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Contents

Part III: Multicriteria Decision Making and Optimization

Part IV: Issues in Intuitionistic Fuzzy Sets

Part V: Fuzzy Cognitive Maps and Applications

Part XV: Perception, Judgment, Affect, and Sentiment Analyses

InterCriteria Decision Making Approach to EU Member States Competitiveness Analysis: Trend Analysis

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Abstract. In this paper, we continue our investigations of the newly developed InterCriteria Decision Making (ICDM) approach with considerations about the more appropriate choice of the employed intuitionistic fuzzy threshold values. In theoretical aspect, our aim is to identify the relations between the thresholds of inclusion of new elements to the set of strictly correlating criteria and the numbers of correlating pairs of criteria thus formed. We illustrate the findings with data extracted from the World Economic Forum's Global Competitiveness Reports for the years 2008–2009 to 2013–2014 for the current 28 Member States of the European Union. The study of the findings from the considered six-year period involves trend analysis and computation of two approximating functions: a linear function and a polynomial function of 6^{th} order. The per-year trend analysis of each of the 12 criteria, called 'pillars of competitiveness' in the WEF's GCR methodology, gives an opportunity to prognosticate their values for the forthcoming year 2014–2015.

Keywords: Global Competitiveness Index, InterCriteria decision making, Intuitionistic fuzzy sets, Multicriteria decision making, Trend analysis.

1 Introduction

In a series of papers, we have started investigating the application of the newly proposed InterCriteria Decision Making (ICDM) approach, based on the concepts of

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intuitionistic fuzzy sets (see [1, 3, 4]) and index matrices (see [2]). ICDM aims to support a decision maker, who disposes of datasets of evaluations or measurements of multiple objects against multiple criteria, to more profoundly understand the nature of the utilized evaluation criteria, and discover some correlations existing among the criteria themselves. Theoretically, the ICDM approach has been presented in details in [5], and in [6, 7, 8] the approach was further discussed by the coauthors in the light of its application to data about EU Member States' competitiveness in the period 2008–2014, as obtained from the World Economic Forum's (WEF) annual Global Competitiveness Reports(GCRs), [9].

Shortly presented, in the ICDM approach, we have (at least one) matrix of evaluations or measurements of m evaluated objects against n evaluating criteria, and from these we obtain a respective $n \times n$ matrix giving the discovered correlations between the evaluating criteria in the form of intuitionistic fuzzy pairs, or, which is the same but more practical, two $n \times n$ matrices giving in separate views the membership-values (a μ-matrix) and the non-membership pairs (a ν-matrix). Once having these, we are interested to see which of the criteria are in *positive consonance* (situation of definitively correlating criteria), in *negative consonance* (situation of definitively non-correlating criteria), or in *dissonance* (situation of uncertainty, when no definitive conclusion can be made). In order to categorize all the values of the resultant $n(n-1)/2$ pairs of criteria, we need to define two thresholds, α and β, for the positive and for the negative consonance, respectively.

In [5, 7], where the emphasis was put on some other aspects of the ICDM's approach, we considered the rather simplistic case when the [0; 1]-limited threshold values α and β were changing with a predefined precision step and were always summing up to 1. Later, in [6], we notice that this approach is not enough discriminative and helpful for the decision maker, and reformulate the problem statement aiming to identify (shortlist) the k most strongly positively correlated criteria out of the totality of n disposable evaluation criteria. A general problem-independent algorithm for this shortlisting procedure is proposed there, and will be partially relied on here as well.

2 Data Presentation

The presented in [6] algorithm for identifying the values of threshold α under which a given element of the set of evaluating criteria starts entering in positive consonances with the rest criteria. The algorithm involves taking the maximal values of positive consonance per criterion (which in the terms of index matrices is the operation *max-row-aggregation*), sorting this list in descending order, and thus finding the ordering of the criteria by positive consonance.

In [6], we illustrated this algorithm using the datasets of EU Member States' competitiveness, as evaluated by the World Economic Forum. We made the calculations for both the positive and the negative consonance, in order to compare the results on this plane, as well as in time. We presented the results only for years 2008−2009 and 2013−2014, which are the two extreme years in the period we analyse from the publicly available GCRs, [9]. Here we will present the tables for all six years separately (Tables 1–6), as well as in aggregation (Table 7).

Table 1. Results for year 2008–2009

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when $\alpha \leq$
2	1	11	0.860
		12	
4	2	1	0.844
		2	
5	3	6	0.833
6	5	8	0.828
7	6	9	0.823
8	14	5	0.796
9	18	4	0.780
10	37	3	0.693
11	41	7	0.664
12	45	10	0.648

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when $\beta \geq$
2	1	1	0.077
		6	
4	2	11	0.079
		12	
5	3	8	0.09
6	4	9	0.095
8	5	4	0.108
		5	
9	8	2	0.114
11	35	3	0.204
		7	
12	54	10	0.307

Table 2. Results for year 2009–2010

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when $\alpha \leq$
2	1	1	0.856
		6	
4	2	11	0.852
		12	
5	3	9	0.849
7	8	2	0.807
		5	
8	16	8	0.783
9	18	4	0.778
10	36	7	0.693
11	37	3	0.690
12	52	10	0.622

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when $\beta \geq$
2	1	11	0.071
		12	
4	2	1	0.077
		6	
5	4	9	0.106
6	6	5	0.119
7	9	8	0.122
8	12	4	0.124
9	15	2	0.135
10	35	7	0.206
11	37	3	0.212
12	55	10	0.302

Table 3. Results for year 2010–2011

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when $\alpha \leq$
2	1	11	0.852
		12	
3	2	1	0.849
4	3	9	0.828
5	4	6	0.825
6	8	5	0.812

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when $\beta \geq$
2	1	11	0.087
		12	
3	2	1	0.095
4	3	6	0.103
5	5	9	0.106
6	6	4	0.114

Table 4.*(continued)*

7	9	2	0.810
8	18	4	0.751
9	24	8	0.720
10	31	7	0.690
11	34	3	0.683
12	42	10	0.653

7	7	5	0.116
8	10	2	0.127
9	28	8	0.185
10	29	3	0.190
11	30	7	0.198
12	54	10	0.294

Table 4. Results for year 2011–2012

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when $\alpha \leq$
2	1	11	0.870
		12	
3	2	9	0.854
4	3	1	0.841
5	6	2	0.831
6	10	5	0.807
7	11	6	0.796
8	19	8	0.738
9	24	7	0.706
10	25	4	0.704
11	29	3	0.685
12	35	10	0.672

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when $\beta \geq$
2	1	11	0.074
		12	
3	2	9	0.090
4	3	1	0.095
5	4	5	0.098
6	6	2	0.114
7	8	6	0.116
8	17	4	0.153
9	22	8	0.175
10	23	7	0.180
11	35	3	0.241
12	49	10	0.283

Table 5. Results for year 2012–2013

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when $\alpha \leq$
2	1	1	0.870
		9	
4	2	11	0.865
		12	
5	5	5	0.836
6	7	6	0.831
7	9	2	0.815
9	18	4	0.749
		8	
10	22	7	0.741
11	40	10	0.659
12	42	3	0.648

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when $\beta \geq$
2	1	1	0.071
		9	
3	2	6	0.074
5	3	11	0.077
		12	
6	6	5	0.090
7	10	2	0.111
8	11	4	0.114
10	25	7	0.153
		8	
11	42	3	0.267
12	46	10	0.286

Table 6. Results for year 2013–2014

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when α ≤
2	1	11	0.873
		12	
4	2	1	0.854
		9	
5	3	5	0.847
6	11	2	0.804
7	13	6	0.788
9	20	7	0.749
		8	
10	25	4	0.730
11	37	3	0.675
12	39	10	0.661

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when β ≥
2	1	11	0.071
		12	
4	2	1	0.077
		6	
5	3	5	0.079
6	4	9	0.090
8	13	2	0.135
		7	
9	17	4	0.143
10	19	8	0.146
11	38	3	0.251
12	45	10	0.286

Table 7. Results for year 2008–2014

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by positive consonance	True when α ≤
2	1	11	0.836
		12	
4	2	1	0.821
		6	
6	5	5	0.804
		9	
7	7	2	0.789
8	18	8	0.745
9	21	4	0.725
10	25	7	0.693
11	34	3	0.672
12	44	10	0.622

Number of correlating criteria	Number of pairs of correlating criteria	Criteria ordered by negative consonance	True when β ≥
2	1	11	0.091
		12	
4	2	1	0.092
		6	
5	3	5	0.109
6	4	9	0.124
7	8	4	0.139
8	9	2	0.144
9	18	8	0.163
10	26	7	0.190
11	34	3	0.239
12	48	10	0.306

While columns 1, 3 and 4 in each of the Tables 1–7 have been discussed and determined within the algorithm, we also support information in column 2 about the number of pairs formed by the so ordered correlating criteria. This separately determined, completely data-dependent, number gives information about the level of interconnectedness between the involved criteria, and is also considered by us to be useful to keep track of. From these 7 tables, we are interested to detect the dependences between the increase of the threshold values and the interconnectedness between the correlating criteria, and thus propose another way of determining the threshold values.

We are also interested to perform trend analysis of the threshold values for all the years from 2008–2009 to 2013–2014, and formulate a prognosis for year 2014–2015.

3 Main Results

Taking the data from Tables 1–6 from columns 2 and 4, we obtain six charts (Fig. 1–6), of the dependence between the number of pairs of correlating criteria, i.e. the interconnectedness (as plotted on the axis x), and the thresholds of inclusion of a new criterion to the set of correlating criteria (in descending order, as plotted on the axis y).

These figures allow us to make observations about the homogeneity of the positive consonances exhibited by the evaluation criteria, and thus more easily decide how to divide the set of criteria on strongly and weakly correlating ones. Finally, this helps us decide about the number k of the totality of n criteria, on which to focus our attention, as was formulated for parts of the problems ICDM solves, [6].

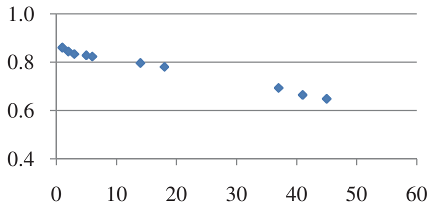

Fig. 1. Results for year 2008–2009.

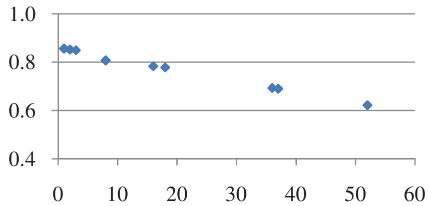

Fig. 2. Results for year 2009–2010.

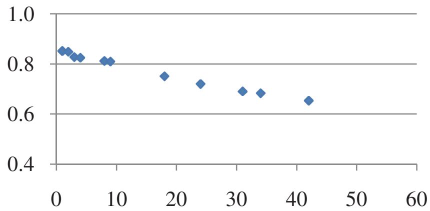

Fig. 3. Results for year 2010–2011.

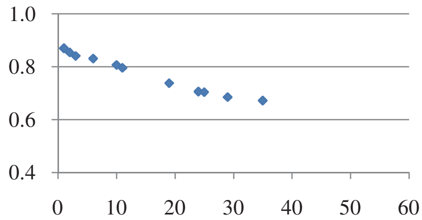

Fig. 4. Results for year 2011–2012.

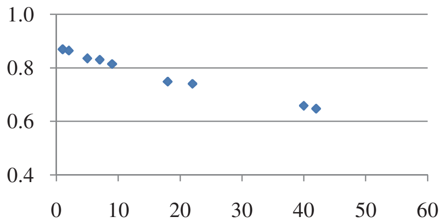

Fig. 5. Results for year 2012–2013.

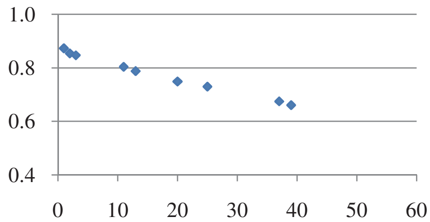

Fig. 6. Results for year 2013–2014.

On this basis we can conclude that for year 2013–2014, we can see that four groups of criteria are formed:

- five strongly correlating, with α varying from 0.847 to 0.873: '11. Business sophistication', '12. Innovation', '1. Institutions', '9. Technological readiness' and '5. Higher education and training';
- two weakly correlating, with α varying from 0.788 to 0.804: '2. Infrastructure' and '6. Goods market efficiency';
- three weakly non-correlating, with α varying from 0.730 to 0.749: '7. Labor market efficiency', '8. Financial market sophistication' and '4. Health and primary education'; and
- two strongly non-correlating, with α varying from 0.661 to 0.675: '3. Macroeconomic stability' and '10. Market size'.

With the data from this case, involving 12 criteria only, the decision maker can easily make the above observation without further calculations or application of other sophisticated methods. However, in cases involving a greater number of criteria, application of cluster analysis methods may prove unavoidable.

It is also interesting, to see how all these six charts combine in a single picture, as given in Fig. 7.

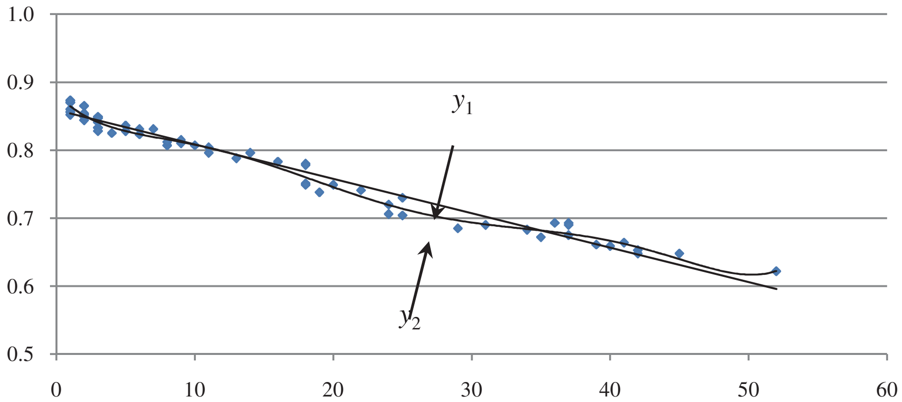

Fig. 7. Combined results for the years 2008–2014, based on dependencies between number of pairs in correlation (axis x) and level of positive consonance (axis y). Functions y_1 and y_2 approximate the set of plotted points.

We have further elaborated it by approximating the 72 points with a simple linear function, y_1, and with a polynomial function of 6th order, y_2. The form of both functions was produced with the aid of MS Excel, as follows:

$$y_1 = -0.0051x + 0.8591, \tag{1}$$

$$y_2 = 9e{-}^{10}x^6 - 1e{-}^{7}x^5 + 8e{-}^{6}x^4 - 0.0002x^3 + 0.0028x^2 - 0.0203x + 0.8822. \tag{2}$$

Although we have already settled to give priority to the results related to positive consonance in this example, it is interesting to show also the last result, as obtained for the negative consonance. Skipping the charts for the six individual years, we show only the combined picture for negative consonance in the following Fig. 8.

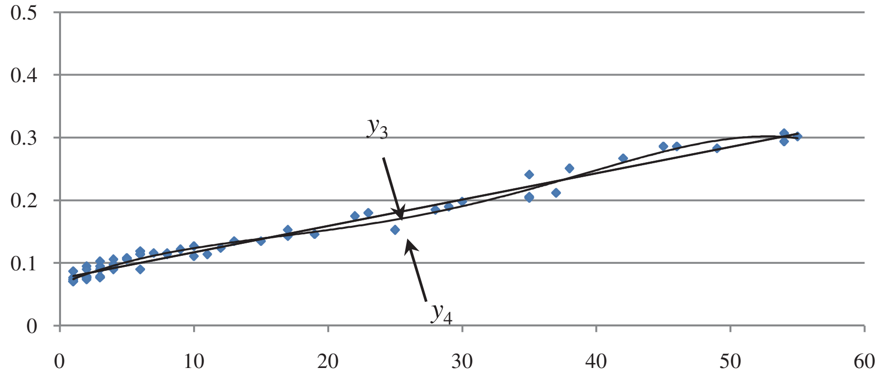

Fig. 8. Combined results for the years 2008–2014, based on dependencies between number of pairs in correlation (axis x) and level of negative consonance (axis y). Functions y_1 and y_2 approximate the set of plotted points.

Again, for approximating the 72 points we use a linear function, y_3, and a polynomial function of 6[th] order, y_4, as follows:

$$y_3 = 0.0042x + 0.0751, \tag{3}$$

$$y_4 = -3e-^{12}x^6 - 4e-^{10}x^5 - 6e-^{8}x^4 + 1e-^{5}x^3 - 0.0004x^2 + 0.009x + 0.0658. \tag{4}$$

4 Conclusions

In the present work, we show that taking into consideration the proximity between the intercriteria's exhibited consonance is a more appropriate approach for shortlisting the subset of criteria than taking the first k out of n, as discussed in [6].

We also propose here to employ trend analysis over the results obtained with the application of the InterCriteria Decision Making approach to the examined data from the Global Competitiveness Reports of the World Economic Forum. Further research in this direction has potential to reveal more knowledge about the nature of the evaluation criteria involved and their future development. Eventually, these results may help policy makers identify and strengthen the transformative forces that will drive future economic growth, [9].

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