2nd International IFS Conference, Mersin, Turkey, 14–18 Oct. 2015
Notes on Intuitionistic Fuzzy Sets
ISSN 1310–4926
Vol. 21, 2015, No. 4, 136–142

Application of intercriteria analysis to the rankings of Australian universities

Evdokia Sotirova[1] and Anthony Shannon[2,3]

[1] Laboratory of Intelligent Systems, University "Prof. Dr. Assen Zlatarov"
1 "Prof. Yakimov" Blvd., Burgas 8010, Bulgaria
e-mail: esotirova@btu.bg

[2] Faculty of Engineering & IT, University of Technology, Sydney, NSW 2007, Australia

[3] Campion College, PO Box 3052, Toongabbie East, NSW 2146, Australia
e-mails: t.shannon@campion.edu.au, Anthony.Shannon@uts.edu.au

Abstract: The InterCriteria Analysis (ICA) approach is applied to data extracted from the Australian University Ranking System for the years 2012–2014. The aim is to analyze the correlations among groups of indicators.
Keywords: Intercriteria analysis, Intuitionistic fuzzy sets, Index matrix, University ratings, Multicriteria decision making.
AMS Classification: 03E72.

1 Introduction

Australia has a relatively large area (>7 million km^2) with a population of approximately 24 million people. It has 43 universities (such as UTS) and 130 smaller higher education providers (such as Campion College) regulated by the Tertiary Education Quality and Standards Agency (TEQSA) [15]. While most academic staff prefers to teach and to engage in research and other scholarly activity, more and more of their time is devoted to administrative data mining to satisfy their institution's search for 'good' rankings in the various international league tables.

In this paper we present the third application of the ICA method for the ratings of universities. The purpose is to analyse the correlations among the criteria which provide some of the summative ranking assessments among Australian universities. For our observation we use the QS World University Rankings for Australian university rankings [13]. The rankings compare the universities across four key areas (research, teaching, employability and international outlook) that are assessed using six indicators, each of which is given a weight [14]. These rankings reflect regional priorities and challenges. By applying the ICA approach we can find the dependencies between and among indicators – the indicators that have the highest dependencies and the opposite indicators that frequently are independent from each other. In this way we can observe the behavior of them over time.

We explore real data extracted from a Universities Ranking System, that is, from the sites of a relevant rating system which provides free access to data. Using the ICA method the behavior of the criteria can be monitoring and optimized. In [11] the application of the ICA method for the ratings of Bulgarian universities was presented. The correlations among groups of indicators in the area of "Communication and Computer Technology" were analyzed. Similarly in [12] the purpose was to identify the most correlated indicators in the Ranking System for the Polish universities. In this paper we use data sets from overall ranking of the universities of the QS World University Rankings – Australian university rankings [13, 14].

2 Presentation of the InterCriteria Analysis

The ICA method was introduced by K. Atanassov, D. Mavrov and V. Atanassova in [1]. Several applications of the method have already been published [5–9, 11, 12]. The method is based on the theory of intuitionistic fuzzy sets and index matrices. Intuitionistic fuzzy sets were first defined by Atanassov [2, 4] as an extension of the concept of fuzzy sets defined by L. Zadeh [16]. The theory of index matrices was introduced in [3].

The objects can be estimated on the basis of several criteria. The number of 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 evaluations in the interval [0, 1]. The relations can be established between any two groups of indicators C_w and C_t.

Let us have a number of C_q groups of indicators, $q = 1, \dots, n$, and a number of O_p universities, $p = 1, \dots, m$; that is, we use the following sets: a set of group of indicators $C_q=\{C_1 ,\dots, C_n\}$ and a set of universities $O_p = \{O_1,\dots, O_m\}$.

We obtain an index matrix M that contains two sets of indices, one for rows and another for columns. For for every p, q ($1 \le p \le m$, $1 \le q \le n$), 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 a relation R with all the other elements of the index matrix M.

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

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:

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

The last step of the algorithm is to determine the degrees of correlation between groups 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 used in previous studies that is shown in Figure 1 [10].

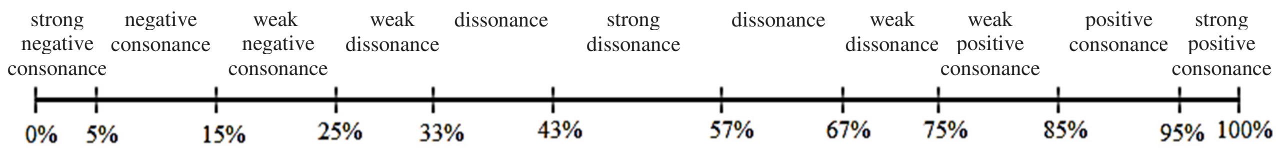

Figure 1. Scale for determination of the relative values the correlations between the criteria

3 Application of the ICA to Australian university rankings

The ICA method was applied to the top ten Australian Universities (according to QS World University Rankings system [13, 14]). Six indicators with a given weight are used [14]:

- Academic Reputation,
- Employer Reputation,
- Faculty/Student Ratio,
- International Faculty,
- International Students and
- Citations per Faculty.

In the current paper the ICA method is applied over ratings of Australian universities in the years 2012–2014.

3.1. Applying the method for the year 2012

The testing matrices which contain μ-values and ν-values for the 2012 year are presented in the Tables 1a and 1b. The values in the matrices are colored in shades of gray for the varying degrees of consonance and dissonance from darkest gray (highest values) to white.

μ	Academic Reputation	Employer Reputation	Faculty/ Student	International Faculty	International Students	Citations per faculty
Academic Reputation	1,000	0,778	0,800	0,511	0,533	0,778
Employer Reputation	0,778	1,000	0,578	0,422	0,622	0,556
Faculty/ Student	0,800	0,578	1,000	0,622	0,467	0,844
International Faculty	0,511	0,422	0,622	1,000	0,533	0,556
International Students	0,533	0,622	0,467	0,533	1,000	0,356
Citations per faculty	0,778	0,556	0,844	0,556	0,356	1,000

Table 1a. Membership part of the intuitionistic fuzzy pairs for 2012

ν	Academic Reputation	Employer Reputation	Faculty/ Student	International Faculty	International Students	Citations per faculty
Academic Reputation	0,000	0,222	0,200	0,489	0,467	0,222
Employer Reputation	0,222	0,000	0,422	0,578	0,378	0,444
Faculty/Student	0,200	0,422	0,000	0,378	0,533	0,156
International Faculty	0,489	0,578	0,378	0,000	0,467	0,444
International Students	0,467	0,378	0,533	0,467	0,000	0,644
Citations per faculty	0,222	0,444	0,156	0,444	0,644	0,000

Table 1b. Non-membership part of the intuitionistic fuzzy pairs for 2012

3.2. Applying the method for the year 2013

The testing matrices which contain μ-values and ν-values for the 2013 year are presented in the Tables 2a and 2b.

μ	Academic Reputation	Employer Reputation	Faculty/ Student	International Faculty	International Students	Citations per faculty
Academic Reputation	1,000	0,844	0,844	0,489	0,667	0,822
Employer Reputation	0,844	1,000	0,689	0,467	0,711	0,667
Faculty/ Student	0,844	0,689	1,000	0,489	0,600	0,800
International Faculty	0,489	0,467	0,489	1,000	0,511	0,533
International Students	0,667	0,711	0,600	0,511	1,000	0,533
Citations per faculty	0,822	0,667	0,800	0,533	0,533	1,000

Table 2a. Membership part of the intuitionistic fuzzy pairs for 2013

ν	Academic Reputation	Employer Reputation	Faculty/ Student	International Faculty	International Students	Citations per faculty
Academic Reputation	0,000	0,133	0,133	0,489	0,333	0,156
Employer Reputation	0,133	0,000	0,267	0,489	0,267	0,289
Faculty/Student	0,133	0,267	0,000	0,467	0,378	0,156
International Faculty	0,489	0,489	0,467	0,000	0,467	0,467
International Students	0,333	0,267	0,378	0,467	0,000	0,444
Citations per faculty	0,156	0,289	0,156	0,467	0,444	0,000

Table 2b. Non-membership part of the intuitionistic fuzzy pairs for 2013

3.3. Applying the method for the year 2014

The testing matrices which contain μ-values and ν-values for the 2014 year are presented in the Tables 3a and 3b.

μ	Academic Reputation	Employer Reputation	Faculty/ Student	International Faculty	International Students	Citations per faculty
Academic Reputation	1,000	0,844	0,800	0,400	0,667	0,800
Employer Reputation	0,844	1,000	0,711	0,378	0,711	0,689
Faculty/Student	0,800	0,711	1,000	0,378	0,667	0,711
International Faculty	0,400	0,378	0,378	1,000	0,311	0,444
International Students	0,667	0,711	0,667	0,311	1,000	0,489
Citations per faculty	0,800	0,689	0,711	0,444	0,489	1,000

Table 3a. Membership part of the intuitionistic fuzzy pairs for 2014

ν	Academic Reputation	Employer Reputation	Faculty/ Student	International Faculty	International Students	Citations per faculty
Academic Reputation	0,000	0,133	0,156	0,444	0,311	0,178
Employer Reputation	0,133	0,000	0,267	0,489	0,289	0,311
Faculty/Student	0,156	0,267	0,000	0,467	0,311	0,267
International Faculty	0,444	0,489	0,467	0,000	0,556	0,422
International Students	0,311	0,289	0,311	0,556	0,000	0,511
Citations per faculty	0,178	0,311	0,267	0,422	0,511	0,000

Table 3b. Non-membership part of the intuitionistic fuzzy pairs for 2014

4 Analysis of the results

From the comparisons of the results obtained during the period of research (2012–2014) the following conclusions can be obtained:

a) There is no strong dependence among the groups of indicators. The correlations between them are in “weak positive consonance”, “weak dissonance”, “dissonance”, or “strong dissonance”;

b) The indicator “Citations per faculty” becomes more independent with the indicator “Faculty/Student Ratio”. They go from weak positive consonance to weak dissonance;

c) The indicator “Academic reputation” is in weak positive consonance with the indicators “Faculty/Student Ratio”, “Employer Reputation”, and “Citations per faculty” during the period of our research. But the pairs of indicators “Academic reputation” –“Employer Reputation” and “Academic reputation” – “Citations per faculty” become more dependent with each other;

d) The indicator “International Faculty“ is in dissonance with the indicators “Faculty/ Student Ratio” and “Employer Reputation” but they become more independent for the period of research. A similar trend can be observed for the pair “Citations per Faculty“ – “International Faculty“ but the indicators are in strong dissonance;

e) For the indicator “Employer Reputation” the dependences with the indicators “International Students”, “Faculty Students” and “Citations per faculty” increase, namely, from dissonance to weak dissonance. The same trend is observed for the indicator “International Students” with indicators “International Faculty”, “Academic reputation” and “Faculty/Student Ratio”, but the relations become from strong dissonance to weak dissonance (pair “International Students” – “International Faculty”) and from strong dissonance to dissonance (pairs International Students” – “Academic reputation” and International Students” – Faculty/Student Ratio”);

f) The indicator “International Faculty” becomes more independent from the indicator “Academic reputation” and the indicators “Citations per faculty” and “International Students” become more dependent.

5 Conclusion

In the research reported here the authors have applied the InterCriteria Analysis (ICA) method to the data of the Ratings of Australian Universities for the three years (2012-2014). There is reasonable consistency across the indices for the three years. This would seem to indicate that the criteria and their measurements are reasonably reliable. The observations can thus help to determine the behavior of the indicators and relations among them over time. This raises the question of the validity of the indices which, in practice, has more to do with the use to which different readers may put the results. For example, the Faculty/Student Ratio may mean a lot more to a potential undergraduate student, whereas Citations/Faculty may be a more important index for a potential postgraduate research candidate.

This is the third application of the ICA method for the ratings of universities. The previous two applications were implemented with data for the ratings of Bulgarian and Polish universities. The comparisons among the results in these studies can also help to analyze the effectiveness of the indicators actually used in these international rating comparisons.

Acknowledgments

The authors are thankful for the support provided by the Bulgarian National Science Fund under Grant DFNI-I-02-5 “*InterCriteria Analysis: A New Approach to Decision Making*”.

References

[1] Atanassov, K., Mavrov, D., & Atanassova, V. (2014) InterCriteria Decision Making: A New Approach for Multicriteria Decision Making, Based on Index Matrices and Intuitionistic Fuzzy Sets. *Issues in Intuitionistic Fuzzy Sets and Generalized Nets*, 11, 1–8.

[2] Atanassov, K., Szmidt, E. & Kacprzyk, J. (2013) On intuitionistic fuzzy pairs, *Notes on Intuitionistic Fuzzy Sets*, 19(3), 1–13.

[3] Atanassov, K. (2014) *Index Matrices: Towards an Augmented Matrix Calculus*. Studies in Computational Intelligence Series, Volume 573, Springer, Cham.

[4] Atanassov, K. (2012) *On Intuitionistic Fuzzy Sets Theory*, Springer, Berlin.

[5] Atanassova, V., D. Mavrov, L. Doukovska & K. Atanassov (2014) Discussion on the threshold values in the InterCriteria Decision Making approach, *Notes on Intuitionistic Fuzzy Sets*, 20(2), 94–99.

[6] Atanassova, V., L. Doukovska, K. Atanassov & D. Mavrov, (2014) InterCriteria Decision Making Approach to EU Member States Competitiveness Analysis, *Proceedings of the International Symposium on Business Modeling and Software Design – BMSD'14*, 24–26 June 2014, Luxembourg, Grand Duchy of Luxembourg, 289–294.

[7] Atanassova, V. & I. Vardeva (2014) Sum- and average-based approach to criteria shortlisting in the InterCriteria Analysis. *Notes on Intuitionistic Fuzzy Sets*, 20(4), 41–46.

[8] Atanassova, V., L. Doukovska, D. Karastoyanov & F. Capkovic (2014) InterCriteria Decision Making Approach to EU Member States Competitiveness Analysis: Trend Analysis. In P. Angelov *et al.* (eds), *Intelligent Systems'2014, Advances in Intelligent Systems and Computing 322*, 107–115.

[9] Atanassova, V., L. Doukovska, D. Mavrov, & K. Atanassov (2014) InterCriteria Decision Making Approach to EU Member States Competitiveness Analysis: Temporal and Threshold Analysis. In P. Angelov *et al.* (eds), *Intelligent Systems'2014, Advances in Intelligent Systems and Computing 322*, 95–106.

[10] Atanassov, K, V. Atanassova & G. Gluhchev (2015) InterCriteria Analysis: Ideas and problems, *Notes on Intuitionistic Fuzzy Sets*, 21(1), 81–88.

[11] Bureva, V., E. Sotirova, S. Sotirov, D. Mavrov (2015) Application of the InterCriteria Decision Making method to Bulgarian universities ranking, *Notes on Intuitionistic Fuzzy Sets*, 21(2), 111—117.

[12] Krawczak, M., V. Bureva, E. Sotirova & E. Szmidt (2015) Application of the InterCriteria decision making method to universities ranking, *Novel Developments in Uncertainty Representation and Processing Advances in Intuitionistic Fuzzy Sets and Generalized Nets*, Springer-Verlag Berlin Heidelberg, (in press).

[13] *Rankings of Australian Universities*, `http://www.australianuniversities.com.au/rankings/#rankingsoverview`.

[14] *QS Top Universities, Worldwide University Rankings, Guides and Events*, `http://www.topuniversities.com/`.

[15] TEQSA (2015) *Statistics Reports on TEQSA Registered Higher Education Providers.* Australian Government, Canberra, 30pp.

[16] Zadeh, L. A. (1965) Fuzzy Sets. *Information and Control*, 8, 333–353.