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Evaluation of Turkish Health System Capacity at Provincial Level by WISP Method Based on Weighting Methods

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ABSTRACT

Purpose: The study aims to evaluate the capacity and capacity gaps of the Turkish health system at the provincial level in relative terms. The secondary objective of the study is to develop application algorithms for the weighting methods utilized in the R programming language.

Methodology: The decision criteria used in evaluation of health system capacity were weighted by CRITIC, Shannon Entropy, and NMV methods. The WISP method was used to evaluate the health system capacity of provinces. Data were drawn from the Ministry of Health's Health Statistics Yearbook for 2022.

Findings: Tunceli, Bayburt, and Kilis are the three provinces closest to the optimal solution among 81 provinces in terms of health system capacity in Türkiye, according to CRITIC-based WISP scores. On the contrary, Bursa, İstanbul and Şanlıurfa are the three provinces furthest from an optimal solution.

Originality: At the provincial level, gaps in the health system's capacity can be identified and subsequently improved. It is possible to develop self-sufficient health system capacity and enhance its resilience. The development of application algorithms for weighting methods makes a significant contribution. Decision makers are capable of generating immediate solutions for both small and large-scale data sets using the algorithms.

Keywords: CRITIC, Entropy, NMV, WISP, Health System Capacity.

JEL Codes: C44, C61, I18.

Türk Sağlık Sistemi Kapasitesinin Ağırlıklandırma Yöntemlerine Dayalı WISP Yöntemi ile İl Düzeyinde Değerlendirilmesi

ÖZET

Amaç: Bu çalışmanın birincil amacı, Türkiye sağlık sisteminin kapasite ve kapasite açıklarını il düzeyinde göreceli olarak değerlendirmektir. Çalışmanın ikincil amacı ise R programlama dilinde kullanılan ağırlıklandırma yöntemleri için uygulama algoritmaları geliştirmektir.

Yöntem: Sağlık sistemi kapasitesinin değerlendirilmesinde kullanılan karar kriterleri CRITIC, Shannon Entropy ve NMV yöntemleri ile ağırlıklandırılmıştır. İllerin sağlık sistemi kapasitesini değerlendirmek için WISP yöntemi kullanılmıştır. Veriler Sağlık Bakanlığı'nın 2022 Sağlık İstatistikleri Yıllığı'ndan alınmıştır.

Bulgular: Tunceli, Bayburt ve Kilis, CRITIC tabanlı WISP skorlarına göre Türkiye'de sağlık sistemi kapasitesi açısından 81 il arasında optimal çözüme en yakın üç ildir. Buna karşılık, Bursa, İstanbul ve Şanlıurfa optimal çözümden en uzak üç ildir.

Özgünlük: İl düzeyinde, sağlık sisteminin kapasitesindeki boşlukları tespit edebilir ve geliştirebiliriz. Kendi kendine yeterli sağlık sistemi kapasitesi oluşturabilir ve sağlık sistemini daha dirençli hale getirilebilir. Öte yandan, ağırlıklandırma yöntemleri için uygulama algoritmalarının geliştirilmesi önemli bir katkıdır. Böylece karar vericiler küçük ve özellikle büyük ölçekli veri setleri üzerinde anlık çözümler üretebilir.

Anahtar Kelimeler: CRITIC, Entropi, NMV, WISP, Sağlık Sistemi Kapasitesi.

JEL Kodları: C44, C61, I18.

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1. INTRODUCTION

Unpredictability of disasters and crises can cause significant human suffering and loss of life. Inadequate preparedness, particularly in health systems, increases vulnerability and overwhelms institutions, making lifesaving interventions difficult. Health systems, in preparing for health crises, encounter multiple hazards, constrained resources for management, and elevated performance expectations (WHO, 2012) Health systems consist of individuals and activities aimed at enhancing health (WHO, 2024a). Health systems must be constructed to withstand many shocks and stresses, including sudden external occurrences like natural disasters and epidemics, as well as persistent internal issues like as insufficient funding or a shortage of human resources (WHO, 2024b). Health system resilience is defined as the capacity to absorb, adapt and transform when exposed to a shock (Blanchet et al. 2017).

Health system resilience at the provincial level refers to the capacity and flexibility of cities to respond to and adapt to external pressures during crises, hazards, or disasters. An enhanced comprehension of urban resilience during health emergencies facilitates socioeconomic recovery following crises and highlights critical factors and issues pertinent to potential health crises (Chen et al., 2021).

Decision-making is a complex and balanced issue that takes place at micro, meso, and macro levels in health services (Hsu et al., 2008). Therefore, a range of criteria, including effectiveness or efficiency, stakeholder interests and pressures, equity or fairness, cost-effectiveness, strength of evidence, and safety, inform decision-making (Guindo et al., 2012). Multi-criteria decision making (MCDM) involves evaluating available decision alternatives based on multiple decision criteria. The objective of MCDM is to prioritize alternatives according to multiple criteria.

First, in the decision-making process, we decide on the decision criteria to use in evaluating decision alternatives (Broekhuizen et al., 2015). Next, we determine the method for calculating the weights of the decision criteria. Next, we decide which method to employ for assessing the alternatives based on the criteria. The weight coefficients obtained from the method or methods used in weighting decision criteria are multiplied by the weighted decision matrix in the MCDM method. The final case determines the priority order of decision alternatives based on the obtained scores.

The main objective of the study is to evaluate Turkish health system capacity at provincial level using the WISP method and to reveal the relative health system capacities and capacity gaps at provincial level. The decision criteria used in evaluation of health system capacity are weighted by CRITIC (CRiteria Importance Through Intercriteria Correlation), Shannon entropy, and NMV (Normalized Maximum Values) methods. The WISP (Weighted Sum Product) method was used to evaluate the health system capacity of the provinces in Türkiye according to the decision criteria. The study's secondary goal is to develop application algorithms for weighting methods in the R programming language. In this way, it is aimed at producing instant solutions for decision-makers on small and large-scale data sets.

Criteria weighting methods have become increasingly used in decision making in healthcare (Németh et., 2019). Some of these methods are subjective weighting methods that include value judgments of decision makers, while others are objective weighting methods that do not incorporate value judgments of decision makers. This study employed the objective weighting methods of CRITIC, Shannon Entropy, and NMV. Therefore, it includes studies that employ these methods in health services.

The following studies employ the entropy weighting method in health services: Departments in Peru have evaluated the health system level (Delgado et al., 2018), the Eastern Mediterranean Region's health system financing (Pourmohammadi et al., 2018), the performance of buildings in health facilities (Hassanain et al., 2022), the Health Intrinsic Drivers Index (GOH-IDI) study (Feng et al., 2022), the safety performance of healthcare providers during the COVID-19 pandemic (Salehi et al., 2023), the physical health levels of students (Zhang et al., 2023), and the resilience of countries' health systems during COVID-19 (Zhao et al., 2023).

Some of the studies using the CRITIC weighting method in healthcare are as follows: hospital site selection (Adalı and Tuş, 2019), evaluation of smart health management (Peng et al., 2021), evaluation of stress level in urban areas during the COVID-19 pandemic (Gupta et al., 2021), evaluation of online health interventions (Lin et al., 2023).

The NMV method, developed as an objective weighting method, has not yet been used in healthcare. This study will introduce the NMV method to the healthcare sector for the first time. However, up until now, the financial sector has primarily employed the NMV method. Some of these studies include the evaluation of enterprises traded in the Borsa Istanbul (BIST) IPO Index (Bağcı and Sarıay, 2021), the financial performance evaluation of asset management companies in Türkiye (Kılıçarslanand Sucu, 2021), the transaction performance evaluation of companies in the licensed warehousing sector (Ergun et al., 2022), and the analysis of the financial performance of renewable energy sector companies operating in Borsa Istanbul (BIST) (Kılıçarslan, 2023).

The number of studies that can be given as an example for use of WISP method, which is used as a MCDM method in this study, in healthcare is quite small. This is because WISP method is a new method. An example of use of WISP method in healthcare is the study on evaluation of health performance of provinces in Türkiye (Keleş, 2023).

2. METHODOLOGY

The data set of the study is taken from the Turkish Ministry of Health's Health Statistics Yearbook for 2022 published in 2024 (MoH, 2024). Population statistics are taken from the population data published by the Turkish Statistical Institute for the year 2022 (TURKSTAT, 2023). This health statistics yearbook is the most recent one published. The number of decision criteria used in evaluating the health system capacities of provinces is 15, and the number of provinces with decision alternatives is 81. To weight the decision criteria, the study used objective weighting methods such as CRITIC, Shannon Entropy, and NMV. WISP method was used to evaluate the decision alternatives by the decision criteria.

Microsoft Office Excel software (Microsoft Corporation, 2018) was used to create decision matrices. The R programming language (R Core Team, 2024) was used to calculate weights of decision criteria using weighting methods and to evaluate the health system capacity of 81 provinces by the WISP method, and implementations were made on R Markdown (Allaire et al., 2024). In weighting the decision criteria by the NMV method, an NMV application algorithm developed in the R environment and revised within the scope of this study was used (Appendix) (Bulut, 2022a). The study utilized the application algorithms developed in the R environment for the Shannon Entropy (Appendix) and CRITIC (Appendix) weighting methods (Appendix). The appendix also provides concrete examples to help users understand the application algorithms. Since the application algorithms are not presented as a package, they do not need to be installed in the R environment. Users can copy the application algorithms directly into the R environment and run them. The application algorithms are given in the appendix because they take up a lot of space in the main text. The "rwisp" package was used in the R environment in the evaluation of 81 provinces by the WISP (Simple Weighted Sum Product) method (Stanujkic et al., 2023). Other packages used in R in the study are as follows: 'corrplot' (Wei and Simko, 2021), 'dplyr' (Wickham et al., 2023), 'energy' (Rizzo and Szekely, 2022), 'ggplot2' (Wickham, 2016), 'ggthemes' (Arnold, 2024), 'openxlsx' (Schauberger and Walker, 2023), 'readxl' (Wickham and Bryan, 2023), 'rmarkdown' (Allaire et al., 2024), 'sf' (Pebesma and Bivand, 2023), 'sp' (Pebesma and Bivand, 2005; Bivand et al., 2013), 'tibble' (Müller and Wickham, 2023), 'tidyr' (Wickham et al., 2024), 'TRmaps' (Tastan, 2024), 'viridis' (Garnier et al., 2024). Table 1 presents the decision criteria and optimality criteria determined within the scope of the study.

Table 1. Decision criteria and optimality criteria

Decision Criteria	*Code*	*Optimality Criteria*
Population per hospital	c1	Minimum
Number of beds per 10,000 people	c2	Maksimum
Number of intensive care beds per 10,000 people	c3	Maksimum
Population per family medicine unit	c4	Minimum
Average length of stay	c5	Minimum
Bed occupancy rate	c6	Minimum
Population per physician	c7	Minimum
Population per dentist	c8	Minimum
Population per pharmacist	c9	Minimum
Population per nurse	c10	Minimum
Population per midwife	c11	Minimum
Population per other health personnel	c12	Minimum
Population per emergency aid station	c13	Minimum
Population per emergency ambulance	c14	Minimum
Unfounded call rate (%)	c15	Minimum

The energy test (Szkely and Rizzo, 2005), a multivariate normality test, was used to test the normality of the decision criteria. For this purpose, the 'energy' package in the R programming language (Rizzo and Szekely, 2022) was utilized. The hypotheses established in the multivariate normality test are as follows:

- Null hypothesis (H_0): Decision criteria show multivariate normal distribution.
- Alternative hypothesis (H_A): Decision criteria do not show multivariate normal distribution.

Energy test was used to test whether values of the decision criteria in the WISP method are normally distributed. According to the result obtained, the correlation method was decided. Energy test was also used to test whether the weights obtained from weighting methods are normally distributed. This process determined the correlation method to be used in the relationship between the weights of decision criteria obtained from weighting methods.

The non-parametric Spearman's rank correlation test was used to test whether there is a statistically significant relationship between WISP method rankings based on weighting methods. Spearman's rank correlation test is widely used to compare whether two rankings are statistically different from each other (Taylor, 1987). The tests are used in comparison of rankings obtained from MCDM methods (Zamani-Sabzi et al., 2016; Lee and Chang, 2018; Huang et al., 2021; Paradowski et al., 2021; Pramanik et al., 2021; Shekhovtsov, 2021; Bhaskar and Khan, 2022; Top and Bulut, 2022). In Spearman's rank correlation test, null hypothesis (H_0) and alternative hypothesis (H_A) are defined as follows:

H_0: There is no monotonic relationship between CRITIC-based WISP and Entropy-based WISP.

H_0: There is no monotonic relationship between CRITIC-based WISP and NMV-based WISP.

H_0: There is no monotonic relationship between Entropy-based WISP and NMV-based WISP.

H_A: There is a monotonic relationship between CRITIC-based WISP and Entropy-based WISP.

H_A: There is a monotonic relationship between CRITIC-based WISP and NMV-based WISP.

H_A: There is a monotonic relationship between Entropy-based WISP and NMV-based WISP.

WISP scores based on weighting methods were categorised into 5 groups equally according to the combinations, and the scores were reflected on the maps in this way.

2.1. Weighting Methods

2.1.1. CRITIC Method

Application steps of CRITIC method, which is one of the objective weighting methods, are as follows (Diakoulaki et al., 1995):

Step 1. Creating decision matrix: A decision matrix (X_{ij}) is created with alternatives in rows and decision criteria in columns.

Step 2. Normalisation of decision matrix: Decision matrix is normalised according to direction of decision criterion, i.e. according to benefit and cost criteria. In this case, Equation 1 is used for benefit criterion and Equation 2 is used for cost criterion.

$$r_{ij} = \frac{x_{ij-x_j^{min}}}{x_j^{max}-x_j^{min}} \quad (1)$$

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

Step 3. Creation of correlation matrix: Correlation matrix of normalised values of decision criteria is calculated by Equation 3. If decision criteria are normally distributed, Pearson correlation coefficient is calculated, if not, Spearman's rank correlation coefficient is calculated.

$$P_{jk} = \frac{\sum_{i=1}^{m}(r_{ij-\bar{r}_j})^2(r_{ik-\bar{r}_k})^2}{\sqrt{\sum_{i=1}^{m}(r_{ij-r_j})^2\sum_{i=1}^{m}(r_{ik-r_k})^2}} \quad (3)$$

Step 4. Calculation of amount of information: In Equation 4, C_j is amount of information, and σ_j is standard deviation of decision criteria. Here, amount of information is calculated from correlation matrix.

$$C_j = \sigma_j \times \sum_{k=1}^{m}(1 - r_{jk}) \quad (4)$$

Step 5. Determination of weights: In Equation 5, weights of decision criteria (w_j) are calculated by proportioning information amount (C_j) of each criterion to sum of information amounts of criteria.

$$w_j = \frac{c_j}{\sum_{k=1}^{m}c_k)} \quad (5)$$

2.1.2. Shannon Entropy Method

Shannon Entropy is an objective weighting method used to determine weights of decision criteria (Shannon, 1948). In other words, it does not include value judgements of decision maker (Wang and Lee, 2009; Kumar et al., 2021). Shannon Entropy application steps are as follows (Shemshadi et al., 2011; Song et al., 2017):

Step 1. Creation of decision matrix: A decision matrix x_{ij} is created with alternatives in rows and decision criteria in columns. X_{ij} is an mxn dimensional matrix where m is the number of rows in matrix, and c is the number of columns in matrix.

Step 2. Normalisation of decision matrix: Normalised decision matrix in Equation 6 is obtained by proportioning each criterion value in decision matrix to sum of values of each criterion.

$$P_{ij} = \frac{x_{ij}}{\sum_{k=1}^{m} x_{ij}} \quad (6)$$

Step 3. Calculation of entropy values: First, the coefficient constant (k) of normalised decision matrix (P_{ij}) is calculated. Then, sum of values of each criterion is multiplied by k. Thus, entropy values (e_j) of decision criteria are determined. These operations are performed with help of Equation 7.

$$e_j = -k \times \sum_{j=1}^{n} P_{ij} \text{ where } k = \frac{1}{\ln(m)} \quad (7)$$

Step 4. Calculation of degrees of differentiation and weights: After entropy values of decision criteria are found, degrees of differentiation (d_j) of decision criteria are calculated. The weights of criteria are obtained by proportioning degree of differentiation of each criterion to sum of the degrees of differentiation of the criteria. These operations are performed using Equation 8.

$$w_j = \frac{d_j}{\sum_{k=1}^{m} d_j)} \text{ where } d_j = 1 - e_j \quad (8)$$

2.1.3. NVM Method

NMV method developed as an objective weighting method is applied in four steps. The application steps of the method are as follows (Bulut, 2017; Bulut 2022b):

Step 1. Creating decision matrix: A decision matrix (X_{ij}) is created with alternatives in rows and decision criteria in columns. In matrix X_{ij}, r indicates number of rows, and c shows number of columns.

Step 2. Creating ratio matrix: In Equation 9, T_i is sub-sum of criteria in decision matrix. R_{ij} matrix is obtained by proportioning value of each criterion to sub-sum of values of criterion to which it belongs.

$$T_j = \sum_{j=1}^{c} X_{ij} \quad (9)$$

Step 3. Calculation of normalised values: The maximum value (max_j) is found from value series of each criterion. Then, mean (A_j) and standard deviation (S_j) of value series of each criterion are calculated. N_j is standardised value of each criterion. These procedures are given in Equations 10-12.

$$A_j = \frac{\sum_{j=1}^{c} R_{ij}}{r} \quad (10)$$

$$S_j = \frac{R_{ij} - A_j}{\sqrt{\sum (R_{ij} - A_j)^2}} \quad (11)$$

$$N_j = \frac{max_i - A_j}{S_j} \quad (12)$$

Step 4. Calculation of weight coefficients: Weight coefficients in Equation 13 are calculated by dividing normalised value of each criterion by sum of normalised criterion values.

$$w_j = \frac{N_j}{\sum_{j=1}^{c} N_j} \quad (13)$$

2.2. WISP Method

The simple WISP method, which is a combination of Weighted Sum (WS) and Weighted Product (WP) methods, is used to solve multi-criteria decision making problems. The method is completed in five steps (Zavadskas et al., 2022; Stanujkic et al., 2023):

Step 1. Creation of decision matrix: As in other MCDM methods, the decision matrix is created in the first step of the WISP method.

Step 2. Normalising decision matrix: In this step, decision matrix is normalised by proportioning each value of decision matrix to maximum value using Equation 14. Here, r_{ij} represents a dimensionless number and i represents normalised degree of alternative with respect to decision criterion j.

$$r_{ij} = \frac{x_{ij}}{max_i x_{ij}} \quad (14)$$

Step 3. Determination of utility measurement values: In this step, 4 utility scores are calculated in Equations 15-18. In the equations, max and min indicate direction of decision criteria. In other words, if decision criterion aims at benefit, it is set as 'max', and if it aims at cost, it is set as 'min'. u_i^{wsd} shows difference of values of utility and non-utility normalised criteria in weighted sum model, u_i^{wpd} shows difference of utility and non-utility normalised criteria in weighted product model. u_i^{wsr} and u_i^{wpr} show ratio of differences obtained from weighted sum and product models, respectively.

$$u_i^{wsd} = \sum_{j\in\Omega_{max}} r_{ij}w_j - \sum_{j\in\Omega_{min}} r_{ij}w_j \quad (15)$$

$$u_i^{wpd} = \prod_{j\in\Omega_{max}} r_{ij}w_j - \prod_{j\in\Omega_{min}} r_{ij}w_j \quad (16)$$

$$u_i^{wsr} = \frac{\sum_{j\in\Omega_{max}} r_{ij}w_j}{\sum_{j\in\Omega_{min}} r_{ij}w_j} \quad (17)$$

$$u_i^{wpr} = \frac{\prod_{j\in\Omega_{max}} r_{ij}w_j}{\prod_{j\in\Omega_{min}} r_{ij}w_j} \quad (18)$$

Step 4. Recalculation of four benefit criteria: Here, u_i^{-wsd}, u_i^{-wpd}, u_i^{-wsr} and u_i^{-wpr} denotes normalised values. Normalised values are calculated with help of Equations 19-22.

$$u_i^{-wsd} = \frac{u_i^{wsd}}{(1+u_{max_i}^{wsd})} \quad (19)$$

$$u_i^{-wpd} = \frac{u_i^{wpd}}{(1+u_{max_i}^{wpd})} \quad (20)$$

$$u_i^{-wsr} = \frac{u_i^{wsr}}{(1+u_{max_i}^{wsr})} \quad (21)$$

$$u_i^{-wpr} = \frac{u_i^{wpr}}{(1+u_{max_i}^{wpr})} \quad (22)$$

Step 5. Calculating overall utility (u_i) score of alternatives and determining the best alternative: The alternative with the highest overall utility score is considered as the best alternative. The overall utility score is obtained by dividing sum of normalised utility values by four. This procedure is shown in Equation 23.

$$u_i = \frac{u_i^{wpr} + u_i^{-wpd} + u_i^{-wsr} + u_i^{-wpr}}{4} \quad (23)$$

3. RESULTS

This section first tests the decision criteria for a multivariate normal distribution using the energy test, then presents the results of the normal distribution. Next, findings of objective weighting methods used in evaluation of health system capacity at the provincial level are presented. WISP scores based on weighting methods present the health system capacity assessment findings at the province level. The appendix provides the decision matrix for weighing decision criteria and the WISP method.

Since normalized decision criteria in the CRITIC weighting method do not show multivariate normal distribution by Energy test, alternative hypothesis (H_A) is accepted (E-statistic = 2.9437, N = 81, R = 100, p<0.000). Here, R denotes the bootstrap replication coefficient. For this reason, Spearman's rank correlation method was used in the third step of the CRITIC method while creating the correlation matrix. The weights of decision criteria obtained from the weighting methods are given in Table 2. The prominent findings are as follows:

- In the CRITIC method, the first three decision criteria have the highest weights: average length of stay (c5) (w_j = 0.0819), number of intensive care beds per 10,000 people (c3) (w_j = 0.0808), and population per pharmacist (c9) (w_j = 0.0883). The first three decision criteria with the lowest weights are population per hospital (c1) (w_j = 0.0449), unfounded call rate (%) (w_j = 0.0488), and population per emergency ambulance (w_j = 0.0501).

- In the entropy method, the first three decision criteria have the highest weights: population per dentist (c8) ($w_j = 0.2941$), population per pharmacist (c9) ($w_j = 0.2806$), and population per midwife (c11) ($w_j = 0.1738$). The first three decision criteria with the lowest weights are population per family medicine unit (c4) ($w_j = 0.0002$), average length of stay (c5) ($w_j = 0.0021$), and bed occupancy rate (c6) ($w_j = 0.0022$).
- In the NMV method, the first three decision criteria have the highest weights: population per dentist (c8) ($w_j = 0.1074$), unfounded call rate (c15) (%) ($w_j = 0.1023$), and population per pharmacist (c9) ($w_j = 0.0883$). The first three decision criteria have the lowest weights: population per family medicine unit (c4) (%) ($w_j = 0.0412$), bed occupancy rate (c6) ($w_j = 0.0416$) and population per nurse (c10) ($w_j = 0.0419$).

Table 2. Weights of decision criteria by weighting method

Criteria	*CRITIC*		*Entropy*		*NMV*	
	w_j	*Rank*	w_j	*Rank*	w_j	*Rank*
c1	0.0449	15	0.0078	9	0.0808	4
c2	0.0730	6	0.0046	12	0.0649	8
c3	0.0808	2	0.0064	11	0.0754	5
c4	0.0661	9	0.0002	15	0.0412	15
c5	0.0819	1	0.0021	14	0.0556	10
c6	0.0694	8	0.0022	13	0.0416	14
c7	0.0775	5	0.0895	4	0.0526	11
c8	0.0648	10	0.2941	1	0.1074	1
c9	0.0799	3	0.2806	2	0.0883	3
c10	0.0792	4	0.0568	5	0.0419	13
c11	0.0613	11	0.1738	3	0.0722	6
c12	0.0717	7	0.0502	6	0.0458	12
c13	0.0506	12	0.0092	8	0.0630	9
c14	0.0501	13	0.0154	7	0.0669	7
c15	0.0488	14	0.0071	10	0.1023	2

Since there is no multivariate normal distribution between weights of decision criteria obtained from the weighting methods, the H_A hypothesis is accepted (E-statistic = E-statistic=1,2019, $N = 15$, $R = 100$, p<0.000). Therefore, Spearman's rank correlation coefficients were estimated. Figure 1 presents the Spearman's rank correlation matrix of the weights. There is a moderately monotonic relationship between entropy weights and NMV weights ($N = 15$, $r = 0.43$). Since the correlation coefficient between the other weighting method pairs is close to 0, there is no monotonic relationship between them.

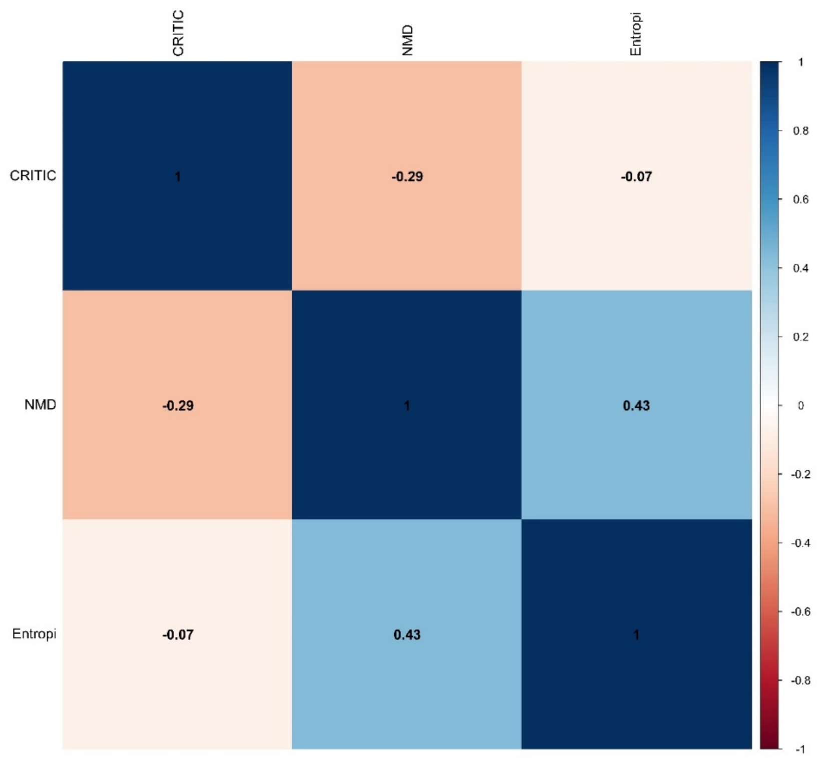

Figure 1. Correlation matrix of weighting methods.

The map of Türkiye presents WISP scores based on weighting methods. The appendix (Appendix 5) presents both the CRITIC-based WISP scores and the WISP scores derived from other weighting methods. Figure 2 first presents the CRITIC-based WISP method scores. The top three provinces with the highest scores are Tunceli ($u_i = 4.0425$), Bayburt ($u_i = 3.4594$), and Kilis ($u_i = 3.4513$) among 81 provinces in Türkiye. On the other hand, the three provinces with the lowest scores are Bursa ($u_i = 2,4136$), İstanbul ($u_i = 2.4755$) and Şanlıurfa ($u_i = 2.4898$).

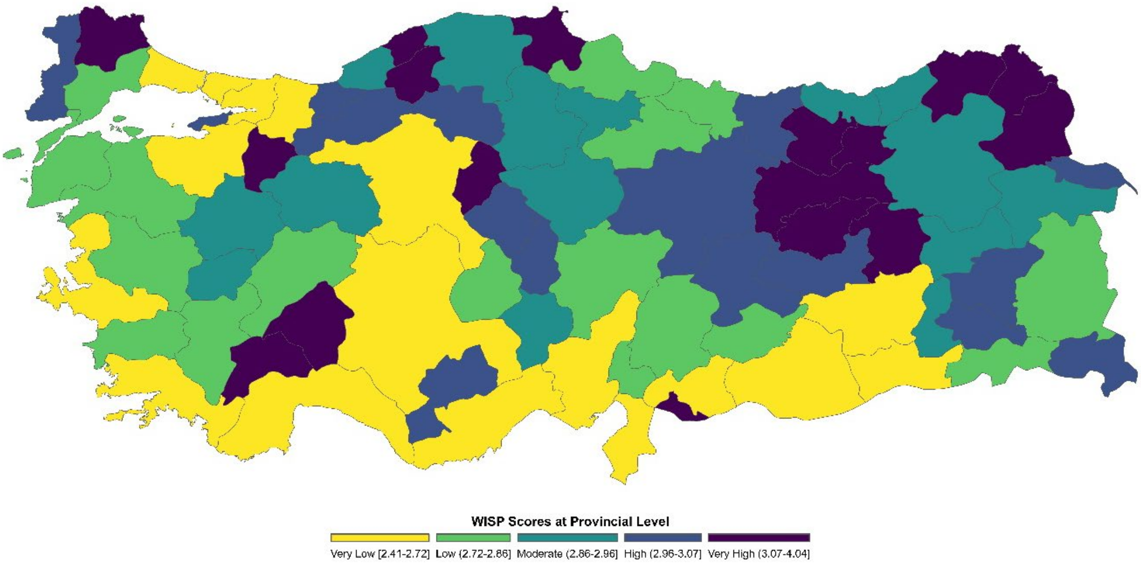

Figure 2. CRITIC-based WISP scores

WISP scores obtained based on entropy weighting method are presented in Figure 3. The first three provinces with the highest scores are Tunceli ($u_i = 4.1154$), Bayburt ($u_i = 3.4494$) and Kilis ($u_i = 3.4452$) among 81 provinces in Türkiye. On the other hand, the three provinces with the lowest scores are Bursa ($u_i = 2.0710$), Konya ($u_i = 2.1397$), and İstanbul ($u_i = 2.1595$).

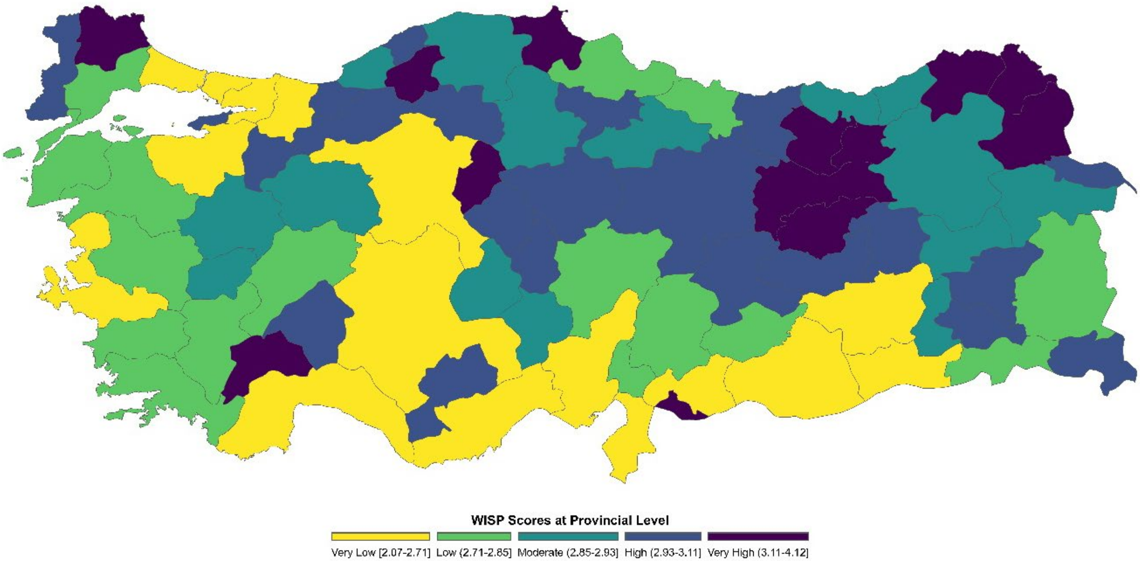

Figure 3. Entropy-based WISP scores

Figure 4 shows WISP scores obtained based on NMV weighting method. The first three provinces with the highest scores are Tunceli ($u_i = 4.0752$), Bayburt ($u_i = 3.4563$), and Sinop ($u_i = 3.4247$) among 81 provinces. On the other hand, the three provinces with the lowest scores are Bursa ($u_i = 2.4208$), İstanbul ($u_i = 2.4535$) and Izmir ($u_i = 2.4785$).

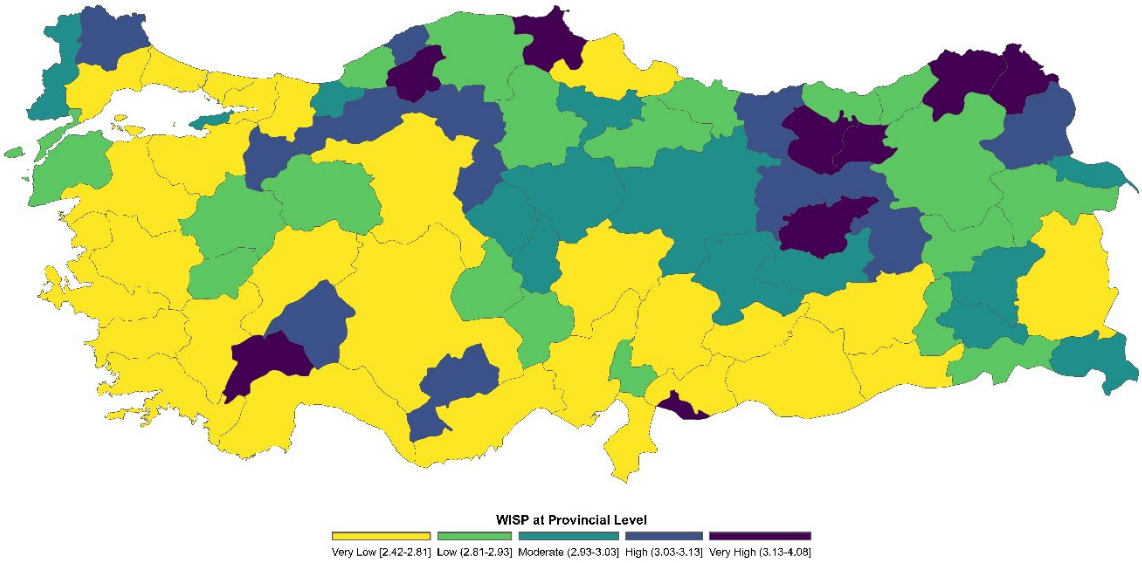

Figure 4. NMV-based WISP scores

Table 3 presents descriptive statistics of WISP scores based on weighting methods for a comprehensive evaluation. The combination with the highest range value is Entropy-based WISP (Range = 2.0444). In the same combination, there are 37 provinces above the average WISP score.

Table 3. Descriptive statistics of WISP scores by combination

Descriptive Statistics	*CRITIC-Based WISP*	*Entropy-Based WISP*	*NMV-Based WISP*
N	81	81	81
Mean	2.9084	2.8874	2.9718
Population standard deviation	0.2463	0.3095	0.2442
Minimum	2.4136	2.0710	2.4208
Maximum	4.0425	4.1154	4.0752
Range	1.6289	2.0444	1.6544
Number of provinces above mean	42	37	42
Number of provinces below mean	39	44	39

Spearman's rank correlation test was used to test whether there is a statistically significant difference between the rankings obtained from the WISP method based on weighting methods. Table 4 presents the results of the correlation test. The correlation between WISP score rankings based on weighting methods was statistically significant and very strong. Therefore, H_A hypothesis was accepted in the correlation test.

Table 4. WISP correlation tests based on weighting methods

Kombinations	*N*	r_s	*p*
CRITIC-based WISP – Entropy-based WISP	81	0.951*	0.000
CRITIC-based WISP – NMV-based WISP	81	0.980*	0.000
Entropy-based-WISP – NMV-based WISP	81	0.901*	0.000

* Correlation is significant at the 0.01 level (2-tailed).

4. DISCUSSION

The COVID-19 pandemic has exposed issues within national health systems, particularly their lack of preparedness for such outbreaks (Shamasunder et al., 2020). As a result, countries is critical for the development of a resilient health system that countries first identify their health systems' capacities and capacity gaps and allocate resources to those gaps. Health systems' resilience plays a crucial role in reacting to both internal and external health threats, as well as effectively addressing global health security threats (Haldane et al., 2021; Vassoney et al., 2021). For this purpose, firstly, it is necessary to evaluate the health system capacity of countries and to determine the importance levels of the decision criteria that stand out in the evaluation of health system capacity. In this context, in this study, the decision criteria used in evaluation of Turkish health system capacity and then the level at which the health system capacity will be evaluated were decided. When weights of decision criteria are evaluated using objective weighting methods, there is a moderately monotonic relationship between Entropy weights and NMV weights. There is no monotonic relationship between other weighting method pairs. One of the primary reasons for this discrepancy is that the CRITIC weighting method, in contrast to other methods, incorporates the direction of decision criteria, specifically the benefit and cost criteria. Another general reason for these differences is that the theoretical concept of the weighting methods is different.

On the other hand, a statistically significant and very strong monotonic relationship was observed between WISP score rankings based on weighting methods. Since the highest monotonic relationship was observed between CRITIC-based WISP and NMV-based WISP scores, it can be said that the results produced from these two combinations are more consistent (Zamani-Sabzi et al., 2016; Vassoney et al., 2021; Baydaş and Pamučar, 2022; Ciardiello and Genovese, 2023). The top three provinces with the highest scores among 81 provinces in Türkiye are Tunceli, Bayburt, and Kilis by CRITIC-based WISP scores. On the contrary, the three provinces with the lowest scores are Bursa, İstanbul, and Şanlıurfa. Tunceli, Bayburt, and Sinop are the top three provinces with the highest NMV-based WISP scores among the 81 provinces. On the contrary, the three provinces with the lowest scores are Bursa, İstanbul, and İzmir. According to the results obtained, the main characteristic of the first three provinces where the optimal solution is reached is that the population is lower in these provinces compared to other provinces, and resource allocation is made more proportionally by population. On the other hand, the main characteristic of the first three provinces, which are furthest from the optimal solution, is the low resources per population compared to other provinces. These results allow for the identification of health system capacity gaps and the enhancement of capacity at the provincial level. By strengthening the national health system from the bottom up, we can build a more resilient and self-sufficient health system capacity. Furthermore, based on the results, decision makers can prioritize health policy decisions at the provincial level.

Decision makers and field workers greatly benefit from the development of the CRITIC, Shannon Entropy, and NMV weighting method application algorithms in the R environment and their open-source sharing in the appendix. Until now, there has been no open sharing of these application algorithms. Instant solutions can be produced on small and especially large-scale data sets, particularly in weighting of decision criteria in health services by the application algorithms.

5. CONCLUSION

This study evaluates the capacity of the Turkish health system at the provincial level using the WISP method, revealing health system capacities and capacity gaps in relative terms. CRITIC, Shannon Entropy, and NMV methods weight the decision criteria used in the evaluation of health capacity. Furthermore, the R programming language was used to develop the application algorithms of these weighting methods.

The provinces that have achieved an optimal solution share a common characteristic: their populations are smaller than those of other provinces, and they allocate resources more proportionally to their populations. In contrast, the provinces that are farthest from optimal solutions share low resources per population. These results allow us to identify health system capacity gaps and enhance capacity at the provincial level. By strengthening the health system from the bottom up, we can build a more resilient and self-sufficient national health system capacity. Moreover, decision-makers can prioritize health policy decisions, particularly resource allocation decisions, at the provincial level. This will strengthen the health system and distribute its capacity more evenly throughout the country. A balanced structure of the health system capacity will also contribute to the elimination of bottlenecks in the health system and easier access of individuals to health services.

The fact that the weighting methods' application algorithms have been developed in a compact manner using the R programming language and shared as open source is thought to be a great contribution to decision makers and field workers. The application algorithms can produce instant solutions on small and especially large-scale decision matrices.

Future studies can use other objective weighting methods not covered in this study to weight the decision criteria used in the evaluation of the Turkish health system capacity. Additionally, by using other MCDM methods, we can assess the capacity of the Turkish health system from a broader perspective, both at the national and provincial level.

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The author declared no potential conflicts of interest.

Compliance with Ethical Standards
It was declared by the author that the tools and methods used in the study do not require the permission of the Ethics Committee.

Ethical Statement
It was declared by the autho that scientific and ethical principles have been followed in this study and all the sources used have been properly cited.

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APPENDIX

The NMV Method's Application Algorithm in R Programming Language

The nmv() function, which is the application algorithm of the NMV (Normalized Maximum Values) weighting method, was developed using the R programming language. The lack of a package for the application algorithm eliminates the need for installation in the R environment. Users can simply copy the application algorithm to the R environment and run it. The nmv() function in R can obtain weights for instant decision criteria in both large-scale and small-scale data sets. Here is the code block for the application algorithm:

```
nmv<-function(dm=NULL){
        colnames(dm)<-paste("C", 1:ncol(dm), sep="")
        rownames(dm)<-paste("A", 1:nrow(dm), sep="")
        dm2 <- dm
        for (r in 1:nrow(dm)){
            for (c in 1:ncol(dm)){
                dm2[r,c] <- dm[r,c]/ apply(dm[,c], 2, sum)
            }
        }
        rmax<-as.matrix(apply(dm2, 2, max))
        mean<-as.matrix(apply(dm2, 2, mean))
        sd<-as.matrix(apply(dm2, 2, sd))
        nv<-as.matrix((rmax-mean)/sd)
        colnames(nv)<-"Normalized Values"
        wj<-round(nv/sum(nv),4)
        colnames(w)<-"weights"
        return(list(dm=as.matrix(dm), rm=as.matrix(dm2), nmv=nv, wj=wj))
}
```

The argument defined in nmv() function is dm. dm is defined as a decision matrix. The rows of dm contain alternatives, and columns contain decision criteria. On the other hand, the outputs that can be obtained from nmv() function are defined in list format within the function. The following outputs are defined in list format:

- dm shows decision matrix (DM) in the first stage.
- rm shows ratio matrix (RM) in the second stage.
- nmv shows normalised values based on maximum criterion values (NMV) in the third stage.
- wj shows weights of decision criteria in the fourth stage.

A Simple Exercise of the NMV Method on R Markdown

Data set

In the following example, a decision matrix (dm) with 4x5 dimensions, i.e., 4 rows and 5 columns, is produced.

```
```{r}
set.seed(1)
data<-rnorm(20, mean=0, sd=1)
dm<-matrix(data, nrow = 4, ncol=5)
dm
```
```

```
           [,1]       [,2]       [,3]        [,4]        [,5]
[1,] -0.6264538  0.3295078  0.5757814 -0.62124058 -0.01619026
[2,]  0.1836433 -0.8204684 -0.3053884 -2.21469989  0.94383621
[3,] -0.8356286  0.4874291  1.5117812  1.12493092  0.82122120
[4,]  1.5952808  0.7383247  0.3898432 -0.04493361  0.59390132
```

nmv () function

The outputs produced by the nmv () function can be taken separately using the $ sign.

```
```{r}
nmv(dm)
```
```

```
$dm
           C1         C2         C3          C4          C5
A1 -0.6264538  0.3295078  0.5757814 -0.62124058 -0.01619026
A2  0.1836433 -0.8204684 -0.3053884 -2.21469989  0.94383621
A3 -0.8356286  0.4874291  1.5117812  1.12493092  0.82122120
A4  1.5952808  0.7383247  0.3898432 -0.04493361  0.59390132

$rm
           C1         C2         C3          C4          C5
A1 -1.9771823  0.4484361  0.2650906  0.35379310 -0.00691074
A2  0.5796059 -1.1165978 -0.1406013  1.26125944  0.40287217
A3 -2.6373694  0.6633555  0.6960263 -0.64064199  0.35053451
A4  5.0349458  1.0048062  0.1794844  0.02558944  0.25350406

$nmv
   Normalized Values
C1         1.3755451
C2         0.8034763
C3         1.2934929
C4         1.2784641
C5         0.8394482

$wj
   weights
C1  0.2461
C2  0.1437
C3  0.2314
C4  0.2287
C5  0.1502
```

The Shannon Entropy Method's Application Algorithm in R Programming Language

The entropy() function, which is an application algorithm of the entropy weighting method, was developed using the R programming language. The lack of a package for the application algorithm eliminates the need for installation in the R environment. Users can simply copy the application algorithm to the R environment and run it. The entropy() function in R can obtain weights for instant decision criteria in both large-scale and small-scale data sets. The following code block outlines the application algorithm:

```
entropy <- function(dm=NULL){
        colnames(dm)<-paste("C", 1:ncol(dm), sep="")
        rownames(dm)<-paste("A", 1:nrow(dm), sep="")
        ndm<-apply(dm, 2, function (x) x/sum(x))
        lndm<-apply(ndm, 2, function (x) x*log(x))
        ec<-1/log(nrow(dm))
        ej<-apply(lndm, 2, function (x) (-ec)*sum(x))
        ej<-ej
        dj<-1-ej
        wj<-dj/sum(dj)
        return(list(dm=dm, ndm=ndm, ej=ej, dd=dj, wj=wj))
}
```

The argument defined in the entropy() function is dm. dm is defined as a decision matrix. The rows of dm contain alternatives, and columns contain decision criteria. On the other hand, the outputs that can be obtained from entropy() function are defined in list format within the function. The outputs defined in list format are as follows: The entropy() function defines its outputs in list format. The following outputs are defined in list format:

- dm shows decision matrix in the first stage.
- ndm shows normalised decision matrix in the second stage.
- ej shows entropy values of the criteria in the third stage.
- dd shows degree of differentiation of information in the fourth stage.
- wj denotes weights of decision criteria in the fifth stage.

A Simple Exercise of the Shannon Entropy Method on R Markdown

Data set

In the following example, a decision matrix (dm) with 4x5 dimensions, i.e. 4 rows and 5 columns, is produced.

```
```{r}
set.seed(1)
data<-abs(rnorm(20, mean=0, sd=1))
dm<-matrix(data, nrow = 4, ncol=5)
dm
```
```

```
          [,1]      [,2]      [,3]       [,4]       [,5]
[1,] 0.6264538 0.3295078 0.5757814 0.62124058 0.01619026
[2,] 0.1836433 0.8204684 0.3053884 2.21469989 0.94383621
[3,] 0.8356286 0.4874291 1.5117812 1.12493092 0.82122120
[4,] 1.5952808 0.7383247 0.3898432 0.04493361 0.59390132
```

entropy () function

The outputs produced by entropy () function can be taken separately using the $ sign.

```
```{r}
entropy(dm)
```
```

```
$dm
          C1        C2        C3         C4         C5
A1 0.6264538 0.3295078 0.5757814 0.62124058 0.01619026
A2 0.1836433 0.8204684 0.3053884 2.21469989 0.94383621
A3 0.8356286 0.4874291 1.5117812 1.12493092 0.82122120
A4 1.5952808 0.7383247 0.3898432 0.04493361 0.59390132

$ndm
           C1        C2        C3         C4          C5
A1 0.19328989 0.1386975 0.2069076 0.15508508 0.006816525
A2 0.05666244 0.3453542 0.1097416 0.55287262 0.397379792
A3 0.25782997 0.2051702 0.5432602 0.28082518 0.345755655
A4 0.49221770 0.3107780 0.1400906 0.01121712 0.250048028

$ej
       C1        C2        C3        C4        C5
0.8502665 0.9589146 0.8477926 0.7384544 0.8039585

$dd
        C1         C2         C3         C4         C5
0.14973350 0.04108544 0.15220739 0.26154564 0.19604145

$wj
        C1         C2         C3         C4         C5
0.18702348 0.05131745 0.19011346 0.32668156 0.24486406
```

The CRITIC Method's Application Algorithm in R Programming Language

The critic() function, which is an application algorithm of the CRITIC (CRiteria Importance Through Intercriteria Correlation) weighting method, was developed using R programming language. The R environment does not require the installation of the application algorithm, as it does not come as a package. Users can simply copy the application algorithm to the R environment and run it. InThe critic () function in R can obtain weights for instant decision criteria in both large-scale and small-scale data sets. Below is the code block for the application algorithm:

```
critic<-function(dm=NULL, dc=NULL, nd=NULL){
            dm2 <- dm
            dc1=ifelse(dc=="max", 1, 0)
            for (r in 1:nrow(dm))
               for (c in 1:ncol(dm))
                  if (dc1[c])
                  {
```

```
            dm2[r,c] <- (dm[r,c]-min(dm[,c]))/(max(dm[,c])-min(dm[,c]))
         } else
         {
            dm2[r,c] <- (max(dm[,c])-dm[r,c])/(max(dm[,c])-min(dm[,c]))
         }
        ndm<-dm2
        if (nd==TRUE) {
        rcm<-cor(ndm)
        rownames(rcm)<-NULL
        } else if (nd==FALSE) {
        rcm<-cor(ndm, method = "spearman")
        rownames(rcm)<-NULL
        }
        rcm1<-1-rcm
        rownames(rcm1)<-NULL
        qj<-apply(ndm, 2, sd)
        cj<-qj*apply(rcm1, 2, sum)
        wj<-cj/sum(cj)
        return(list(dm=as.matrix(dm), ndm=as.matrix(ndm), rcm=as.matrix(rcm),  cj=round(cj,4),
wj=round(wj,4)))
 }
```

The critic () function defines the following arguments:

- dm is defined as a decision matrix. The rows of dm contain alternatives, and columns contain decision criteria.
- dc indicates direction of criterion, which is defined as maximum or minimum in vector format. In other words, maximum is equal to "max", and minimum is equal to "min".
- nd shows whether values of decision criteria conform to normal distribution. nd takes 2 different logic vector values as TRUE and FALSE. If values of decision criteria are normally distributed, nd value will be TRUE.

The outputs that can be obtained from critic () function are defined in list format within the function. The outputs defined in list format are as follows:

- dm shows decision matrix in the first stage.
- ndm shows normalised decision matrix in the second stage.
- rcm shows relationship coefficient matrix in the third stage.
- cj indicates quantity of information in the fourth stage.
- wj denotes weights of decision criteria in the fifth stage.

A simple Application of CRITIC Method on R Markdown

Data set

The provided example generates a decision matrix (dm) with dimensions of 4x5, defined as 4 rows and 5 columns.

```
```{r}
set.seed(1)
data<-rnorm(20, mean=0, sd=1)
dm<-matrix(data, nrow = 4, ncol=5)
colnames(dm)<-paste("C", 1:ncol(dm), sep="")
dm

dc<-c("min", "max", "min", "min", "max")

nd<-FALSE

```
```

```
             C1         C2         C3          C4          C5
[1,] -0.6264538  0.3295078  0.5757814 -0.62124058 -0.01619026
[2,]  0.1836433 -0.8204684 -0.3053884 -2.21469989  0.94383621
[3,] -0.8356286  0.4874291  1.5117812  1.12493092  0.82122120
[4,]  1.5952808  0.7383247  0.3898432 -0.04493361  0.59390132
```

critic () function

The outputs produced by critic () function can be taken separately using the $ sign.

```
```{r}
critic(dm=dm, dc=dc, nd=nd)
```
```

```
$dm
             C1         C2         C3          C4          C5
[1,] -0.6264538  0.3295078  0.5757814 -0.62124058 -0.01619026
[2,]  0.1836433 -0.8204684 -0.3053884 -2.21469989  0.94383621
[3,] -0.8356286  0.4874291  1.5117812  1.12493092  0.82122120
[4,]  1.5952808  0.7383247  0.3898432 -0.04493361  0.59390132

$ndm
            C1        C2        C3        C4        C5
[1,] 0.9139520 0.7377350 0.5150867 0.5228636 0.0000000
[2,] 0.5807034 0.0000000 1.0000000 1.0000000 1.0000000
[3,] 1.0000000 0.8390449 0.0000000 0.0000000 0.8722795
[4,] 0.0000000 1.0000000 0.6174096 0.3502976 0.6354945

$rcm
       C1   C2   C3   C4   C5
[1,]  1.0 -0.2 -0.8 -0.4  0.0
[2,] -0.2  1.0 -0.4 -0.8 -0.4
[3,] -0.8 -0.4  1.0  0.8  0.4
[4,] -0.4 -0.8  0.8  1.0  0.2
[5,]  0.0 -0.4  0.4  0.2  1.0

$cj
    C1     C2     C3     C4     C5
2.4483 2.5684 1.6486 1.7468 1.6887

$wj
    C1     C2     C3     C4     C5
0.2424 0.2543 0.1632 0.1729 0.1672
```

Table A1. Decision matrix

Province	*c1*	*c2*	*c3*	*c4*	*c5*	*c6*	*c7*	*c8*	*c9*	*c10*	*c11*	*c12*	*c13*	*c14*	*c15*
Adana	71065.8	34.3	7.2	3020	4.4	67.3	438339.6	2292.4	1994829.8	363391.8	1438397.2	357395.3	34456	23444	12.4
Adıyaman	52930.8	21.6	4.8	2914	3.9	66.2	616668.9	2540.7	2582.0	378527.4	1021.2	358852.5	17644	10766	6.6
Afyonkarahisar	33979.8	31.4	5.3	2932	5.2	60.1	550077.3	2613.8	2343.4	357853.0	1306.9	333283.5	18233	10679	7.7
Ağrı	56736.2	17.3	2.4	2869	3.2	53.8	802.9	6078.9	3839.3	572.5	1542.7	540.9	21276	9118	8.2
Amasya	48323.9	25.9	3.8	2891	4.3	48.4	651.8	2602.1	2301.1	356.1	1003.8	297770.2	16108	8054	6.4
Ankara	68836.7	41.3	7.3	3223	4.9	52.1	250456.3	1344092.3	1828101.5	261523.5	1506588.1	314186.3	33424	21656	21.1
Antalya	58434.9	28.2	5.5	3072	3.7	59.3	424042.3	1330695.0	1739808.4	408946.3	1474494.8	353917.6	38400	24216	10.6
Artvin	21175.4	21.3	2.5	2871	3.2	42.7	564.7	3604.3	2823.4	396.7	795.3	268.0	6516	3529	6.6
Aydın	47843.4	31.2	5.4	3062	3.8	56.4	506056.0	2103.0	2083.9	372322.0	1123523.5	382110.1	26096	16641	7.7
Balıkesir	50303.6	26.9	4.5	2931	4.3	55.7	572412.4	2303.3	2127.9	359311.4	944136.6	361792.3	19650	13820	7.6
Bilecik	28584.1	26.2	4.5	2970	4.8	39.3	662.8	2931.7	2690.3	330.5	1191.0	307.4	14292	6534	5.5
Bingöl	35319.5	26.7	2.8	2826	3	33.3	706.4	3071.3	3038.2	355.0	923.4	317.8	14871	7245	7.3
Bitlis	44248.5	30.1	5	3161	3.5	48	722.4	4985.7	3436.8	319195.7	1287.2	372.6	17699	8850	9.4
Bolu	29165.8	48	6.6	2839	4.9	59.7	377.4	1485.3	2005.2	269373.6	1069.4	275149.2	13368	6974	7.7
Burdur	34224.9	28.1	3.9	2794	3.8	45.5	618.1	2882.1	2013.2	338.4	832.2	290.0	11408	6367	5.1
Bursa	76064.8	26.3	4.8	3166	4.5	68.8	505253.8	2004215.8	2308323.7	403832.6	1751491.2	456714.8	33629	22341	11.2
Çanakkale	39955.9	32.2	4.9	3160	3.9	51.7	408607.0	2508.4	2202.3	317650.8	889.3	302696.4	19289	11654	10
Çankırı	21751.8	24.3	2.1	3107	4.4	49.6	659.1	2681.7	2796.7	431.2	1322.7	257.2	10303	4350	3.7
Çorum	32758.1	32.7	5.1	2773	4.4	57.8	566.6	2961.2	2393.3	334479.9	1050.4	344822.4	14166	8884	5.9
Denizli	45927.5	30	5.1	3116	3.1	62.6	453945.9	1985.6	1886.3	372603.9	1054223.6	335237.1	29343	17038	7.2
Diyarbakır	64460.0	27.5	6.2	3101	3.4	56.4	543638.6	3038.5	2768.2	378381.6	1652820.5	448194.7	27767	16559	10
Edirne	37701.3	46.7	6.5	3072	4.5	53.3	287198.1	2013.2	1876.5	250582.5	1060.6	296224.3	20736	8640	7.5
Elâzığ	45499.8	53.8	8.9	2803	4.7	66.1	412480.5	2158.7	2474.9	244218.4	941.9	308714.5	17397	9540	7.2
Erzincan	23922.3	26.8	3.8	3107	3.5	58.5	537.6	2416.4	2491.9	313.5	1000.9	291.0	10874	4272	10.1
Erzurum	35702.6	48.5	6.4	2726	5.7	61.7	402444.4	2357.7	2403.1	244538.2	1037.0	309432.1	22720	9865	9.1
Eskişehir	60441.1	39.8	6.9	3094	4.9	67.6	385138.9	1873.2	1854.0	260522.1	1266.2	290582.4	20605	13139	5.1
Gaziantep	65274.3	33.1	7.6	2758	3.6	59.4	588860.3	3046.7	2445.0	384103.2	1772881.5	487783.3	36509	21118	12.2
Giresun	25047.9	38.8	6.9	2928	4.1	59.8	601.1	3886.7	1960.3	268051.1	844.3	253435.6	14544	7514	7.3
Gümüşhane	24090.7	26.9	3.3	2950	3.3	31	599.8	3075.4	3441.5	324.8	1267.9	273.8	9034	3614	7.7
Hakkâri	55066.6	17.9	2.9	3059	2	30.3	734.2	4916.7	5006.1	559.6	1678.9	407.9	10590	4917	11.6
Hatay	70251.8	27.4	5.8	3205	3.5	61	578005.8	2902.0	2156.1	418892.7	1486810.4	452629.0	26344	13934	6.6
Isparta	29688.3	47.7	10.5	2732	5.3	65.5	314273.1	1649.4	1988.1	224798.1	833.9	257711.2	17813	8564	5.5
Mersin	70979.0	26.5	5.4	3096	4.1	59.8	558238.3	2334.3	2080.8	398426.6	1177893.1	423053.4	29037	17265	10.3
İstanbul	67982.7	30.2	6	3187	4.4	56.8	352421.4	1452383.0	2029852.1	358343.7	2373966.7	383656.9	42308	28356	15.6
İzmir	70826.3	28.1	5	3231	4.5	60.4	342971.3	1603325.9	1930790.1	344746.7	1622565.8	354976.6	39487	25497	13.7
Kars	34353.6	29.4	4.1	2776	3.2	31.2	551.9	5388.8	3870.8	386.0	759.2	356.0	17177	6246	9.7
Kastamonu	18005.5	30.9	3.4	3125	4	44.6	596.4	3346.2	2662.8	363222.9	1215.8	311976.1	10503	6002	6.3
Kayseri	53389.7	33.2	6.1	2997	4.1	66.1	437886.7	1958.6	1929.7	320908.9	1316459.4	357875.6	26695	16197	4.9
Kırklareli	36934.7	27.4	5	2955	3.4	51.1	583.5	2601.0	2135.0	398.0	1165.1	393.8	15389	7387	6.6
Kırşehir	40753.2	24.5	3.4	2911	4.5	64.8	560.8	3134.9	2469.9	366.0	899.0	272.0	12869	6270	7.1
Kocaeli	71692.1	23.6	4.8	3243	3.9	61.4	521462.8	2235.6	2750.1	390362.7	1630644.7	409024.6	39228	25049	6.3
Konya	51029.9	38.3	6.9	3112	4.6	57.7	428823.0	2162285.3	2106740.4	306057.2	1388359.7	367709.7	26702	18081	6
Kütahya	41478.6	34.1	4.2	2889	5.4	54.8	586.0	2471.1	2439.9	292839.6	987.6	304350.6	20024	12098	6.7
Malatya	40629.0	43.7	8.1	2851	4.3	58.9	406493.2	2094.3	2138.4	267120.3	867.2	302074.3	20835	10834	6.8
Manisa	50630.3	33.7	6.8	3124	4.9	59.1	514824.3	3299.5	2162.4	379204.3	1259244.4	424972.2	25759	15137	8.2
Kahramanmaraş	65413.1	26.4	7.6	2900	4.1	65.6	599509.2	3199.6	2526.7	380554.6	1338.0	388977.9	25596	14359	7.3
Mardin	72531.2	16.6	3.7	2854	3.4	59.5	729567.5	4125.0	2853.7	501656.5	1588.3	477702.5	29012	18133	9.9
Muğla	47644.8	22.3	3.2	3167	3.7	56.3	496064.8	1712.7	1855.2	411698.7	1150.6	375558.9	17470	11271	11.1
Muş	57028.9	18.9	2.6	3047	3	50.2	833.4	7258.2	4696.5	442.1	1750.9	488.6	22178	10236	9
Nevşehir	31001.1	27.6	4.6	2981	4.7	62.9	704.6	2672.5	2214.4	372.2	1115.1	312.5	18236	7949	8.3
Niğde	45677.4	25	3.7	2833	4.5	56.4	729.4	3582.5	2372.9	422.9	1087.6	352721.0	15226	7944	5.9
Ordu	42399.4	30.2	4.9	2958	3	56.9	587069.2	2469.9	2205.8	356131.6	1129.0	334292.6	16238	10903	8.3
Rize	31274.2	32.6	3	3185	3.6	54.6	441.0	1600.1	2389.0	326390.9	1260.1	325464.5	14334	6880	5.7
Sakarya	60004.4	22.1	3.8	3273	4.1	58.7	552188.1	2394.9	2432.6	414141.1	1348.4	470828.2	25118	17421	6.8
Samsun	52634.2	38.9	6.7	3068	5.2	70.4	408138.4	1971.9	2061.0	293856.1	1209980.5	304785.7	26833	18247	5.7
Siirt	41413.9	23.6	3.8	3068	3.3	61.3	726.6	4801.6	2984.8	414.7	1392.1	382.6	17437	7888	8.5
Sinop	31542.7	35.6	5.7	3154	4.6	40.8	629.1	3066.7	2300.0	313.6	955.8	275.3	8832	4698	6
Sivas	31746.2	46.1	6.6	2981	4.1	39.8	438786.5	2123.5	2227.8	264001.7	929.6	278231.4	16280	8466	6.9
Tekirdağ	57122.6	28.2	6.4	3236	3.7	59.9	606074.8	2446.4	2656.9	434722.6	1620.5	438729.3	28561	17052	10.3

Table A1. (*Continued*)

Province	*c1*	*c2*	*c3*	*c4*	*c5*	*c6*	*c7*	*c8*	*c9*	*c10*	*c11*	*c12*	*c13*	*c14*	*c15*
Tokat	39763.6	37.6	5	2895	3.9	55	561632.8	2474.9	2329.9	297780.3	1028.4	302308.2	19882	12426	6.1
Trabzon	37182.9	41.4	5.7	2880	4.4	58.2	361797.0	2009.9	1947.7	254123.3	1134.6	253886.7	19477	11855	6.5
Tunceli	14061.0	17.8	2.7	2721	3.7	28.4	466.1	2008.7	3124.7	334.8	570.0	211.4	7031	2481	9.5
Şanlıurfa	108505.5	19.5	5.4	3100	3.6	72.5	819527.9	5452.5	2643.3	535037.0	2060883.2	585093.0	35576	18236	10.7
Uşak	53636.3	30.7	4.2	2910	3.5	50.1	631.0	1849.5	2289.4	354536.4	720.6	357575.2	19761	10147	5.5
Van	75249.9	26.8	5.9	2917	4.1	59.8	645368.2	3988.5	3319.9	362126.7	1650.2	405878.8	24016	14471	11.6
Yozgat	26152.6	30.1	3.8	2886	3.3	42.1	611.8	3487.0	2866.0	327932.6	1040.9	313439.7	16094	8047	4.1
Zonguldak	49042.5	39.3	6.3	2987	4.4	57	487177.2	2229.2	2204.2	302575.8	1213.4	343354.7	22635	12010	8
Aksaray	43305.5	25.8	4.3	3028	3.4	48.4	696.2	3331.2	2353.6	389788.5	1366.1	408928.2	17322	10071	7.7
Bayburt	84241.0	38	5.6	2553	3.8	31.8	577.0	3510.0	3008.6	319.1	1015.0	240.7	10530	2478	4.5
Karaman	43473.0	22	4.7	2746	4.7	64	624.0	2745.7	2248.6	366.3	1026.9	345.9	14491	6521	4
Kırıkkale	39578.0	45.3	6.5	2947	5	53	416.0	1583.1	2328.1	302.8	1029.9	204010.3	15391	7696	5.4
Batman	52874.3	28.8	7	3021	3.5	50.1	729.3	3822.2	2897.2	374773.2	1419.4	388781.3	23500	15107	8.8
Şırnak	79657.9	13.8	1.7	3186	2.6	38.5	906.7	5069.1	3954.6	615.5	2212.7	603.5	22304	12673	18
Bartın	50837.8	24.7	5.7	2676	4.4	54.2	694.0	3279.9	2259.5	374.5	1070.3	382.2	14525	7012	5.2
Ardahan	23120.3	23.2	2.8	2569	4.1	45.3	589.1	2890.0	3699.2	400.4	833.2	281.1	7114	2371	7.2
Iğdır	50898.5	16	3.2	3181	2.4	54.5	789.1	3510.2	3231.7	495.4	1288.6	415.5	16966	7020	8.1
Yalova	42333.3	23.7	5.8	3256	2.8	68.9	588.0	2043.7	2409.2	432.6	1619.3	284388.7	18521	9878	6.4
Karabük	42009.7	29.8	5.2	2931	3.8	56.7	472.0	2032.7	2520.6	337.4	1033.0	289.7	14827	6633	6.2
Kilis	73959.5	42.6	7.9	3082	3.5	40.2	506.6	2207.7	2083.4	279.6	826.4	308.2	10566	3893	12
Osmaniye	55940.5	22.6	5.2	2840	2.9	60.5	794.6	2715.6	2159.9	469299.5	1185.2	340685.1	20719	11654	5.7
Düzce	45014.6	22.2	3.6	2894	2.8	55	486.4	3267.2	2873.3	431.9	1646.9	420.3	21323	9881	5.9

Table A2. WISP scores based on weighting methods

	CRITIC-Based WISP		*Entropy-Based WISP*		*NMV-Based WISP*	
Alternatives	*Overall Utility*	*Rank*	*Overall Utility*	*Rank*	*Overall Utility*	*Rank*
Tunceli	4.0425	1	4.1154	1	4.0752	1
Bayburt	3.4594	2	3.4494	2	3.4563	2
Kilis	3.4513	3	3.4452	3	3.4179	4
Sinop	3.3631	4	3.4451	4	3.4247	3
Gümüşhane	3.2225	5	3.2674	6	3.2556	5
Burdur	3.1862	6	3.2371	8	3.2341	7
Artvin	3.1855	7	3.2594	7	3.2364	6
Ardahan	3.1794	8	3.2677	5	3.2315	8
Karabük	3.1508	9	3.2089	9	3.1929	11
Kars	3.1288	10	3.1240	16	3.1265	18
Kırıkkale	3.1228	11	3.0451	22	3.1936	10
Erzincan	3.1183	12	3.2079	10	3.1590	12
Kırklareli	3.1145	13	3.1567	12	3.1497	14
Bilecik	3.1015	14	3.1710	11	3.1554	13
Bingöl	3.0871	15	3.1006	18	3.1006	22
Bartın	3.0854	16	3.1451	14	3.1267	17
Isparta	3.0710	17	2.9022	34	3.2021	9
Bolu	3.0405	18	2.9375	31	3.1473	15
Çankırı	3.0401	19	3.1477	13	3.1173	20
Karaman	3.0322	20	3.1302	15	3.0953	23
Giresun	3.0308	21	2.9349	33	3.1354	16
Hakkâri	3.0225	22	3.0418	23	3.0036	37
Nevşehir	3.0162	23	3.1074	17	3.0618	26
Elâzığ	3.0157	24	2.8680	43	3.1253	19
Düzce	3.0042	25	3.0486	21	3.0276	32
Sivas	2.9981	26	2.8551	48	3.1038	21
Siirt	2.9920	27	3.0619	20	3.0199	35
Kırşehir	2.9906	28	3.0939	19	3.0398	28
Yalova	2.9775	29	2.9661	27	3.0370	29
Bitlis	2.9765	30	2.9407	30	3.0279	31
Edirne	2.9705	31	2.8757	40	3.0684	25
Malatya	2.9677	32	2.8565	47	3.0723	24
Iğdır	2.9610	33	3.0294	24	2.9786	42
Amasya	2.9464	34	2.9493	28	2.9986	38
Yozgat	2.9404	35	2.8888	37	3.0457	27
Muş	2.9257	36	2.9950	25	2.9301	50
Trabzon	2.9242	37	2.8599	45	3.0230	34
Çorum	2.9199	38	2.8900	36	3.0297	30
Niğde	2.9184	39	2.9359	32	2.9840	41
Ağrı	2.9151	40	2.9932	26	2.9269	51
Erzurum	2.9131	41	2.8541	49	3.0132	36
Kastamonu	2.9110	42	2.8844	39	3.0275	33
Batman	2.8950	43	2.8732	42	2.9646	44
Rize	2.8903	44	2.8847	38	2.9959	39
Eskişehir	2.8837	45	2.8515	50	2.9865	40
Uşak	2.8837	46	2.8749	41	2.9685	43
Kütahya	2.8711	47	2.8920	35	2.9596	46
Zonguldak	2.8604	48	2.8231	52	2.9577	47
Tokat	2.8565	49	2.8149	53	2.9630	45
Aksaray	2.8520	50	2.8610	44	2.9406	48
Osmaniye	2.8427	51	2.8571	46	2.9349	49
Şırnak	2.8426	52	2.9467	29	2.8006	66
Çanakkale	2.8364	53	2.8289	51	2.9232	52
Ordu	2.8189	54	2.7982	55	2.9219	53
Afyonkarahisar	2.7915	55	2.8042	54	2.9137	54
Samsun	2.7840	56	2.7305	62	2.8737	56
Kahramanmaraş	2.7762	57	2.7878	56	2.8795	55

Table A2. (*Continued*)

	CRITIC-Based WISP		*Entropy-Based WISP*		*NMV-Based WISP*	
Alternatives	*Overall Utility*	*Rank*	*Overall Utility*	*Alternatives*	*Overall Utility*	*Rank*
Kayseri	2.7667	58	2.7089	66	2.8579	57
Denizli	2.7471	59	2.7197	64	2.8304	60
Aydın	2.7396	60	2.7054	67	2.8266	61
Adıyaman	2.7386	61	2.7838	58	2.8544	58
Manisa	2.7350	62	2.6927	68	2.8314	59
Van	2.7280	63	2.7754	59	2.8069	64
Tekirdağ	2.7273	64	2.7701	60	2.8237	62
Balıkesir	2.7208	65	2.7143	65	2.8154	63
Muğla	2.7113	66	2.7873	57	2.8059	65
Diyarbakır	2.6939	67	2.6511	71	2.7637	69
Gaziantep	2.6906	68	2.6311	73	2.7461	70
Hatay	2.6837	69	2.6567	70	2.7764	67
Sakarya	2.6665	70	2.7675	61	2.7737	68
Mersin	2.6639	71	2.6828	69	2.7385	71
Ankara	2.6231	72	2.2988	76	2.5769	76
Adana	2.6121	73	2.4338	75	2.6504	74
Kocaeli	2.6116	74	2.6466	72	2.6841	73
Mardin	2.6056	75	2.7300	63	2.7007	72
Konya	2.6023	76	2.1397	80	2.6131	75
Antalya	2.5413	77	2.2728	77	2.5547	78
İzmir	2.4907	78	2.2126	78	2.4785	79
Şanlıurfa	2.4898	79	2.5485	74	2.5719	77
İstanbul	2.4755	80	2.1595	79	2.4535	80
Bursa	2.4136	81	2.0710	81	2.4208	81