19th Int. Workshop on IFSs, Burgas, 4–6 June 2015
Notes on Intuitionistic Fuzzy Sets
ISSN 1310–4926
Vol. 21, 2015, No. 2, 111–117

Application of the InterCriteria decision making method to Bulgarian universities ranking

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Abstract: In the current paper is presented an application of the InterCriteria Decision Making (ICDM) approach to data extracted from the Bulgarian University Ranking System [13] for the years 2012–2014. The aim is to analyze the correlations between groups of indicators against which specialty "Communication and Computer Technology" is measured.
Keywords: InterCriteria Method, Intuitionistic fuzzy sets, Index matrix, Bulgarian university ratings, University ratings, Multicriteria decision making.
AMS Classification: 03E72.

1 Introduction

The current research presents the first application of the InterCriteria Decision Making (ICDM) method for the ratings of bulgarian universities. The purpose of this development is to identify the best correlated groups of indicators. By applying ICDM approach over extracted data for ratings of Bulgarian universities, we can find the group of indicators that have the most dependencies. In this way we can observe the behavior of them during the years. Analogously we can receive the opposite indicators or indicators that frequently are independent from each other. Thinking about this it is necessary to know that in Bulgarian University Ranking System every group of indicators has a weight. It is calculated on the base of the weights of indicators in the group. The method of selection of indicators and weights of indicators are defined by experts after considering many factors. This application of the ICDM method using Ratings of Bulgarian Universities can help to determine the precision and confirm the current weights of the groups of indicators [13, 14].

2 Presentation of the InterCriteria Analysis

The relationships, correlations between the indicators in the Bulgarian university ratings are developed by the ICDM method. It is introduced by Atanassov, Mavrov and Atanassova in [1]. Several applications of the method are already published [5–9]. It is based on the theory of the intuitionistic fuzzy sets and the index matrices. The intuitionistic fuzzy sets are defined by Atanassov [2, 4]. They are an extension of the concept of fuzzy sets defined by Zadeh [12]. The theory of index matrices is introduced in [3]. In [10, 11] is presented techniques for assessment performed by Bayesian networks that can be applied in assessment of the ICDM software.

The can estimate objects on the base of several criteria. The number of the criteria can be reduced by calculating the correlations in each pair of criteria in the form of intuitionistic fuzzy pairs of values [2]. The intuitionistic fuzzy pairs of values are the intuitionistic fuzzy evaluation in the interval [0, 1]. The relations can be established between any two group of indicators C_w and C_t.

Let us have a number of C_j group of indicators, $j = 1, \ldots, q$, and a number of O_k universities, $k = 1, \ldots, s$. So we use the following sets: a set of group of indicators $C_j = \{C_1, \ldots, C_q\}$ and a set of universities $O_k = \{O_1, \ldots, O_s\}$.

Using the method we will evaluate 13 universities (objects) using 6 groups of criteria. We obtain an index matrix that contains two sets of indices, one for rows and another for columns:

$$M = \begin{array}{c|ccccc} & O_1 & \ldots & O_k & \ldots & O_s \\ \hline C_1 & a_{C_1,O_1} & \ldots & a_{C_1,O_k} & \ldots & a_{C_1,O_s} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ C_j & a_{C_j,O_1} & \ldots & a_{C_j,O_k} & \ldots & a_{C_j,O_s} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ C_q & a_{C_q,O_1} & \ldots & a_{C_q,O_k} & \ldots & a_{C_q,O_s} \end{array}.$$

The next step is applying the InterCriteria Analysis for calculating evaluations. The result is a new index matrix M^* with intuitionistic fuzzy pairs $\langle \mu_{C_w,C_t}, \nu_{C_w,C_t} \rangle$ that represents an intuitionistic fuzzy evaluation of the relations between every pair of criteria C_w and C_t:

$$M^* = \begin{array}{c|ccc} & C_1 & \ldots & C_q \\ \hline C_1 & \langle \mu_{C_1,C_1}, \nu_{C_1,C_1} \rangle & \ldots & \langle \mu_{C_1,C_q}, \nu_{C_1,C_q} \rangle \\ \ldots & \ldots & \ldots & \ldots \\ C_q & \langle \mu_{C_q,C_1}, \nu_{C_q,C_1} \rangle & \ldots & \langle \mu_{C_q,C_q}, \nu_{C_q,C_q} \rangle \end{array}$$

The last step of the algorithm is to determine the degrees of correlation between group of indicators depending of the chosen threshold for μ and ν from the user. The correlations between the criteria are called "positive consonance", "negative consonance" or "dissonance". Here we use the scale that is shown on Fig. 1, [15].

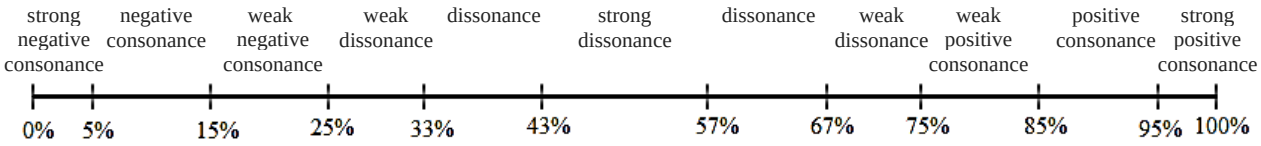

Figure 1. Scale for determining the type of the correlations between the criteria

3 Application of the ICDM to the Bulgarian University Ranking System

The Bulgarian University Ranking System is developed by the project "Development of a Ranking System for Higher Education Institutions in the Republic of Bulgaria" by the Higher Education Directorate at the Ministry of Education and Science (MES) with the financial support of the Human Resource Development Operational Program. The current version of the system contains information on 51 accredited universities in Bulgaria, which offer education in a variety of majors that have been grouped into 52 professional fields [13, 14].

The ranking system contains information and data with more than 80 indicators, which measure different aspects of university activities including teaching and learning, university environment, welfare and administrative services, science and research, prestige, career development and relevance to the labor market. The rating indicators are created using different units because they are developed based on statistical data collected from different sources, including sociological surveys. In this reason it is required standardization of the results. In this purpose is applied statistical procedure called *z*-score. It isolates the data as it retains the arrangement and proportions between them. The final assessment is provided in the range from 0 to 100 [13, 14].

In the current paper the ICDM method is applied over Bulgarian ratings of universities in the "Communication and computer technology" area from 2012 to 2014. In the testing matrices the groups of indicators are named by number. The numbering is following:

1 – Teaching and learning process;
2 – Science and research;
3 – University environment;
4 – Welfare and administrative services;
5 – Prestige;
6 – Career development and relevance to the labor market.

3.1. Applying the method for 2012th year

The testing matrices containing μ-values and ν-values in the "Communication and computer technology" area for 2012th year are presented on the Table 1a and Table 1b. The values in the matrices are colored in shades of gray. Darkest gray is used to mark the highest values and white stays for the lowest values.

Table 1a. Membership part of the intuitionistic fuzzy pairs in the Communication and computer technology area 2012th year

μ	1	2	3	4	5	6
1	1,00	0,80	0,54	0,70	0,63	0,73
2	0,80	1,00	0,54	0,55	0,69	0,66
3	0,54	0,54	1,00	0,46	0,54	0,59
4	0,70	0,55	0,46	1,00	0,37	0,67
5	0,63	0,69	0,54	0,37	1,00	0,62
6	0,73	0,66	0,59	0,67	0,62	1,00

Table 1b. Non-membership part of the intuitionistic fuzzy pairs in the Communication and computer technology area 2012th year

ν	1	2	3	4	5	6
1	0,00	0,20	0,46	0,30	0,37	0,27
2	0,20	0,00	0,46	0,45	0,31	0,34
3	0,46	0,46	0,00	0,54	0,46	0,41
4	0,30	0,45	0,54	0,00	0,63	0,33
5	0,37	0,31	0,46	0,63	0,00	0,38
6	0,27	0,34	0,41	0,33	0,38	0,00

In Table 2 are given the results of the applying the ICDM method for groups of indicators in the "Communication and computer technology" area for 2012th year.

Table 2. Correlations between indicators for 2012th year

	Pair of criteria
weak positive consonance	1-2
weak dissonance	1-4, 1-6, 2-5, 4-6
dissonance	1-5, 2-6, 3-6, 4-5, 5-6
strong dissonance	1-3, 2-3, 2-4, 3-4, 3-5

3.2. Applying the method for 2013th year

The testing matrices containing μ-values and ν-values in the "Communication and computer technology" area for 2013th year are presented on the Table 3a and Table 3b.

Table 3a. Membership part of the intuitionistic fuzzy pairs in the Communication and computer technology area in 2013th year

μ	1	2	3	4	5	6
1	1,00	0,67	0,62	0,62	0,60	0,63
2	0,67	1,00	0,51	0,38	0,71	0,53
3	0,62	0,51	1,00	0,46	0,50	0,58
4	0,62	0,38	0,46	1,00	0,50	0,60
5	0,60	0,71	0,50	0,50	1,00	0,72
6	0,63	0,53	0,58	0,60	0,72	1,00

Table 3b. Non-membership part of the intuitionistic fuzzy pairs in the Communication and computer technology area in 2013th year

ν	1	2	3	4	5	6
1	0,00	0,33	0,38	0,38	0,40	0,37
2	0,33	0,00	0,49	0,62	0,29	0,47
3	0,38	0,49	0,00	0,54	0,50	0,42
4	0,38	0,62	0,54	0,00	0,50	0,40
5	0,40	0,29	0,50	0,50	0,00	0,28
6	0,37	0,47	0,42	0,40	0,28	0,00

In Table 4 are given the results of the applying the ICDM method for the groups of indicators for the "Communication and computer technology" area for 2013th year.

Table 4. Correlations between indicators for 2013th year

	Pair of criteria
weak dissonance	1-2, 2-5, 5-6
dissonance	1-3, 1-4, 1-5, 1-6, 2-4, 3-6, 4-6
strong dissonance	2-3, 2-6, 3-4, 3-5, 4-5

3.3. Applying the method for 2014th year

The testing matrices containing μ-values and ν-values in the "Communication and computer technology" area for 2014th year are presented on the Table 5a and Table 5b.

Table 5a. Membership part of the intuitionistic fuzzy pairs in the Communication and computer technology area for 2014th year

μ	1	2	3	4	5	6
1	1	0,63	0,47	0,54	0,62	0,69
2	0,63	1	0,44	0,45	0,68	0,65
3	0,47	0,44	1	0,6	0,5	0,58
4	0,54	0,45	0,6	1	0,49	0,51
5	0,62	0,68	0,5	0,49	1	0,64
6	0,69	0,65	0,58	0,51	0,64	1

Table 5b. Non-membership part of the intuitionistic fuzzy pairs in the Communication and computer technology area for 2014th year

ν	1	2	3	4	5	6
1	0	0,37	0,53	0,46	0,38	0,31
2	0,37	0	0,56	0,55	0,32	0,35
3	0,53	0,56	0	0,4	0,5	0,42
4	0,46	0,55	0,4	0	0,51	0,49
5	0,38	0,32	0,5	0,51	0	0,36
6	0,31	0,35	0,42	0,49	0,36	0

In Table 6 are given the results of the applying the ICDM method for the groups of indicators in the "Communication and computer technology" area for 2014th year.

Table 4. Correlations between indicators for 2014th year

	Pair of criteria
weak dissonance	1-6, 2-5
dissonance	1-2, 1-5, 2-6, 3-4, 3-6, 5-6
strong dissonance	1-3, 1-4, 2-3, 2-4, 3-5, 4-5, 4-6

4 Analysis of the obtained results

Via the comparison of the results during the period of research (2012–2014) the following outcomes are obtained:

1) From the obtained results it is seen that there is no strong dependence between the groups of indicators. The correlations between them are “weak dissonance”, “dissonance”, or “strong dissonance”;
2) The indicator “Teaching and learning process” becomes more independent with indicators “Science and research”, “Career development and relevance to the labor market” and “Welfare and administrative services”. The only pair of criteria that is in weak positive consonance in the research is “Teaching and learning process” – “Science and

research" (2012). But it becomes in weak dissonance in 2013 and in dissonance in 2014. The correlations between the indicator "Welfare and administrative services" and indicators "Career development and relevance to the labor market" and "Prestige" becomes from dissonance to strong dissonance in 2014;

3) For pairs of indicators "Prestige" – "Career development and relevance to the labor market" and "Welfare and administrative services" – "Prestige" the correlations increase. They become from dissonance to weak dissonance and from strong dissonance to dissonance respectively;

4) For pairs of indicators "Science and research" – "Prestige", "Science and research" – "Career development and relevance to the labor market", "Teaching and learning process" – "Prestige", "University environment" – "Career development and relevance to the labor market", "Science and research" – "Welfare and administrative services", "Teaching and learning process" – "University environment", "Science and research" – "University environment" and "University environment" – "Prestige", the correlations are constant. The pair "Science and research" – "Prestige" is in weak dissonance. The pairs "Science and research" – "Career development and relevance to the labor market" and "Teaching and learning process" – "Prestige" are in dissonance. The pairs "University environment" – "Career development and relevance to the labor market", "Science and research" – "Welfare and administrative services", "Teaching and learning process" – "University environment", "Science and research" – "University environment" and "University environment" – "Prestige" are in strong dissonance.

5 Conclusion

In the current research the authors use an ICDM method to discover some hidden patterns in the data using Ratings of Bulgarian Universities. Ratings of Bulgarian Universities are compiled by three years. We use them and analyze them to identify the best correlations between the groups of indicators, to discover dependent and independent group of indicators and the relationships between them. The comparison can help to describing the behavior of the used indicators and assessment of the groups. In the next research the authors will analyze the indicators individually - it will make comparison to a single indicator to everyone else.

The increase of the coefficient of consonance and the entry in the zone of strong positive consonance means strong correlation between the respective pair of criteria, which may justify the removal of one of the criteria in the pair on the basis that its informational values is lesser. Removal of indicators leads to simplification of the process of evaluation.

Acknowledgments

The authors are thankful for the support provided by the Bulgarian National Science Fund under Grant Ref. No. DFNI-I-02-5 *"InterCriteria Analysis: A New Approach to Decision Making"*.

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