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## Intercriteria analysis applied to university ranking system of Turkey

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**Abstract:** In the current investigation, an application of the InterCriteria Analysis over a daaset of university rankings of Turkey is discused. InterCriteria Analysis is used to deremine possible dependencies or independencies between indicators used for universities evaluation. The comparison of the results is presented. The obtained results can be helpful for improvement of the universities estimation process using the appropriate parameters.

Keywords: InterCriteria Analysis, University rankings.2010 Mathematics Subject Classification: 03E72.

### 1 A brief introduction of InterCriteria Analysis

InterCriteria Analysis (ICA) is a new method for decision making based on the theories of the intuitionistic fuzzy sets [5, 6, 8] and index matrices [4]. Let us have an index matrix containing the criteria on the rows and objects on the columns.

	$O_1$	•••	$O_i$	•••	$O_{j}$	•••	$O_n$
$A = C_1$	$a_{C_{1},O_{1}}$		$a_{C_1,O_i}$		$a_{C_1,Oj_1}$		$a_{C_1,O_n}$
÷	:	·.	:	·.	÷	·.	:
$C_k$	$a_{C_k,O_1}$		$a_{C_k,O_i}$		$a_{C_k,O_j}$		$a_{C_k,O_n}$
:	:	·.	:	·.	÷	·.	:
$C_l$	$a_{C_l,O_1}$		$a_{C_l,O_i}$		$a_{C_l,O_j}$		$a_{C_l,O_n}$
:	:	·.	:	••.	÷	•.	:
$C_m$	$a_{C_m,O_1}$		$a_{C_m,O_i}$		$a_{C_m,O_j}$		$a_{C_m,O_n}$

The intercriteria analysis makes comparison between every two criteria from adjacent rows and adjacent columns. There are counters that calculate the type of the relations between the criteria. If there are  $\langle, \langle \text{ or } \rangle, \rangle$  the first counter increments, while if there are the relations  $\langle, \rangle$  or  $\rangle, \langle$  the value of the second counter increments. The procedure of ICA functioning is explained in [7]. The resulting index matrix has the following form:

The situation with the relations of type =,= is investigated in [23] and different scenarios and algorithms for calculation are proposed.

The method is extended in several research works. Intercriteria analysis over intuitionistic fuzzy data is presented in [15]. ICA with triples is proposed in [10]. A version of the method using a special type of intuitionistic fuzzy implications is investigated in [3]. InterCriteria Analysis with interval-valued intuitionistic fuzzy evaluations is proposed in [2]. Three-dimensional version of ICA is presented in [33].

InterCriteria analysis is successfully applied in different science fields. With respect to university rankings, there are similar steps of research conducted for the following countries: Bulgaria [16], Poland [18], Slovakia [14], United Kingdom [28], Australia [30], and India [20]. In the area of healthcare and medicine, there are applications of ICA from the recent years [1, 13, 19, 27, 31, 32, 36]. The topic of ecology is discussed in [29]. Applications of the ICA over data of global competitiveness reports of the World Economic Forum are implemented in [9, 11, 12]. The ICA applications in the area of neural networks and genetic algorithms are presented in [21, 22, 24–26].

### 2 Intercriteria analysis applied to the university rankings of Turkey

The university rankings of Turkey are presented by URAP-University Ranking by Academic Performance which are established at the Informatics Institute of Middle East Technical University in 2009. The aim is to provide a ranking system for the ranking system for the world universities based on academic performance indicators that reflect the quality and the quantity of

their scholarly publications [34, 35]. The University Ranking by Academic Performance evaluates 157 universities according to 5 indicators. The indicators are the following: paper score, total citation score, total scientific document score, number of graduated doctoral students, scientist/student score. The methodology of the indicators selection for the university rankings is described in [34, 35]. The dependencies between the indicators are presented in the Figure 1 after ICA application over input data. The investigation is performed using the ICrAData Software [17].

μ	paper score	total citation score	total scientific document score	number of graduated doctoral students	scientist/ student score
paper score	<b>〈1.00, 0.00〉</b>	$\langle 0.87, 0.13 \rangle$	$\langle 0.90, 0.10  angle$	$\langle 0.73, 0.25 \rangle$	$\langle 0.57, 0.43 \rangle$
total citation score	$\langle 0.87, 0.13 \rangle$	<b>(1.00, 0.00)</b>	$\langle 0.89, 0.11 \rangle$	$\langle 0.72, 0.26 \rangle$	$\langle 0.53, 0.47 \rangle$
total scientific document score	(0.90, 0.10)	(0.89, 0.11)	<b>&lt;1.00, 0.00&gt;</b>	$\langle 0.76, 0.22 \rangle$	$\langle 0.56, 0.44 \rangle$
number of graduated doctoral students	(0.73, 0.25)	⟨0.72, 0.26⟩	⟨0.72, 0.26⟩	<b>〈1.00, 0.00〉</b>	$\langle 0.48, 0.50 \rangle$
scientist/student score	(0.57, 0.43)	(0.53, 0.47)	⟨0.56, 0.44⟩	$\langle 0.48, 0.50 \rangle$	<b>〈1.00, 0.00〉</b>

Figure 1. Results of ICA application over input data for criteria relationships investigation

The results are visualized in the intuitionistic fuzzy triangle (Figure 2). The green points are the data (criteria) that have dependencies. The pink points present the independent indicators.



Figure 2. Results of ICA presented on the IF-triangle

The relationships between the indicators are determined using the intuitionistic fuzzy pairs from ICA application. The results are presented in the Figure 3. There are three pairs of indicators in strong dissonance, one pair of indicators in dissonance, two pairs of indicators in weak dissonance, one pair of criteria in weak positive consonance and 3 pairs of indicators in positive consonance.

Type of consonance	Number of pairs	Description	
<b>Strong Dissonance</b> [0,43; 0,57)	3	total citation score – scientist/student score, total scientific document score – scientist/student score, number of graduated doctoral students – scientist/student scor	
<b>Dissonance</b> [0,57; 0,67)	1	paper score – scientist/student score	
<b>Weak Dissonance</b> [0,67; 0,75)	2	paper score – number of graduated doctoral students, total citation score – number of graduated doctoral students	
Weak Positive Consonance [0,75; 0,85)	1	total scientific document score – number of graduated docto students	
Positive Consonance [0,85; 0,95)paper score - total citation score, paper score - total scientific document score, total citation score - total scientific document score		paper score – total citation score, paper score – total scientific document score, total citation score – total scientific document score	

Figure 3. Pairs of indicators (2018–2019)

The results of application of the ICA to the data for ranking system of Turkey show dependencies between the pairs of indicators "*paper score – total citation score*", "*paper score – total scientific document score*", "*total citation score – total scientific document score*" and "*total scientific document score*", "*total citation score – total scientific document score*" and "*total scientific do* 

# **3** Comparison of the results with investigations for the previous and next years

The ICA is applied to the data of university rankings for two years: 2017–2018 and 2019–2020. The aim is to compare the results against the one obtained in the previous section. The outputs will determine the constant or variable behavior of the selected indicators. The results for year 2019–2020 are presented in Figure 4. Obviously, in the second application, the pair of indicators "*paper score – scientist/student score*" is moved from dissonance to strong dissonance. This arrangement confirms the harder independency between these two indicators.

At the next step, ICA is applied over the data for university rankings of 2017–2018. The results are presented in Figure 5. The third application confirms again the constant behavior of the indicators. There are 4 pair of indicators with dependencies and 6 pairs of indicators that are independent. The pairs in positive and weak positive consonance are "paper score – total citation score", "paper score – total scientific document score", "total citation score – total scientific document score" and "total scientific document score – number of graduated doctoral students". The pairs in dissonance, weak dissonance or strong dissonance are: "total citation score – scientist/student score", "paper score – scientist/student score".

Type of consonance	Number of pairs	Description		
<b>Strong Dissonance</b> [0,43; 0,57)	4	paper score – scientist/student score, total citation score – scientist/student score, total scientific document score – scientist/student score, number of graduated doctoral students – scientist/student score		
<b>Weak Dissonance</b> [0,67; 0,75)	2	paper score – number of graduated doctoral students, total citation score – number of graduated doctoral students		
Weak Positive Consonance [0,75; 0,85)	1	total scientific document score – number of graduated doctoral students		
<b>Positive Consonance</b> [0,85; 0,95)	3	paper score – total citation score, paper score – total scientific document score, total citation score – total scientific document score		

Figure 4. Pairs of indicators (2019–2020)

Type of consonance	Number of pairs	Description	
<b>Strong Dissonance</b> [0,43; 0,57)	3	total citation score – scientist/student score, total scientific document score – scientist/student score, number of graduated doctoral students – scientist/student scor	
<b>Dissonance</b> [0,57; 0,67)	1	paper score – scientist/student score	
<b>Weak Dissonance</b> [0,67; 0,75)	2	paper score – number of graduated doctoral students, total citation score – number of graduated doctoral students	
Weak Positive Consonance [0,75; 0,85)	1	total scientific document score – number of graduated docto students	
Positive Consonance [0,85; 0,95)3paper score - total citation score, paper score - total scientific document score, total citation score - total scientific document		paper score – total citation score, paper score – total scientific document score, total citation score – total scientific document score	

Figure 5. Pairs of indicators (2017–2018)

### 4 Conclusion

In the current research the ICA method for discovering hidden patterns in data is applied to the university rankings of Turkey, extracted from University Ranking by Academic Performance website. The results are confirmed in the years. The current investigation will be extended by investigation of the universities relationships.

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