

THE INTERCRITERIA DECISION MAKING METHOD TO BULGARIAN UNIVERSITY RANKING SYSTEM

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Abstract: In the current paper an application of the InterCriteria Decision Making Method (ICDM) is described. The ICDM analysis is used to find relationships between the criteria if they exist. The initial data are extracted from the website of the Bulgarian University Ranking System. The aim of the analysis is to determine, explore, analyze and monitor the behavior of the existing indicators in time.

Keywords: Bulgarian University Ranking System, InterCriteria Analysis, Intuitionistic fuzzy sets, Index matrix, University ratings, Multicriteria decision making.

1 Introduction

Nowadays there are several international university ranking systems providing information for the universities in the world. Examples of such ratings are QS World University Rankings [14], The Times Higher Education World University Rankings [15] and Academic Ranking of World Universities [1]. These websites present different kind of ratings. The rankings can be generated by country, by region, by faculty and etc. Many countries form their own rankings to determine the best universities to study. Each rating has developed a methodology for classification of the universities [12]. The ranking systems use different indicators against which universities can be compared. Frequently these indicators are collected in groups according the activity that they evaluate. The indicators may have weights.

The topic of the current research is an application of the InterCriteria Decision Making Method using the data from the Bulgarian university ranking system [11]. The data for the university rankings are extracted. The authors apply the InterCriteria Decision Making Method (ICDM) to the existing data. The purpose of this investigation is the need to monitor the behavior of the indicators during the years. By applying ICDM approach over ratings of Bulgarian universities, we can find indicators that have dependencies. Analogously we can

receive the opposite indicators or indicators that frequently are independent from each other. These applications can help to determine the precision and confirm the current weights of the indicators. There are several published research works of the method [7, 8, 9, 13].

2 Presentation of the ICDM Analysis

We have already mentioned what is the purpose of the application of the ICDM method to Bulgarian university ratings - ICDM method helps to discover the relationships and examine the correlations between the indicators. The basics of the method are the theory of the intuitionistic fuzzy sets and the theory of the index matrices [3, 4, 6].

Let us describe the process of the InterCriteria Decision Making Method [2, 5, 10]. We have some objects which we estimate on the base of several criteria. The number of the criteria can be reduced by taking into account the correlations of each pair of criteria presented in the form of intuitionistic fuzzy pairs of values. The intuitionistic fuzzy pairs of values are the intuitionistic fuzzy evaluations 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_q group of indicators, $q = 1, \dots, n$, and a number of O_p universities, $p = 1, \dots, m$. So we use the following sets: a set of indicators $C_q = \{C_1, \dots, C_n\}$ and a set of universities $O_p = \{O_1, \dots, O_m\}$.

We will evaluate 13 universities (objects) using 27 criteria (indicators). We obtain an index matrix M that contains two sets of indices, one for rows and another for columns. For every p, q ($1 \leq p \leq m, 1 \leq q \leq n$), O_p in an evaluated object, C_q is an evaluation criterion, and a_{O_p, C_q} is the evaluation of the p -th object against the q -th criterion, defined as a real number or another object that is comparable according to relation R with all the rest elements of the index matrix M .

$$M = \begin{array}{c|cccccc} & C_1 & \dots & C_k & \dots & C_l & \dots & C_n \\ \hline O_1 & a_{O_1, C_1} & \dots & a_{O_1, C_k} & \dots & a_{O_1, C_l} & \dots & a_{O_1, C_n} \\ \dots & \dots \\ O_i & a_{O_i, C_1} & \dots & a_{O_i, C_k} & \dots & a_{O_i, C_l} & \dots & a_{O_i, C_n} \\ \dots & \dots \\ O_j & a_{O_j, C_1} & \dots & a_{O_j, C_k} & \dots & a_{O_j, C_l} & \dots & a_{O_j, C_n} \\ \dots & \dots \\ O_m & a_{O_m, C_1} & & a_{O_m, C_k} & & a_{O_m, C_l} & \dots & a_{O_m, C_n} \end{array}.$$

The next step is to apply the InterCriteria Analysis for calculating the evaluations. The result is a new index matrix M^* with intuitionistic fuzzy pairs $\langle \mu_{C_k, C_l}, \nu_{C_k, C_l} \rangle$ that represents an intuitionistic fuzzy evaluation of the relations between every pair of criteria C_k and C_l . In this way the index matrix M that relates the evaluated objects with the evaluating criteria can be transformed to another index matrix M^* that gives the relations among the criteria:

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

The final step of the algorithm is to determine the degrees of correlation between the criteria, depending on the user's choice of μ and ν . We call the correlations between the criteria as: 'positive consonance', 'negative consonance' or 'dissonance'.

Let $\alpha, \beta \in [0; 1]$ be the threshold values, against which we compare the values of μ_{C_k, C_l} and ν_{C_k, C_l} . The criteria C_k and C_l are in:

- (α, β) -positive consonance, if $\mu_{C_k, C_l} > \alpha$ and $\nu_{C_k, C_l} < \beta$;
- (α, β) -negative consonance, if $\mu_{C_k, C_l} < \beta$ and $\nu_{C_k, C_l} > \alpha$;
- (α, β) -dissonance, otherwise.

The following scale is used to determine in detail the relationships between the pairs of the indicators [2]:

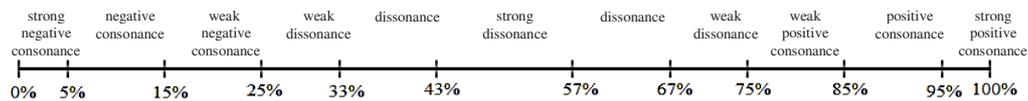


Figure 1. Scale for determination of the type of the correlations between the criteria

3 Application of the InterCriteria Decision Making Method to Bulgarian University Rankings

The aim of the current research work is an investigation of the behavior of indicators from Bulgarian university rankings analyzed by the InterCriteria Decision Making Method. Thereunder we extract the rankings of the professional field "Communication and computer technology" in the years 2012 - 2015 from the website of the Bulgarian University Ranking System. An application of the ICDM method using 27 identical indicators for the years 2012-2015 and an application of the ICDM method using the 45 identical indicators for the years 2013-2015 are made. Then, in the third application, the method is applied to all values of the criteria over the years 2012-2015. The estimated objects are 13 Bulgarian universities.

The pre-processing step of the preparation of data is applied in each of the application. The indicators "Regulated majors" and "Unemployment among graduates" are removed from all rankings. The universities Sofia University "St. Kliment Ohridski", "European Politechnical University" and Plovdiv University "Paisii Hilendarski" are deleted from several years. The removed indicators and universities have null or inappropriate values and they are deleted from the input data. In each application of the method is performed a unification of the indicators over the years.

3.1 Application 1 of the ICDM to the Bulgarian Rankings

The ICDM method is applied over the Bulgarian university rankings for the years 2012-2015. Part of the indicators from 2013, 2014 and 2015 are removed according the existing indicators in the university rankings for 2012. The indicators are renamed with numbers 1, 5, 6, 7, 8, 9, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37, 40, 41, 42, 43, 46, 47, 48, 50. The list of the numbers corresponding to indicators is shown in the Section 3.2. After applying the ICDM method to Bulgarian university rankings over the years 2012-2015 we receive the results given in the Table 1.

<i>Type of correlations</i>	<i>Number of pairs of criteria for a year</i>			
	<i>2012</i>	<i>2013</i>	<i>2014</i>	<i>2015</i>
<i>strong positive consonance</i> [0,95; 1,00)	1	1	1	1
<i>positive consonance</i> [0,85; 0,95)	0	1	0	0
<i>weak positive consonance</i> [0,75; 0,85)	5	9	9	4
<i>weak dissonance</i> [0,67; 0,75)	32	40	36	29
<i>dissonance</i> [0,57; 0,67)	90	92	40	102
<i>strong dissonance</i> [0,43; 0,57)	133	145	169	157
<i>dissonance</i> [0,33; 0,43)	79	54	64	59
<i>weak dissonance</i> [0,25; 0,33)	8	7	26	16
<i>weak negative consonance</i> [0,15; 0,25)	1	2	5	2
<i>negative consonance</i> [0,05; 0,15)	0	0	1	0

Table 1. The ICDM method applied over the Bulgarian university rankings for the years from 2012 to 2015

It can be seen that the most pairs of indicators are in strong dissonance and dissonance (Table 1). This confirms the identity of selected indicators. They have no dependency with each other. The indicators are well chosen. More precise distribution of the resulting pairs of indicators is presented in the Table 2. It is evident that some of the pairs of indicators are repeated over the years.

<i>Type of the pairs of indicators</i>	<i>Pairs of indicators for a year</i>			
	<i>2012</i>	<i>2013</i>	<i>2014</i>	<i>2015</i>
<i>in strong positive consonance</i>	27-26	27-26	27-26	27-26
<i>in positive consonance</i>	-	48-47	-	-
<i>in weak positive consonance</i>	33-5, 43-41, 47-46, 48-46, 48-47.	32-1, 37-1, 6- 5, 23-8, 43-9, 50-27, 46-43, 47-46, 48-46.	9-1, 23-9, 24- 9, 46-23, 34- 31, 33-32, 46- 41, 47-46, 48- 46.	46-1, 23-9, 40-36, 48-46

Table 2. Pairs of indicators after applying the ICDM method to the Bulgarian university rankings for the years from 2012 to 2015

Obviously the pair of indicators “Funds attracted for science and research per student- Total funds for science and research per student” is in strong positive consonance. These two indicators have the strongest correlation with each other. The degree of membership decreases with 0.01 in the years 2012-2014 and increases in the 2015 (from 0.98 to 0.95). Finally the degree of reduction is very small and it will not be taken into account especially after the increasing of the value of μ in 2015. It will be useful to eliminate the needless indicator if additionally the indicator is determined as redundant. In the Bulgarian universities ranking the indicators are preserved because they are useful to different kind of universities (state or private).

The pair of indicators “Graduates’ insurance income - Contribution to the social security system” is in weak positive consonance for 2012, in positive consonance for 2013, weak dissonance for 2014 and 2015. The correlation between the indicators decreases from positive consonance to weak dissonance in the years. It is helpful to continue monitoring the behavior of this pair of indicators. If the degree of membership continues to decrease the indicators will be independent. If the degree of membership increases the behavior of the indicators will be similar and one of them can be removed.

The pair of indicators “Graduates’ insurance income - Applicability of degree acquired and realization by vocation” with numbers 48-46 appears in weak positive consonance in the years from 2012 to 2015. The correlation of the indicators is constant over the time. The pair of indicators “Contribution to the social security system - Applicability of degree acquired and realization by vocation” appears in weak positive consonance in the years 2012, 2013 and 2014 and in weak dissonance in 2015. The pair of indicators “Ph.D. programs in the professional field - Exclusive full-time academic staff” appears in weak positive consonance in 2014 and 2015 and in dissonance in 2012 and 2013. They have a small correlation between them. The pairs of indicators “Library stock per student - Student load”, “Prestige among students- Student housing”, “Graduates’ insurance income - Contribution to the social security system”, “Equipment - Accreditation assessment grade”, “Scholarships - Accreditation assessment grade”, “International mobility - Student load”, “Ph.D. programs in the professional field - Master level majors”, “Prestige among students - Exclusive full-time academic staff”, “Regional importance - Funds attracted for science and research per student”, “Applicability of degree acquired and realization by vocation - Prestige among students”, “Exclusive full-time academic staff - Accreditation assessment grade”, “Doctoral-to-undergraduate and graduate students ratio - Exclusive full-time academic staff”, “Applicability of degree acquired and realization by vocation - Ph.D. programs in the professional field”, “Rate of library stock use - Stock in trade”, “Applicability of degree acquired and realization by vocation - Secondary education diploma GPA”, “Applicability of degree acquired and realization by vocation - Accreditation assessment grade”, “Student housing - Scholarships” appears in weak positive consonance in one year only and their presence is not tendentiously.

3.2 Application 2 of the InterCriteria Decision Making Method to Bulgarian University Rankings

In the second application of the ICDM method 45 indicators are used to estimate 13 universities. In this application can be find additional correlations between the indicators but only for the years 2013, 2014 and 2015. The indicators are shown below:

1. Accreditation assessment grade
2. Participation in internships
3. Student load
4. International mobility
5. Bachelor level majors
6. Master level majors
7. Exclusive full-time academic staff
8. Intensity of teaching
9. University citation index (Scopus)
10. University citation index (Web of Science)
11. Citation index by scientific area (Scopus)
12. Citation index by scientific area (Scopus)
13. Citation index by scientific area (Web of Science, WOS)
14. Number of citations per paper (Scopus)
15. Number of citations per paper (WOS)
16. Papers with at least one citation (Scopus)
17. Papers with at least one citation (WOS)
18. Articles in scientific journals (Scopus)
19. Articles in scientific journals (WOS)
20. Student involvement in science and research
21. Ph.D. programs in the professional field
22. Doctoral-to-undergraduate and graduate students ratio
23. PhD programs in the university
24. Total funds for science and research per student
25. Funds attracted for science and research per student
26. Intensity of science and research
27. Use of scientific products and services by employers
28. Stock in trade
29. Equipment
30. Library stock per student
31. Rate of library stock use
32. Availability of information resources
33. Teaching premises per student
34. Scholarships
35. Student housing
36. Secondary education diploma GPA
37. Foreign students
38. Prestige among students
39. Prestige among employers
40. Prestige among professors
41. Applicability of degree acquired and realization by vocation
42. Contribution to the social security system
43. Graduates' insurance income
44. Ratio of Graduates' insurance income to the average for the district (or the region)
45. Regional importance

The results from applying the ICDM method over the Bulgarian university rankings for the years from 2013 to 2015 are **presented in the Table 3.**

<i>Type of correlations</i>	<i>Number of pairs of criteria for a year</i>		
	<i>2013</i>	<i>2014</i>	<i>2015</i>
<i>strong positive consonance [0,95; 1,00)</i>	1	1	1
<i>positive consonance [0,85; 0,95)</i>	4	5	10
<i>weak positive consonance [0,75; 0,85)</i>	26	31	47
<i>weak dissonance [0,67; 0,75)</i>	116	101	76
<i>dissonance [0,57; 0,67)</i>	212	170	190
<i>strong dissonance [0,43; 0,57)</i>	402	401	410
<i>dissonance [0,33; 0,43)</i>	186	192	194
<i>weak dissonance [0,25; 0,33)</i>	37	74	56
<i>weak negative consonance [0,15;0,25)</i>	5	24	7
<i>negative consonance [0,05;0,15)</i>	0	0	3

Table 3. The ICDM method applied over the Bulgarian university rankings for the years from 2013 to 2015

The pairs of indicators are concentrated in the area of strong dissonance, dissonance and weak dissonance. Very small part of pairs of indicators appears in weak positive consonance, positive consonance, strong positive consonance, weak negative consonance and negative consonance. The results distinctly indicate the good choice of the indicators. Obviously the pairs of the indicators from the previous application of the ICDM method over Bulgarian university rankings repeat in the years again. These pairs are in italics and with highlighting. In the current application we will describe besides them the pairs of the additional indicators. More precise distribution of the resulting pairs of indicators is presented in the Table 4. It is obvious that several of the pairs of the indicators repeat in the years again.

<i>Type of the pairs of indicators</i>	<i>Pairs of indicators for a year</i>		
	2013	2014	2015
<i>in strong positive consonance</i>	<i>27-26</i>	<i>27-26</i>	<i>27-26</i>
<i>in positive consonance</i>	13-11, 19-15, 45-43, <i>48-47</i> .	13-11, 21-15, 20-18, 21-19, 29-25.	13-11, 19-15, 19-18, 20-18, 20-19, 21-19, 29-25, 44-43, 45-44, 49-46.
<i>in weak positive consonance</i>	<i>32-1, 37-1, 6-5, 23-8, 43-9, 29-11, 14-12, 18-12, 17-13, 19-13, 20-14, 21-15, 20-18, 21-19, 29-20, 26-21, 27-21, 50-27, 49-41, 44-43, 46-43, 45-44, 48-45, 47-46, 48-46, 49-48.</i>	<i>9-1, 23-9, 24-9, 32-10, 33-10, 18-12, 20-12, 19-15, 19-17, 21-17, 25-18, 29-18, 29-20, 25-20, 46-23, 44-29, 34-31, 33-32, 36-32, 36-33, 46-41, 49-41, 44-43, 45-44, 49-44, 48-45, 47-46, 48-46, 49-46.</i>	<i>46-1, 22-4, 23-9, 45-9, 12-11, 15-11, 17-11, 18-11, 19-11, 20-11, 21-11, 14-12, 15-12, 17-12, 18-12, 19-12, 20-12, 21-12, 28-12, 17-13, 18-13, 19-13, 20-13, 21-13, 18-14, 19-14, 20-14, 28-14, 16-15, 18-15, 20-15, 21-15, 17-16, 28-16, 19-17, 20-17, 21-18, 28-18, 21-20, 28-20, 29-28, 40-36, 45-41, 49-41, 45-43, 48-46, 49-48.</i>

Table 4. Pairs of indicators received after applying the ICDM method to the Bulgarian university rankings for the years 2013 - 2015

The pair of indicators “Funds attracted for science and research per student - Total funds for science and research per student” is in strong positive consonance again. Between the indicators has a strong correlation.

In positive consonance appear 4 pairs of indicators in 2013, 5 pairs of indicators in 2014 and 10 pairs of indicators in 2015. The pair of indicators “Citation index by scientific area (Scopus) - University citation index (Scopus)” appears in positive consonance in each year. The degree of membership of these pair of indicators increases in the years. The movement of the indicators in strong positive consonance is possible in the years. In two years the pairs of indicators: “Papers with at least one citation (Web of Knowledge) - Citation index by scientific area (Web of Science)”, “Articles in scientific journals (Scopus) - Papers with at

least one citation (Scopus)”, “Articles in scientific journals (Web of Knowledge) - Papers with at least one citation (Web of Knowledge)”, “Use of scientific products and services by employers - PhD programs in the university” appear in positive consonance. The pair of indicators “Papers with at least one citation (Web of Knowledge) - Citation index by scientific area (Web of Science)”, “Articles in scientific journals (Scopus) - Papers with at least one citation (Scopus)” and “Articles in scientific journals (Web of Knowledge) - Papers with at least one citation (Web of Knowledge)” decrease in the years while The indicators “Use of scientific products and services by employers - PhD programs in the university” do not change their behavior. If these pairs of indicators continue to decrease they can be moved to the weak positive consonance in the next years. The behavior of the indicators in positive consonance should be monitored to determine their change in years - whether their values will reduce to weak positive consonance or will grow into a strong positive consonance.

In weak positive consonance appear 26 pairs of indicators in 2013, 31 pairs of indicators in 2014 and 48 pairs of indicators in 2015. Three of them appear in 2013, 2014 and 2015. These pairs of indicators are “Papers with at least one citation (Scopus) - University citation index (Web of Science)”, “Ratio of Graduates’ insurance income to the average for the district (or the region) - Secondary education diploma GPA” and “Graduates’ insurance income - Applicability of degree acquired and realization by vocation”. In weak positive consonance 18 pairs of indicators appear in two years. The criteria "Equipment - Accreditation assessment grade”, “Use of scientific products and services by employers - Articles in scientific journals (Scopus)”, “Prestige among employers - Prestige among students”, “Graduates’ insurance income - Prestige among professors”, “Contribution to the social security system - Applicability of degree acquired and realization by vocation”, “Graduates’ insurance income - Applicability of degree acquired and realization by vocation” are in weak positive consonance in the years 2013 and 2014. The pairs of indicators "Citation index by scientific area (Scopus) - University citation index (Web of Science)”, “Number of citations per paper (Web of Science) - Citation index by scientific area (Scopus)”, “Papers with at least one citation (Web of Knowledge) - Citation index by scientific area (Scopus)”, “Citation index by scientific area (Scopus) - Articles in scientific journals (Scopus)”, “Articles in scientific journals (Web of Knowledge) - Citation index by scientific area (Web of Science)”, “Prestige among employers - Prestige among professors”, “Graduates’ insurance income - Ratio of Graduates’ insurance income to the average for the district (or the region)” are in weak positive consonance in the years of 2013 and 2015. There are 4 pairs of indicators in weak positive consonance in 2014 and 2015: “Ph.D. programs in the professional field - Exclusive full-time academic staff”, “Articles in scientific journals (Scopus) - University citation index (Web of Science)”, “Papers with at least one citation (Web of Knowledge) - Number of citations per paper (Web of Science)”, “Ratio of Graduates’ insurance income to the average for the district (or the region) - Applicability of degree acquired and realization by vocation”. In weak positive consonance in one year appear 11 pairs of indicators in 2013, 17 pairs of indicators in 2014 and 34 pairs of indicators in 2015:

- In 2013 “Scholarships - Accreditation assessment grade”, “Student load -International mobility”, “Ph.D. programs in the professional field - Master level majors”, “Prestige among students - Exclusive full-time academic staff”, “Use of scientific products and services by employers - University citation index (Scopus)”, “Papers with at least one citation (Scopus) -Articles in scientific journals (Scopus)”, “Papers with at least one

citation (Web of Knowledge) - Articles in scientific journals (Web of Knowledge)", "Total funds for science and research per student - Articles in scientific journals (Web of Knowledge)", "Funds attracted for science and research per student - Articles in scientific journals (Web of Knowledge)", "Regional importance - Funds attracted for science and research per student", "Applicability of degree acquired and realization by vocation - Prestige among students" are in weak positive consonance.

- In weak positive consonance appears 17 pairs of indicators in 2014: "Exclusive full-time academic staff - Accreditation assessment grade", "Doctoral-to-undergraduate and graduate students ratio - Exclusive full-time academic staff", "Equipment - Intensity of teaching", "Library stock per student - Intensity of teaching", "Papers with at least one citation (Web of Knowledge) - Citation index by scientific area (Web of Science)", "Articles in scientific journals (Web of Knowledge) - Number of citations per paper (Web of Science)", "PhD programs in the university - Papers with at least one citation (Scopus)", "Use of scientific products and services by employers- Papers with at least one citation (Scopus)", "PhD programs in the university - Articles in scientific journals (Scopus)", "Applicability of degree acquired and realization by vocation - Ph.D. programs in the professional field", "Prestige among employers - Use of scientific products and services by employers", "Stock in trade - Rate of library stock use", "Equipment - Library stock per student", "Teaching premises per student - Library stock per student", "Teaching premises per student - Library stock per student", "Secondary education diploma GPA - Applicability of degree acquired and realization by vocation", "Ratio of Graduates' insurance income to the average for the district (or the region) - Prestige among employers".
- In weak positive consonance appears 35 pairs of indicators in 2015: "Applicability of degree acquired and realization by vocation - Accreditation assessment grade", "Student involvement in science and research - Participation in internships", "Prestige among professors - Exclusive full-time academic staff", "University citation index (Scopus) - University citation index (Web of Science)", "Citation index by scientific area (Web of Science) - University citation index (Web of Science)", "Number of citations per paper (Web of Science) - University citation index (Web of Science)", "Papers with at least one citation (Scopus) - University citation index (Web of Science)", "Papers with at least one citation (Web of Knowledge) - University citation index (Web of Science)", "Articles in scientific journals (Scopus) - University citation index (Web of Science)", "Articles in scientific journals (Web of Knowledge) - University citation index (Web of Science)", The indicators "Citation index by scientific area (Web of Science)", "Number of citations per paper (Web of Science)", "Papers with at least one citation (Web of Knowledge)", "Articles in scientific journals (Web of Knowledge)", "Intensity of science and research" correlate with the criteria "University citation index (Web of Science)". The indicators "Papers with at least one citation (Scopus)", "Articles in scientific journals (Scopus)", "Articles in scientific journals (Web of Knowledge)" correlate with "Citation index by scientific area (Scopus)". The indicators "Papers with at least one citation (Scopus)", "Papers with at least one citation (Web of Knowledge)", "Intensity of science and research" are in weak positive consonance with "Citation index by scientific area (Scopus)". The indicators "Number of citations per paper (Scopus)", "Papers with at least one citation (Scopus)", "Articles in scientific journals (Scopus)" correlates with "Citation index by scientific area (Web of Science)". The pairs of

indicators in weak positive consonance in 2015 are “Number of citations per paper (Web of Science) - Number of citations per paper (Scopus)”, “Intensity of science and research - Number of citations per paper (Scopus)”, “Articles in scientific journals (Scopus) - Number of citations per paper (Web of Science)”, “Articles in scientific journals (Web of Knowledge) - Papers with at least one citation (Scopus)”, “Intensity of science and research - Papers with at least one citation (Scopus)”, “Articles in scientific journals (Scopus) - Articles in scientific journals (Web of Knowledge)”, “Intensity of science and research - Articles in scientific journals (Scopus)”, “Intensity of science and research - Use of scientific products and services by employers”, “Student housing - Teaching premises per student”, “Prestige among professors- Secondary education diploma GPA”, “Prestige among professors - Prestige among students”, “Graduates’ insurance income - Ratio of Graduates’ insurance income to the average for the district (or the region)”.

3.3 Application 3 of the InterCriteria Decision Making Method to Bulgarian University Rankings

In the third application 108 indicators from the years 2012-2014 are used. The purpose of the investigation is to determine the behavior of the criteria when they are used together. The evaluated objects are 13 universities in Bulgaria that have specialties in professional field “Communication and computer technology”. The indicators has the following form: before all indicators of 2012 the letter “a” is added, before all indicators from 2013 the letter “b” is added, before all indicators from 2014 - the letter “c” is added and before all indicators from 2015 the letter “d” is added.

After applying the ICDM method over the data the pairs of indicators are presented in the Table 5.

<i>Type of correlations</i>	<i>Pairs of indicators for 2012-2015</i>
<i>strong positive consonance</i> [0,95; 1,00)	4
<i>positive consonance</i> [0,85; 0,95)	13
<i>weak positive consonance</i> [0,75; 0,85)	131
<i>weak dissonance</i> [0,67; 0,75)	650
<i>dissonance</i> [0,57; 0,67)	1122
<i>strong dissonance</i> [0,43; 0,57)	2473
<i>dissonance</i> [0,33; 0,43)	1104
<i>weak dissonance</i> [0,25; 0,33)	271
<i>weak negative consonance</i> [0,15; 0,25)	61
<i>negative consonance</i> [0,05; 0,15)	5

Table 5. Results of applying the ICDM method using the Bulgarian university rankings for the years from 2012-2015 together

According to the distribution of the pairs of the indicators in the years from 2012 to 2015 the most indicators have not dependencies each other. This is confirmed by the number of pairs in dissonance and strong dissonance. Within the boundaries of dissonance there are 2226 pairs of indicators. The group of pairs in strong dissonance contains 2473 pairs of indicators. Initially let us divide the pairs of indicators in two parts. The first part contains the pairs of indicators with elements from only one year. Therefore in the beginning of the each element in the pair will be recorded the same letter. The second part includes the pairs which elements have different letters. Every pair of indicators in strong positive consonance, positive consonance or weak positive consonance for all years is shown in the Table 6.

<i>Type of the pairs of indicators</i>	<i>Pairs of indicators for all years 2012-2015</i>
<i>strong positive consonance</i>	a26 - a27(0.99), d26 - d27(0.99), b26 - b27(0.96), c26 - c27(0.95)
<i>positive consonance</i>	a46 - b46(0.90), b48 - d46(0.88), b41 - d43(0.86), c47 - d46(0.87), a5 - a33(0.86), a9 - c41(0.86), b1 - d1(0.86), b47 - d46(0.86), c46 - d46(0.86), b27 - d48(0.85), b47 - b48(0.85), b47 - c46(0.85), c48 - d46(0.85)
<i>weak positive consonance</i>	d9 - d23(0.82), a42 - b42(0.83), a42 - d43(0.82), a31 - b34(0.83), a48 - b48(0.83), b32 - d1(0.83), b8 - b23(0.76), a25 - a41(0.81), a1 - b50(0.82), a26 - b27(0.82), a48 - d46(0.82), b1 - b32(0.82), b33 - d33(0.82), b43 - c46(0.82), b46 - b48(0.82), b48 - c41(0.82), b48 - c46(0.82), c33 - c36(0.82), a8 - d41(0.76), b25 - d25(0.81), a46 - d23(0.77), b43 - d8 (0.77), b47 - c23(0.77), c9 - c23(0.77), a1 - d48(0.81), a26 - b26(0.81), a27 - b27, a41 - c50, a46 - a48, a48 - b46, a48 - b47, b26 - d48, b32 - d32, b32 - d46, b46 - c48, b46 - d46, b47 - c47, b48 - d47, b50 - d48, c32 - c36, c46 - c47, d46 - d48, d48 - d46(0.81), a46 - d9 , a48 - d9, d9 - a46(0.78), b1 - d23, b32 - d23, c23 - c46(0.76), a27 - b26, a46 - c46, a47 - d1, a48 - d47, b9 - d46, b33 - c33, b40 - d1, b48 - d48, c1 - c9(0.79), a42 - d9(0.76), a41 - a43(0.80), a1 - a37, a1 - b48, a9 - c46, a46 - c48, a46 - d1, a46 - d46, b42 - c43, b43 - c47, b43 - d31, b43 - d46, b47 - c9, b47 - d47, b48 - c47, b48 - c48, c31 - d34, c32 - c33, c46 - c48(0.78), b5 - b6, b6 - d32, b32 - d9, b42 - d9, b46 - d9(0.76), a42 - b46, b42 - d43(0.77), a42 - b41(0.76), a1 - c48, a1 - d46, a34 - c33, a41 - b46, a46 - b32, a46 - b48, a47 - b40, b9 - c47, b32 - a46, b43 - b46, b46 - b47, b46 - c46, c1 - d46, c9 - d46, c41 - c46, c48 - d41, d46 - d47(0.77), a41 - a42, a41 - d43, c9 - c24(0.76), a1 - b27, a26 - c48, a32 - c46, a32 - d48, a37 - c47, a46 - a47, a46 - c1, a46 - d32, a47 - b47, a47 - b48, a48 - b32, a48 - b43, a48 - c46, b1 - b37, b9 - b43, b27 - b50, b27 - c48, b33 - c32, b36 - d36, b48 - c42, c31 - c34, c41 - d42, c41 - d46, c46 - d41, c48 - d48, d47 - d48(0.76)

Table 6. Pairs of indicators from applying the ICDM method to the Bulgarian university rankings for the years 2012 -2015 together

Let us describe the pairs of indicators from the first group:

- The strong correlation between The indicators “Total funds for science and research per student-Funds attracted for science and research per student” is confirmed for the third time. It is available four times for the four years with the degree of membership from 0.95 to 0.99. This pair of indicators is correlated. None of the indicators are not removed because they are useful depending the type of the universities -state or private universities.
- The pair of indicators “Graduates’ insurance income - Applicability of degree acquired and realization by vocation” appears four times in the result of the application of the ICDM method. Although in the current testing the pair appears four times in the weak positive consonance and in the individual tests for the years 2012, 2013, 2014 and 2015. Categorically these two indicators have a weak correlation between them.
- The pair of indicators “Applicability of degree acquired and realization by vocation - Contribution to the social security system” appears four times in the result of the application of the ICDM method. Four times it is in weak positive consonance. In the individual testing for 2012, 2013 and 2014 the pair is in weak positive consonance again. In the 2015 only it is in weak dissonance. Overall, it can be considered that the both indicators are in weak correlation.
- The pair of indicators “Graduates’ insurance income - Contribution to the social security system” appears two times in the result of the application of the ICDM method. The pairs are selected two times respectively for 2013 and for 2015 in positive consonance. In the individual applications of the ICDM method over university rankings the pair is in weak positive consonance in 2012, in positive consonance in 2013 and in weak dissonance in 2014 and 2015. Therefore this pair of indicators has a variable character. Probably the indicators in the pair have a very small correlation.
- The pair of indicators “Exclusive full-time academic staff - Ph.D. programs in the professional field” is in weak positive consonance for the years 2014 and 2015. In the individual applications of the ICDM method this pair of indicators was in dissonance in 2012 and 2013 and in weak positive consonance in 2014 and 2015. Therefore a weak correlation between the indicators begins to appear.
- The pair of indicators “Accreditation assessment grade – Scholarships” is in weak positive consonance for the years 2012 and 2013 in the overall application of the ICDM method. In the individual applications of the ICDM method the pair is in weak dissonance in 2012, weak positive consonance in 2013, dissonance in 2014 and in strong dissonance in 2015. The behavior of the pair is very variable.
- The last pairs of indicators from the first group appears once in overall application of ICDM method using university rankings for a given year and once in the individual applications of ICDM for the same year in weak positive consonance. They have the following form:
 - For 2012: “Student load - Library stock per student”, “Secondary education diploma GPA - Prestige among students”, “Accreditation assessment grade - Scholarships”, “Secondary education diploma GPA - Foreign students”.
 - For 2013: “Master level majors - Ph.D. programs in the professional field”, “Accreditation assessment grade - Equipment”, “Student load - International mobility”, “Prestige among students - Applicability of degree acquired and realization by

vocation”, “Exclusive full-time academic staff - Prestige among students”, “Funds attracted for science and research per student - Regional importance”.

- For 2014: “Teaching premises per student - Library stock per student”, “Accreditation assessment grade - Exclusive full-time academic staff”, “Secondary education diploma GPA - Applicability of degree acquired and realization by vocation”, “Doctoral-to-undergraduate and graduate students ratio - Exclusive full-time academic staff”, “Equipment - Library stock per student”.
- For 2015: “Exclusive full-time academic staff -Ph.D. programs in the professional field”.

Let us describe the pairs of indicators from the second group: The second part includes pairs of indicators which elements correlate in different years. They are in positive consonance and in weak positive consonance. There are several particularities:

- there are indicators that correlate with themselves (once or several times);
- there are pairs of indicators that correlate with each other several times over the years;
- naturally there are pairs of indicators that correlate with each other only once.

For these reasons the results were searched for duplicate pairs of indicators. Then they are rearranged and counted. The obtained results are the following:

- **pairs of indicators with elements from different years in positive consonance**
 - *indicators that correlate with themselves (once or several times)*: Applicability of degree acquired and realization by vocation - 2 times and Accreditation assessment grade - once
 - *pairs of indicators that correlate with each other several times over the years*: “Applicability of degree acquired and realization by vocation - Contribution to the social security system” - 3 times and “Graduates’ insurance income - Applicability of degree acquired and realization by vocation” - 2 times and
 - *pairs of indicators that correlate with each other only once*: “Secondary education diploma GPA - Prestige among students”, “Secondary education diploma GPA - Exclusive full-time academic staff”, “Graduates’ insurance income - Funds attracted for science and research per student”, “Library stock per student - Student load-once” and “Contribution to the social security system - Graduates’ insurance income”.
- **pairs of indicators with elements from different years in weak positive consonance**
 - *indicators that correlate with themselves (once or several times)*: Graduates’ insurance income - 4 times, Applicability of degree acquired and realization by vocation - 4 times, Contribution to the social security system - 3 times, Library stock per student - 2 times. The indicators that appear once as pair are PhD programs in the university, Total funds for science and research per student, Funds attracted for science and research per student, Stock in trade, Equipment, Teaching premises per student and Foreign students.
 - *pairs of indicators that correlate with each other several times over the years*: “Graduates’ insurance income - Applicability of degree acquired and realization by vocation” - 7 times, “Contribution to the social security system - Graduates’ insurance income” - 5 times, “Exclusive full-time academic staff -Applicability of degree acquired and realization by vocation” - 5 times, “Applicability of degree acquired and realization by vocation - Accreditation assessment grade” - 4 times,

“Graduates’ insurance income - Accreditation assessment grade” - 3 times, “Applicability of degree acquired and realization by vocation - Equipment” - 3 times, “Secondary education diploma GPA - Applicability of degree acquired and realization by vocation” - 3 times. The pairs of indicators that appear twice as pair are: “Prestige among students - Foreign students”, “Funds attracted for science and research per student - Total funds for science and research per student”, “Applicability of degree acquired and realization by vocation - Prestige among students”, “Secondary education diploma GPA - Graduates’ insurance income”, “Ph.D. programs in the professional field - Applicability of degree acquired and realization by vocation”, “Exclusive full-time academic staff - Contribution to the social security system”, “Secondary education diploma GPA - Foreign students” and “Graduates’ insurance income - Equipment”.

- *pairs of indicators that correlate with each other only once*: “Rate of library stock use - Stock in trade”, “Equipment - Accreditation assessment grade”, “Accreditation assessment grade - Regional importance”, “Secondary education diploma GPA - Master level majors”, “Master level majors - Prestige among students”, “Ph.D. programs in the professional field - Contribution to the social security system”, “Secondary education diploma GPA - Regional importance”, “Graduates’ insurance income - Regional importance”, “Exclusive full-time academic staff - Graduates’ insurance income”, “Ph.D. programs in the professional field - Accreditation assessment grade”, “Equipment - Ph.D. programs in the professional field”, “Contribution to the social security system - Accreditation assessment grade”, “Student housing - Accreditation assessment grade”, “Foreign students - Exclusive full-time academic staff”, “Prestige among students - Contribution to the social security system”, “Prestige among students - Stock in trade”, “Equipment - International mobility”, “Equipment - Exclusive full-time academic staff”, “Foreign students - Exclusive full-time academic staff”, “Foreign students - Applicability of degree acquired and realization by vocation”, “Foreign students - Prestige among students”, “Library stock per student - Rate of library stock use”, “Student housing - Contribution to the social security system”, “Secondary education diploma GPA - Prestige among students”, “Funds attracted for science and research per student - Accreditation assessment grade”, “Total funds for science and research per student - Graduates’ insurance income”, “Contribution to the social security system - Scholarships”, “Applicability of degree acquired and realization by vocation - Equipment”, “Graduates’ insurance income - Prestige among students”, “Graduates’ insurance income - Funds attracted for science and research per student”, “Equipment - Library stock per student” and “Graduates’ insurance income - Foreign students”.

4 Short remarks on the obtained results

The correlations between the indicators in each of the applications are described. However, it is necessary to be specified several dependencies repeated in the time and relationships that

appears in the applications. Via the comparison of the results during the period of research (2012–2014) some obtained outcomes are confirmed:

- From the obtained results it is seen that the indicators have not strong dependencies. In each of the applications the correlations of the most pairs of indicators is “strong dissonance”, “weak dissonance” or “dissonance”.
- The indicators “Funds attracted for science and research per student” and “Total funds for science and research per student” are in strong correlation. In all applications the pair of indicators appears in strong positive consonance. The indicator “Funds attracted for science and research per student” has more correlations with the other indicators. None of the indicators are not removed because they are useful depending the type of the universities -state or private universities.
- The indicators “Citation index by scientific area (Scopus)” and “University citation index (Scopus)” have a correlation “positive consonance” in the years 2013-2015. In the future they can be monitored to determine more strictly their behavior.
- The indicators “Applicability of degree acquired and realization by vocation”, “Contribution to the social security system” and “Graduates’ insurance income” have an average correlation “weak positive consonance”. The dependencies between the pairs “Applicability of degree acquired and realization by vocation - Contribution to the social security system” and “Applicability of degree acquired and realization by vocation - Graduates’ insurance income” occur more often than the pair “Contribution to the social security system - Graduates’ insurance income”. Sometimes these pairs have a correlation “positive consonance”. Therefore these pairs of indicators are categorically in weak positive consonance but it is possible to have stronger relationships.
- The pairs of indicators “Ratio of Graduates’ insurance income to the average for the district (or the region) - Secondary education diploma GPA” and “Papers with at least one citation (Scopus) - University citation index (Web of Science)” have a correlation “weak positive consonance”.

The described outcomes are valid for all the years of the all the applications. If we want to observe more detailed the indicators we can read the applications of the ICDM method from the previous pages. Obviously the third application can confirm the received results and can generate new dependencies.

5 Conclusion

In the presented paper three applications of the ICDM method over data from Bulgarian University Ranking System are explored. The ICDM method is a useful tool for determining the dependencies between the indicators. Furthermore the ICDM method can help to define the weights of the indicators. In the Bulgarian rankings the indicators are well chosen. The independent indicators have correlation “strong dissonance”, “weak dissonance” or “dissonance”. Results indicated that only a few pairs have a significant correlation with each other. There are in “strong positive consonance” or “positive consonance”. The ICDM method revealed the indicators whose correlation is still very small and will be clarified in future. These pairs of indicators have correlation “weak positive consonance”. If we analyze the university rankings for several years we will receive the behavior of the indicators in time.

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