to determine the weights of the decision criteria in this step.

Step 4. Determination of the oveall relative weights: To determine the overall relative weights of the alternatives, it was summed the relative weights obtained according to the WSM and WPM approaches, as shown in equation (12). The best decision alternative will be the one with the highest Q value. When the lambda (λ) value is equal to 0, the WASPAS method becomes the WPM method, and when the lambda (λ) value is equal to 1, the WASPAS method transforms into the WSM method.

$$Q_i = \lambda Q_{\mathrm{i}}^{(1)} + (1-\lambda) Q_{\mathrm{i}}^{(1)} \text{ where } (\lambda = 0, 0.1, \dots, 1) \quad (12)$$

In this study, the lambda (λ) parameter was set to 0.5.

MULTIMOORA MCDM method

In 2006, Brauers and Zavadskas [22] introduced MOORA, a Multi-Objective Optimization on the basis of a Ratio Analysis, which combined Ratio System and Reference Point Approach. In 2010, Brauers and Zavadskas [23] improved MOORA to MULTIMOORA, which includes the full Multiplicative form and Dominance Theory for a final integrative ranking. Ratio System and Full Multiplicative Form belong to the first group of MCDM approaches, while Reference Point Approach belongs to the second group. MULTIMOORA uses vector normalization and three subordinate ranking methods: Ratio System, Reference Point Approach, and Full Multiplicative Form. Each method has its advantages but has limitations, so MULTIMOORA uses multiple approaches. This section provides a detailed description of these methods to enhance understanding of the MULTIMOORA method.

The initial step in an MCDM problem construction involves creating a decision matrix and weight vector, such as MULTIMOORA, which is a decision matrix based on the ratings of m decision alternatives. In equation (13), the decision matrix is denoted as the X_{ij} matrix, where m defines the number of decision alternatives and n indicates the number of decision criteria.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (13)$$

The ratings of alternatives should be normalized before being used in a MCDM model due to potential differences in dimensions [24]. MULTIMOORA uses a ratio system where each alternative's response to an objective is compared to a denominator that represents all alternatives related to that objective, chosen as the square root of the sum of squares of each alternative per objective [23]. This operation is called vector normalization [25] and is given in equation (14):

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^{2}}} \quad (14)$$

Ratio system

Ratio System, the first part of MULTIMOORA, is a fully compensatory model that uses the arithmetic weighted aggregation operator to compensate for small normalized values of an alternative. This means that an alternative with poor performance in some criteria can be replaced by one with moderate performance in all criteria. The utility of the Ratio System is calculated by adding weighted normalized ratings for beneficial criteria and deducting them for cost criteria [26]. To calculate the utility of Ratio System, the weighted normalized ratings are added for benefit criteria and subtracted for cost criteria as in equation (15) [23,24]. w_j shows the weights of the decision criteria in equation (15).

$$y_j^{*} = \sum_{i=1}^{i=g} w_j x_{ij}^{*} - \sum_{i=g+1}^{i=n} w_j x_{ij}^{*} \quad (15)$$

y_j^{*} indicates the normalized evaluation of alternative j regarding all objectives.

i=g + 1,g + 2,…,n as the objectives to be minimized, and i=1,2,…,g as the objectives to be maximized. An ordinal ranking of the y_j reflects the final preference.

Reference point approach

Reference Point Approach is used for the second part of MULTIMOORA. Tchebycheff Min-Max Metric is the foundation of Reference Point Method [23]. The broad idea of Murkowski Metric, which serves as the foundation for various decision analysis techniques in the literature, including goal programming, is where the Tchebycheff Min-Max Metric got its start [18]. Reference Point Approach starts from normalized ratios (x_{ij}^{*}) and is calculated using equation (16) [23,24].

$$\underset{j}{Min} \left\{ \underset{i}{max} \left| w_j r_i - w_j x_{ij}^{*} \right| \right\} \quad (16)$$

Full multiplicative form

Full Multiplicative Form is the third part of MULTIMOORA [23]. In equation (17), A_j represents the objectives that need to be maximized. In equation (18), B_j indicates the objectives that need to be minimized. $U_j^{'}$ denotes the overall utility of alternative j with objectives to be minimized and maximized in equation (19). In the equations, w_j shows the weight coefficients of the decision criteria [24].

$$A_j = \prod_{g=1}^{i} (x_{gi})^{w_j} \quad (17)$$

$$B_j = \prod_{k=i+1}^{n} (x_{kj})^{w_j} \quad (18)$$

$$U_j^{\prime} = \frac{A_j}{B_J} \quad (19)$$

Determining overall ranking

The alternatives are ranked based on their overall significance, maximal distance to the reference point, and utility. Three different ranking lists are formed, representing the RS, RP, and FMF approaches of the MULTIMOORA method. The final ranking is based on dominance theory, with the best-ranked alternative having the highest number of appearances [23,27].

RESULTS

Table 3 shows descriptive statistics for the WHO European Region's NCD indicators utilized as decision criteria in the study. This descriptive statistical analysis reveals notable patterns in mortality and health conditions. The finding that cancer age-standardized death rates (c1) exhibit substantial variability (Mean=117.78, Sd=21.83) suggests significant regional disparities in access to cancer care, screening programs, and environmental risk factors. The fact that a notable proportion of cancer deaths occur before the age of 70 (c2), (Mean=46.45) underscores the need for targeted prevention efforts aimed at younger populations, potentially focusing on lifestyle modifications and early detection. Cardiovascular disease (CVD) age-standardized death rates (c8) demonstrate even greater variability (Mean=236.18, Sd=155.38), potentially reflecting differences in dietary habits, physical activity levels, and access to specialized cardiac care across regions. This highlights the importance of tailored CVD prevention strategies. The substantial number of adults aged 30-79 experiencing hypertension (c10) (Mean=38.38) suggests a significant public health concern requiring widespread awareness campaigns and accessible screening programs. The challenge in achieving adequate control of hypertension (c13) (Mean=24.6), despite available treatments, suggests potential issues with medication adherence, access to follow-up care, or the need for more intensive lifestyle interventions. Finally, the significant number of diabetes-related deaths occurring before age 70 (c15) (Mean=31.04) emphasizes the importance of early diabetes diagnosis, effective disease management, and interventions targeting modifiable risk factors such as obesity and sedentary behavior.

Alternative hypothesis (H_A) is accepted (E-statistic=2.3452, N=50, R=150, p<0.000) since the normalized decision criteria in CRITIC weighing method do not demonstrate multivariate normal distribution by the Energy test. R in this case stands for the bootstrap replication coefficient. Because of this, when building the correlation matrix in the third phase of CRITIC method, Spearman's rank correlation method was applied.

When weighting the decision criteria in the CRITIC weighting method, the countries of the European Region with no missing observations in the decision criteria were taken into consideration. In this case, the data of fifty European Region countries were taken into account in determining the weights of the decision criteria. The weights of

Table 3. Descriptive Statistics of Decision Criteria in the WHO European Region

Description	Code	N	Mean	Sd	Min	Max	Range
Cancer age-standardized death rate	c1	50	117.78	21.83	64.98	162.44	97.46
Percentage of cancer deaths occurring under 70 years	c2	50	46.45	15.66	25.45	83.10	57.65
CRD age-standardized death rate	c3	50	22.40	9.14	8.41	51.04	42.63
Percentage of CRD deaths occurring under 70 years	c4	50	23.79	11.96	7.48	52.98	45.50
Percentage of asthma deaths occurring under 70 years	c5	50	28.73	13.74	9.85	68.11	58.26
Percentage of asthma deaths occurring under 30 years	c6	50	1.57	1.72	0.01	8.16	8.16
Exceedance of WHO PM guidelines (by a multiple of)	c7	53	3.17	1.92	1.09	10.32	9.220
CVD age-standardized death rate	c8	50	236.18	155.38	68.93	618.25	549.32
Percentage of CVD deaths occurring under 70 years	c9	50	21.40	9.88	9.07	52.04	42.97
Hypertension, adults aged 30–79	c10	51	38.38	7.79	21.90	49.20	27.30
Diagnosed hypertension, adults aged 30–79 with hypertension	c11	51	63.07	8.81	40.50	83.60	43.10
Treated hypertension, adults aged 30–79 with hypertension	c12	51	50.75	10.01	25.90	71.30	45.40
Controlled hypertension, adults aged 30–79 with hypertension	c13	51	24.60	10.76	7.40	51.80	44.40
Diabetes age-standardized death rate	c14	50	14.38	10.94	2.71	55.09	52.39
Percentage of diabetes deaths occurring under 70 years	c15	50	31.04	19.00	10.48	79.20	68.73
Raised fasting blood glucose, adults aged 18+	c16	51	7.42	2.30	4.00	13.60	9.60

Table 4. Weights of NCD Decision Criteria

Decision Criteria	Code	w_j	Rank
Diagnosed hypertension, adults aged 30–79 with hypertension	c11	0.090	1
CRD age-standardized death rate	c3	0.083	2
Percentage of asthma deaths occurring under 30 years	c6	0.081	3
Cancer age-standardized death rate	c1	0.078	4
Treated hypertension, adults aged 30–79 with hypertension	c12	0.073	5
Hypertension, adults aged 30–79	c10	0.064	6
Controlled hypertension, adults aged 30–79 with hypertension	c13	0.062	7
Diabetes age-standardized death rate	c14	0.058	8
Percentage of asthma deaths occurring under 70 years	c5	0.056	9
CVD age-standardized death rate	c8	0.055	10
Percentage of diabetes deaths occurring under 70 years	c15	0.055	11
Percentage of CRD deaths occurring under 70 years	c4	0.053	12
Percentage of cancer deaths occurring under 70 years	c2	0.051	13
Raised fasting blood glucose, adults aged 18+	c16	0.050	14
Exceedance of WHO PM guidelines (by a multiple of)	c7	0.048	15
Percentage of CVD deaths occurring under 70 years	c9	0.045	16

NCD decision criteria in CRITIC weighting method are shown in Table 4. The first three decision criteria, c11 (Diagnosed hypertension, adults aged 30-79 with hypertension) (w_j=0.090), c3 (CRD age-standardized death rate) (w_j=0.083), and c6 (Percentage of asthma deaths occurring under 30 years) (w_j=0.081), have the highest weights in the CRITIC method. Conversely, the following three decision criteria have the lowest weight values among the first three: c9 (Percentage of CVD fatalities occurring under 70 years of age) (w_j=0.045), c7 (Exceeding WHO PM limits (by a multiple of)) (w_j=0.048), and c16 (Raised fasting blood glucose, adults aged 18+) (w_j=0.050).

Table 5 shows the comparison results of CRITIC based MULTIMOORA and CRITIC based WASPAS methods for fifty countries in the European Region. The results of the application steps that come before the last step of the WASPAS and MULTIMOORA techniques are not presented due to space restrictions. According to CRITIC based WASPAS method, there are twenty-four countries in the European Region with above-average Q scores (Q=0.410) and twenty-six countries with below-average scores. The twenty-four countries with above-average scores are: Finland (Q=0.573), Cyprus (Q=0.558), Switzerland (Q=0.546), Spain (Q=0.541), Iceland (Q=0.538), Sweden (Q=0.518), Slovenia (Q=0.518), Italy (Q=0.505), Norway (Q=0.501), Latvia (Q=0.5), Portugal (Q=0.497), Luxembourg (Q=0. 484), Belgium (Q=0.479), France (Q=0.475), Greece (Q=0.461), Netherlands (Q=0.456), United Kingdom (Q=0.456), Germany (Q=0.453), Malta (Q=0.452), Austria (Q=0.45), Ireland (Q=0.44), Israel (Q=0.439), Lithuania (Q=0.438), Estonia (Q=0.413). These countries are also the top twenty-four countries with the highest Q score. In other words, the prevalence of NCDs is lower in twenty-four countries with above-average Q scores than in twenty-six countries in the European Region. On the other hand, Türkiye falls below the average Q score of the European Region (Q=0.343). In other words, Türkiye's NCD prevalence is above the average of the European Region.

On the other hand, according to overall MULTIMOORA rankings, Switzerland, Finland, Iceland, Spain, Cyprus, Slovenia, Sweden, Portugal, Norway, and Luxembourg are the top 10 countries in the European Region with the lowest NCD prevalence according to the NCD decision criteria, making them the closest to the optimal solution. The countries furthest from the optimal solution—in other words, the top 3 countries with the highest NCD prevalence according to the overall ranking—are as follows: Turkmenistan, Tajikistan, and Kyrgyzstan.

Table 5. CRITIC Based WASPAS and CRITIC Based MULTIMOORA Scores

	WASPAS		MULTIMOORA			
Alternatives	**Q**	**Rank**	**RS**	**RP**	**Multiplicative Form**	**Overall Rank**
Albania	0.409	25	-0.099	0.024	2095949275947490000000000000	31
Armenia	0.322	42	-0.114	0.014	63660308462673100000000000	41
Austria	0.450	20	-0.074	0.015	19601654424126800000000000000	19
Azerbaijan	0.282	47	-0.142	0.015	1771581840763280000000000	46
Belarus	0.360	33	-0.103	0.014	296560426798305000000000000	33
Belgium	0.479	13	-0.062	0.009	105168142321801000000000000000	12
Bosnia and Herzegovina	0.347	36	-0.103	0.016	217363122815857000000000000	34
Bulgaria	0.317	43	-0.121	0.022	33281596218291500000000000	43
Croatia	0.396	28	-0.089	0.011	3663087240194790000000000000	27
Cyprus	0.558	2	-0.059	0.009	2690855328451630000000000000000	5
Czechia	0.395	29	-0.080	0.007	2452928426925070000000000000	20
Denmark	0.405	26	-0.083	0.014	5027939376722250000000000000	25
Estonia	0.413	24	-0.103	0.036	2013167869116840000000000000	32
Finland	0.573	1	-0.052	0.008	4726953439942680000000000000000	2
France	0.475	14	-0.066	0.010	68277477467106100000000000000	15
Georgia	0.293	45	-0.133	0.019	3907489498126180000000000	45
Germany	0.453	18	-0.065	0.007	27867717719185100000000000000	13
Greece	0.461	15	-0.068	0.011	34842091849318100000000000000	16
Hungary	0.323	41	-0.108	0.012	80835912766227400000000000	38
Iceland	0.538	5	-0.051	0.008	933629799294909000000000000000	3
Ireland	0.440	21	-0.083	0.019	13978396017475600000000000000	26
Israel	0.439	22	-0.072	0.008	11862117598641700000000000000	18
Italy	0.505	8	-0.060	0.008	181919535175196000000000000000	11
Kazakhstan	0.302	44	-0.127	0.021	15361438250996900000000000	44
Kyrgyzstan	0.271	49	-0.155	0.022	643031914018214000000000	48
Latvia	0.500	10	-0.085	0.011	163226834868945000000000000000	21
Lithuania	0.438	23	-0.083	0.013	39075851160414000000000000000	22
Luxembourg	0.484	12	-0.061	0.007	205551528168787000000000000000	10
Malta	0.452	19	-0.066	0.009	18866447190736800000000000000	14
Montenegro	0.365	30	-0.098	0.009	197024536353496000000000000	30
Netherlands	0.456	16	-0.070	0.010	35529002962043100000000000000	17
Republic of North Macedonia	0.358	34	-0.112	0.015	767293047810188000000000000	40
Norway	0.501	9	-0.060	0.008	283206071242107000000000000000	9
Poland	0.363	32	-0.090	0.008	614921910774377000000000000	29
Portugal	0.497	11	-0.059	0.008	138784797984369000000000000000	8
Moldova	0.340	38	-0.114	0.014	265797234723474000000000000	42
Romania	0.363	31	-0.091	0.007	708288446743524000000000000	28
Russian Federation	0.335	39	-0.108	0.011	99121172055476300000000000	37
Serbia	0.327	40	-0.106	0.011	90624955242803900000000000	36
Slovakia	0.403	27	-0.083	0.008	5247051957314510000000000000	24
Slovenia	0.518	7	-0.062	0.010	1099998597544370000000000000000	6
Spain	0.541	4	-0.055	0.009	935005068745267000000000000000	4
Sweden	0.518	6	-0.057	0.011	395268248360860000000000000000	7
Switzerland	0.546	3	-0.050	0.007	836972154664236000000000000000	1
Tajikistan	0.269	50	-0.165	0.017	452934372046749000000000	49
Türkiye	0.343	37	-0.104	0.011	120912428967956000000000000	35
Turkmenistan	0.281	48	-0.178	0.040	231818891864782000000000	50
Ukraine	0.349	35	-0.110	0.012	101997404729638000000000000	39
United Kingdom	0.456	17	-0.077	0.018	25504602565688300000000000000	23
Uzbekistan	0.291	46	-0.154	0.015	600048680846697000000000	47

RS: Ratio System Approach, RP: Reference Point Approach.

Table 6. Above Average Countries according to MULTIMOORA Approaches

Ratio System (N=28)		**Reference Point (N=30)**		**Multiplicative Form (N=8)**	
Alternatives	**Scores**	**Alternatives**	**Scores**	**Alternatives**	**Multiplicative Form**
Switzerland	-0.0503	Czechia	0.0065	Finland	47269534399426800000000000000
Iceland	-0.0506	Switzerland	0.0067	Cyprus	26908553284516300000000000000
Finland	-0.0520	Germany	0.0069	Slovenia	10999985975443700000000000000
Spain	-0.0549	Luxembourg	0.0074	Spain	9350050687452670000000000000
Sweden	-0.0567	Romania	0.0074	Iceland	9336297992949090000000000000
Cyprus	-0.0586	Poland	0.0076	Switzerland	8369721546642360000000000000
Portugal	-0.0592	Italy	0.0078	Sweden	3952682483608600000000000000
Norway	-0.0598	Portugal	0.0078	Norway	2832060712421070000000000000
Italy	-0.0602	Finland	0.0079		
Luxembourg	-0.0615	Israel	0.0081		
Belgium	-0.0616	Iceland	0.0084		
Slovenia	-0.0619	Slovakia	0.0085		
Germany	-0.0649	Norway	0.0085		
Malta	-0.0655	Malta	0.0087		
France	-0.0660	Spain	0.0090		
Greece	-0.0683	Belgium	0.0092		
Netherlands	-0.0701	Cyprus	0.0092		
Israel	-0.0725	Montenegro	0.0095		
Austria	-0.0737	Netherlands	0.0095		
United Kingdom	-0.0772	Slovenia	0.0096		
Czechia	-0.0800	France	0.0103		
Slovakia	-0.0829	Serbia	0.0105		
Lithuania	-0.0831	Sweden	0.0105		
Denmark	-0.0831	Greece	0.0110		
Ireland	-0.0832	Croatia	0.0111		
Latvia	-0.0845	Russian Federation	0.0112		
Croatia	-0.0886	Latvia	0.0114		
Poland	-0.0895	Türkiye	0.0114		
		Hungary	0.0121		
		Ukraine	0.0125		

In the CRITIC based MULTIMOORA method, the countries above the average score of the European Region according to the approaches in the MULTIMOORA method are given in Table 6. According to the Ratio System approach, one of the MULTIMOORA approaches, the number of countries above the European Region average (Average Score=-0.091) is twenty-eight. These countries also have the lowest NCD prevalence. According to the Reference Point approach, which is one of the MULTIMOORA approaches, 30 countries are above the European Region average (Average Score=0.013). According to this approach, Türkiye is the country with above average. Finally, according to Multiplicative Form, one of the MULTIMOORA approaches, the number of countries above the European Region average (Average Sco re=26032251361428100000000000000) is eight, and these countries are as follows: Finland, Cyprus, Slovenia, Spain, Iceland, Switzerland, Sweden, and Norway.

Based on the results of the analysis, it was found that there is a strong positive relationship between the rankings obtained from the CRITIC based WASPAS and CRITIC based MULTIMOORA ($r_s(48)=0.970$,

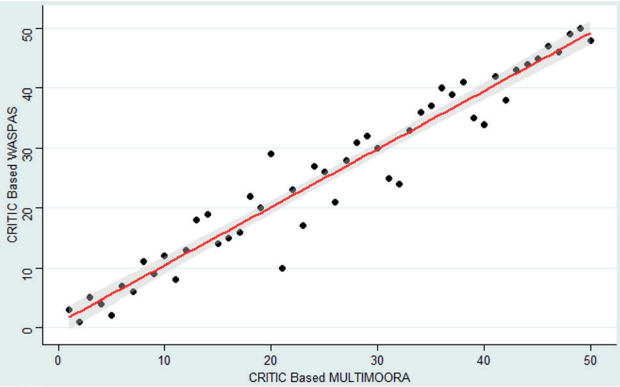

Figure 1. Correlation between CRITIC Based WASPAS and CRITIC Based MULTIMOORA Methods

p<0.05, N=50). In CRITIC based MULTIMOORA, overall rankings were used in the correlation test. As a result, the alternative hypothesis (HA) was accepted. The correlation between the two weighting methods is given in Figure 1.

DISCUSSION

NCDs remain the primary cause of mortality globally, with a growing need for treatment and escalating healthcare expenses [28]. Government officials are required to fulfill their commitment to decrease premature death from non-non-communicable diseases by one third by 2030 by means of preventive measures and medical care, as well as to advance mental health. Failure to make substantial expenditures would result in an annual mortality rate of 15 million individuals from non-communicable diseases (NCDs), with around 800,000 succumbing to suicide. By adopting the WHO "best buys" for non-communicable diseases (NCDs), it is possible to save 17 million strokes and heart attacks by 2030, stimulate $350 billion in economic development, and achieve a minimum return of $7 by 2030 [29]. This study assessed the relative risk prevalence of NCDs in fifty countries within the WHO European Region. Comparative analysis was conducted by examining NCD indicators using the WASPAS and MULTIMOORA MCDM approaches.

The CRITIC weighting method assigns the highest weights to the first three decision criteria: "Diagnosed hypertension, adults aged 30-79 with hypertension", "CRD age-standardized death rate", and "Percentage of asthma deaths occurring under 30 years". Conversely, the three decision criteria with the lowest weights among the first three are "Percentage of cardiovascular disease (CVD) deaths occurring under 70 years of age", "Exceeding WHO guidelines for particulate matter (PM) by a multiple of)", and "Raised fasting blood glucose, adults aged 18+".

The study has demonstrated a strong positive correlation between the rankings derived from the CRITIC based WASPAS and the CRITIC based MULTIMOORA methods.

The CRITIC based WASPAS method reveals that 24 European countries have above-average Q scores, while 26 have below-average scores. The top 24 countries with the highest Q score are Finland, Cyprus, Switzerland, Spain, Iceland, Sweden, Slovenia, Italy, Norway, Latvia, Portugal, Luxembourg, Belgium, France, Greece, Netherlands, United Kingdom, Germany, Malta, Austria, Ireland, Israel, Lithuania, and Estonia. In summary, NCDs are less prevalent in twenty-four countries that have above-average Q scores compared to twenty-six countries in the European Region. In general, the common characteristic of these 24 countries is that they have higher income levels than other countries [24]. On the other hand, the prevalence of NCDs in Türkiye surpasses the average prevalence in the European Region. Türkiye falls into the middle-income group [30], and income distribution among social groups is unequal [31].

Nevertheless, according to the CRITIC based MULTIMOORA overall rankings, Switzerland, Finland, Iceland, Spain, Cyprus, Slovenia, Sweden, Portugal, Norway, and Luxembourg rank among the top 10 countries in the European Region with the lowest prevalence of NCDs. On the other hand, according to the overall ranking, the top three countries with the highest prevalence of NCDs are Turkmenistan, Tajikistan and Kyrgyzstan. According to World Bank data for 2022, Turkmenistan is in the upper middle-income group, while Tajikistan and Kyrgyzstan are in the lower middle-income group [30]. It is known that countries' income levels are linked to the prevalence of NCDs. We also know that the distribution of NCDs is unequal in low- and middle-income countries and among socioeconomic groups [31]. Robust evidence from 283 studies indicates a positive correlation between low income, low socioeconomic status, and NCDs [32].

In summary, according to the CRITIC based WASPAS method and the CRITIC based MULTIMOORA results, NCD prevalence generally varies by income level. It is observed that the prevalence of NCDs is lower in countries with higher income levels than in countries with lower income levels. However, NCD prevalence may also vary across socioeconomic groups.

Author contribution

Study conception and design: TB; data collection: TB; analysis and interpretation of results: TB; draft manuscript preparation: TB. The author reviewed the results and approved the final version of the manuscript.

Ethical approval

Since the data used in the study are publicly published by WHO, ethics committee approval is not required.

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Conflict of interest

The author declare that there is no conflict of interest.

REFERENCES

[1] World Health Organization (WHO). World health statistics 2024: monitoring health for the SDGs, Sustainable Development Goals. Geneva: WHO; 2024.

[2] World Health Organization (WHO). Tackling NCDs: best buys and other recommended interventions for the prevention an control of noncommunicable diseases. 2nd ed. Geneva: WHO; 2024.

[3] World Health Organization (WHO). Global status report on noncommunicable diseases 2010. Geneva: WHO; 2011. Available at: https://iris.who.int/handle/10665/44579

[4] World Health Organization (WHO). Noncommunicable Diseases Data Portal, World Health Organization 2024. Available at: https://ncdportal.org/ (Accessed on June 16, 2024).

[5] R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2024.

[6] Microsoft Corporation. Microsoft Excel; 2018.

[7] Bulut T. Evaluation of Turkish health system capacity at provincial level by WISP method based on weighting methods. Journal of Productivity 2025;59(1):143-66. https://doi.org/10.51551/verimlilik.1549245

[8] BAC M. MCDM: Multi-Criteria Decision Making Methods for Crisp Data. R package version 1.2; 2016.

[9] Kassambara A. ggpubr: "ggplot2" Based Publication Ready Plots. R package version 0.6.0; 2023.

[10] Székely GJ, Rizzo ML. A new test for multivariate normality. J Multivar Anal 2005;93(1):58-80. https://doi.org/10.1016/j.jmva.2003.12.002

[11] Rizzo M and Szekely G. energy: E-statistics: multivariate inference via the energy of data. R package version 1.7-11; 2022.

[12] Taylor JM. Kendall's and Spearman's correlation coefficients in the presence of a blocking variable. Biometrics 1987;43(2):409-16.

[13] Lee HC, Chang CT. Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan. Renew Sustain Energy Rev 2018;92:883-96. https://doi.org/10.1016/j.rser.2018.05.007

[14] Paradowski B, Shekhovtsov A, Bączkiewicz A, Kizielewicz B, Sałabun W. Similarity analysis of methods for objective determination of weights in multi-criteria decision support systems. Symmetry 2021;13(10):1874. https://doi.org/10.3390/sym13101874

[15] Pramanik PKD, Biswas S, Pal S, Marinković D, Choudhury P. A comparative analysis of multi-criteria decision-making methods for resource selection in mobile crowd computing. Symmetry 2021;13(9):1713. https://doi.org/10.3390/sym13091713

[16] Shekhovtsov A. How strongly do rank similarity coefficients differ used in decision making problems? Procedia Comput Sci 2021;192:4570-7. https://doi.org/10.1016/j.procs.2021.09.235

[17] Diakoulaki D, Mavrotas G, Papayannakis L. Determining objective weights in multiple criteria problems: the critic method. Comput Oper Res 1995;22(7):763-70. https://doi.org/10.1016/0305-0548(94)00059-h

[18] Bhumula KB, Kumar GN. Using CRITIC-TOPSIS and python to examine the effect of 1-Hepatnol on the performance and emission characteristics of CRDI CI engine with split injection. Heliyon 2024;10(11):e31484. https://doi.org/10.1016/j.heliyon.2024.e31484

[19] Zhu X, Lin H, Wang S. Practice of clinical wards performance evaluation based on DRG indicators and the CRITIC-TOPSIS method. In: 2024 10th International Conference on Systems and Informatics (ICSAI), IEEE; 2024:1-6. https://doi.org/10.1109/ICSAI65059.2024.10893799

[20] Adalı EA, Tuş A. Hospital site selection with distance-based multi-criteria decision-making methods. Int J Healthc Manag 2021;14(2):534-44. https://doi.org/10.1080/20479700.2019.1674005

[21] Chakraborty S, Zavadskas EK. Applications of WASPAS method in manufacturing decision making. Informatica 2014;25(1):1-20. https://doi.org/10.15388/informatica.2014.01

[22] Brauers WK, Zavadskas EK. The MOORA method and its application to privatization in a transition economy. Control and Cybernetics 2006;35(2):445-69.

[23] Brauers, WKM, Zavadskas, EK. Project management by multimoora as an instrument for transition economies. Technol Econ Dev Econ 2010;16(1):5-24. https://doi.org/10.3846/tede.2010.01

[24] Hafezalkotob A, Hafezalkotob A, Liao H, Herrera F. An overview of MULTIMOORA for multi-criteria decision-making: theory, developments, applications, and challenges. Inf Fusion 2019;51:145-77. https://doi.org/10.1016/j.inffus.2018.12.002

[25] Delft A.van, Nijkamp P. Multicriteria analysis and regional decision-making. The Hague/Boston: Martinus Nijhoff Social Sciences Division; 1977.

[26] Liao H, Qin R, Gao C, Wu X, Hafezalkotob A, Herrera F. Score-HeDLiSF: a score function of hesitant fuzzy linguistic term set based on hesitant degrees and linguistic scale functions: an application to unbalanced hesitant fuzzy linguistic MULTIMOORA. Inf Fusion 2019;48:39-54. https://doi.org/10.1016/j.inffus.2018.08.006

[27] Stanujkic D, Karabasevic D, Zavadskas EK, Smarandache F, Brauers WKM. A bipolar fuzzy extension of the MULTIMOORA method. Informatica 2019;30(1):135-52. https://doi.org/10.15388/informatica.2019.201

[28] World Health Organization (WHO). Preventing noncommunicable diseases (NCDs) by reducing environmental risk factors. Geneva: WHO; 2017.

[29] World Health Organization (WHO). Noncommunicable diseases country profiles 2018. Geneva: WHO; 2018.

[30] World Bank (WB). World Bank Country and Lending Groups. Available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (Accessed on August 10, 2024).

[31] Hosseinpoor AR, Bergen N, Mendis S, et al. Socioeconomic inequality in the prevalence of noncommunicable diseases in low- and middle-income countries: results from the World Health Survey. BMC Public Health 2012;12:474. https://doi.org/10.1186/1471-2458-12-474

[32] Niessen LW, Mohan D, Akuoku JK, et al. Tackling socioeconomic inequalities and non-communicable diseases in low-income and middle-income countries under the Sustainable Development agenda. Lancet 2018;391(10134):2036-46. https://doi.org/10.1016/S0140-6736(18)30482-3