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THE IMPACT OF DECISION-MAKING PROFILES ON THE CONSISTENCY OF RANKINGS OBTAINED BY MEANS OF SELECTED MULTIPLE CRITERIA DECISION-AIDING METHODS

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Abstract: The paper discusses the impact of the decision-making profiles on the consistency of rankings obtained by three multiple criteria methods, i.e. DR, AHP and TOPSIS. The online decision making experiment was organized, based on an electronic questionnaire which is a hybrid of the internet survey system and the decision support system. The participants of the experiment were 418 students of Polish universities. To describe the decision-making profile, the REI test was used which allows to distinguish two decision-making styles: rational and intuitive. The Kendall rank correlation coefficient was used to test the consistency of the rankings obtained by the considered methods. Using different grouping methods, the relationship between the decision profile and the ability to express one's preferences by means of these methods, that differ in cognitive requirements, was examined. The results of the research may be helpful for supporting the decision-maker in decision processes by choosing the method that fits their profile best.

Keywords: decision support, decision-making profile, multiple criteria decision aiding, preference analysis, data analysis.

1. Introduction

Multiple Criteria Decision Aiding (MCDA) methods embrace the techniques of constructing rankings, the selection of the best alternatives or their classification, which takes into consideration the existence of many criteria to be optimized [Roy

1990; Figueira et al., 2005; Triantaphyllou 2000; Trzaskalik 2014]. The variety of MCDA methods causes decision problems with choosing one to support the decision maker (DM) in a particular decision problem. Some researchers proposed guidelines for selecting an appropriate MCDA method [MacCrimmon 1973; Gershon 1981; Ozernoy 1987; Tecle 1988; Guitouni, Martel 1998; Satty, Ergu 2015, among others]. The others applied several MCDA methods to the same real decision problem and compared the results obtained by those methods, or analyzed the usability of several methods in real decision-making problems [Hajkowicz, Higgins 2008; Mela et al. 2012; Górecka 2011; Roszkowska, Wachowicz 2016]. There are also experimental studies where different methods are applied to the same problem or simulation results comparing different methods [Triantaphyllou, Mann 1989; Zanakis et al. 1998; Ishizaka, Sajid 2018]. An interesting literature review on the comparative analysis of MCDA methods can be found in Satty and Ergu [2015].

The general factors for choosing the multiple criteria procedure are related to the problem and the structure of the decision situation, the nature and scope of available information, the simplicity of the calculation algorithm and the availability of software support. To help DMs in overcoming the heuristic-based way of thinking and eliminate the correlated biases and possible errors, decision support is offered. The usage of various multiple criteria decision aiding methods may lead to different support results due to some technical issues related to the process of preference elicitation that affect the cognitive demand of these methods. Yet the efficiency of the preference analysis based on various models depends on the decision-makers' cognitive abilities, i.e. the way of thinking and analyzing the decision-making process. However, the relations between the DM's cognitive abilities and the results obtained by different multiple criteria methods have not been empirically investigated so far.

The goal of this paper is to investigate what is the impact of the decision-making profile on the consistency of the rankings obtained using three MCDA methods. The *consistency of rankings* we define as the similarity of the rankings of the alternatives obtained by those methods. In this research we focus on the Direct Rating (DR) [Edwards, Barron 1994], Analytic Hierarchy Process (AHP) [Saaty 1980] and The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [Hwang, Yoon 1981] methods, which are often used to solve real-life problems, but differ in the process of preference elicitation [Figueira et al. 2016]. In this paper we try to answer the following two research questions:

RQ1: Whether and to what extent the decision-making profile affects the consistency of the rankings obtained by various multiple criteria methods?

RQ2: Does the decision-making profile affect the effectiveness of the multiple criteria method?

Effectiveness we define as the extent to which the method is capable to produce the ranking of alternatives that fits the DM's intrinsic preferences.

To describe the decision-making profile, the Rational-Experiential Inventory (REI) test was used which allows to distinguish two decision styles: rational or analytical

(slow thinking system) and intuitive or experiential ones (fast thinking system). The Kendall rank correlation coefficient was used to test the consistency of the rankings obtained by the methods used in our survey. Using different grouping methods, the relationship between the decision-making profile and the ability to express one's preferences by means of these methods that differ in cognitive requirements, was examined. The answers to the survey question related to the choice of the method that is most suitable for supporting the decision-maker allowed to examine the relationship between the decision profile and the declared usefulness of the multiple criteria methods in the decision support.

In this way we contribute to the behavioral decision analysis by providing descriptive conclusions of how the decision-making profile may influence the rankings obtained by different multiple criteria methods. The results of the research may be helpful for supporting the decision-maker in individual and group decisions and the negotiation process by choosing the method that fits their decision style the best.

The rest of the paper is organized as follows. In Section 2 we define the decision making profiles. In Section 3 we describe the experiment we designed to analyze the effectiveness of the selected MCDA methods, while in Section 4 the results are presented. The latter will consist of a detailed description of the process of the profiling of DMs according to the REI test (Epstein et al. 1996) and examining the relationship between the various classes of the decision styles and Kendall's correlation coefficients. We finish with conclusions and future work.

2. Decision-making profile

To describe the decision-making profile the REI test was used, consisting of 20 questions, which allows to recognize two decision styles: intuitive (*fast thinking*) and rational (*slow thinking*) ones [Stanovich, West 1998; Epstein et al. 1996]. The intuitive style is related to the information processing system called System 1, which works in a quick and automatic manner, without effort and sense of the conscious control of the DM. System 1 is based on experience and is accompanied by a minimal effort of the decision maker. The rational style is related to System 2. It is based on analytical thinking and logic, and involves thorough information processing that requires a large cognitive effort from the DM. This system distributes the necessary attention among activities requiring mental effort such as complicated calculations. System 2 is often associated with a subjective sense of focus, freedom of choice and conscious action.

Fast thinking provides a number of heuristics for streamlining the decision-making processes by reducing the amount of integrated information necessary in making the decisions [Kahneman 2011; Kahneman, Tversky 1984]. Heuristics can introduce errors and bias judgements, hence the understanding of the mechanisms of their work can lead to better decision-making.

It is worth noting that there is a lack of consensus about the theoretical relation between intuition and analysis in the literature [Allinson, Hayes 1996; Stanovich, West 2000; Wand et al. 2017]. As was pointed out [Wand et al. 2017]: "models of individual differences in cognition differ as to whether intuition and analysis are viewed as bipolar opposites or as two independent unipolar dimensions. The distinction concerns whether one can be as follows: (i) either intuitive or analytical or (ii) both intuitive and analytical in orientation. The first implies a negative relation between the constructs, whereas the second implies no relation between intuition and analysis". Wand et al. [2017] also report the meta-analytic investigations of the relation between intuition and analysis and show no evidence for the correlation between intuition and analysis, suggesting that the independence model may be more appropriate.

3. The organization of the experiment

This study is based on an electronic questionnaire designed as a hybrid of a classic internet survey system and a decision support system with the implemented problem of choosing a flat to rent[1]. The problem consisted of five predefined alternatives, each evaluated by means of five criteria. Table 1 presents the decision matrix of the problem under consideration. The participants of the experiment were 418 students of four Polish universities.

At the beginning of the survey the respondents set an individual ranking (I) of five rental offers Then, using three implemented MCDA methods that differed in the preference elicitation schema, they evaluated those five offers. The algorithm of the AHP method used in the survey implemented the linguistic evaluation of the pairs of options for each criterion. The user interface for such an evaluation implemented graphical sliders. When the users moved the slider's handle the verbal description of the strength of preferences between the compared pair of alternatives changed. In the procedure of the DR method the DM assigned to each option (the resolution level of each alternative with respect to each criterion) the numerical score from the interval [0; 100] that described its attractiveness. In the TOPSIS method, the scores for quantitative options were measured automatically using the notion of distance. The qualitative options, however, required prior evaluation by the DM. In our survey the qualitative options of alternatives were evaluated using a pictographic interface (so-called quality stars) associated with a seven-point numerical rating scale.

The respondents were also asked to fill in a series of questionnaires during the survey. One of them was the REI questionnaire consisting of 20 questions, which allowed them to describe the decision style. The declared usefulness of the method was related to the answer to one of the post-questionnaire questions:

[1] Website survey: https://mpar.ue.katowice.pl/ankieta/.

Table 1. Decision matrix

Variant/ offer	The cost of renting (monthly)	No. of rooms	Area	Equipment	Commuting time
A	950 PLN	2 rooms (including 1 room with a kitchenette)	35 m^2	fridge, washing machine, microwave	10-12 min
B	1200 PLN	3 rooms (including a living room with a kitchenette)	54 m^2	fridge, washing machine, dishwasher, internet	30-35 min
C	900 PLN	2 rooms + kitchen (separate)	35 m^2	fridge, washing machine, internet (permanent connection)	20-25 min
D	700 PLN	1 room + kitchen (separate)	25 m^2	fridge, washing machine, TV, cable, internet (permanent connection)	30-35 min
E	950 PLN	1 room + kitchen (separate)	54 m^2	fridge, washing machine, internet (permanent connection)	20-25 min

Source: own elaboration.

Q: Which method (AHP, DR, TOPSIS, none of those presented) do you consider as the most suitable for decision support?

4. Results

The factor analysis with Varimax rotation with Kaiser normalization for the REI test allowed to define the decision styles at the satisfactory level. The Kaiser-Meyer--Olkin measure (KMO) KMO = 0.852 indicates the appropriate sample. The KMO values for individual items between 0.793 and 0.889 are also satisfactory. Bartlett's test shows that the correlations between the questions are large enough to perform a factor analysis [$\chi^2(190) = 2291.639$; $p < 0.001$]. The subscale for the analytical system represented by α Cronbach value is equal to 0.827, for an intuitive system – 0.809. Table 2 contains factor loadings obtained as a result of factor analysis based on 20 questions from the REI-20 test [Stanovich, West 2000].

There is a strong (above 0.99) and statistically significant ($p < 0.01$) correlation between the values of factor loadings of the decision styles and the corresponding average values of the answers for the questions describing this style. Therefore to increase the informative value of the analysis the average answer values were used to describe each style, i.e. to determine the analytical style (A), the average value from questions 1-10, while for the intuitive style – the average value from questions

11-20 of the REI test were determined (Table 2). The Pearson coefficient beetwen AvR and AvI is equal to –0.049 and is statistically insignificant $p = 0.322$. The obtained results confirm also that the intuitive style and the rational style are orthogonal, not bipolar constructs.

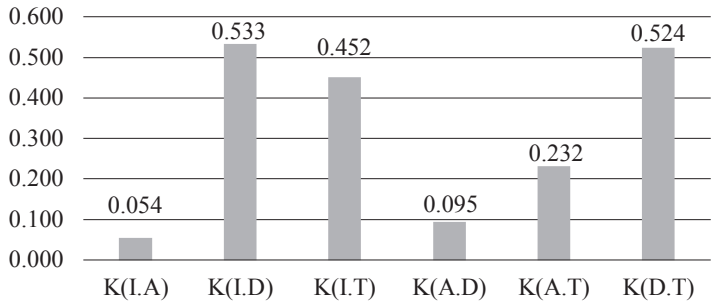
Table 2. Factor analysis – REI test my note: questions 4 and 14 are the same

No.	Question	Intuitive factor	Rational factor
1	I try to avoid situations that require thinking in depth about something (R)*	–0.055	**0.638**
2	I am not that good at figuring out complicated problems (R)	0.019	**0.691**
3	I am not very good at solving problems that require careful logical analysis (R)	–0.037	**0.547**
4	I don't like to have to do a lot of thinking (R)	–0.013	**0.596**
5	Thinking is not my idea of an enjoyable activity (R)	–0.068	**0.707**
6	I am not a very analytical thinker (R)	–0.063	**0.595**
7	Reasoning things out carefully is not one of my strong points (R)	–0.059	**0.529**
8	I don't reason well under pressure (R)	0.040	**0.538**
9	I enjoy intellectual challenges	0.053	**0.578**
10	I enjoy solving problems that require hard thinking	0.021	**0.626**
11	I don't have a very good sense of intuition (R)	**0.394**	0.209
12	If I were to rely on my gut feelings, I would often make mistakes (R)	**0.713**	0.117
13	I don't like situations in which I have to rely on intuition (R)	**0.722**	0.085
14	I think it is foolish to make important decisions based on feelings (R)	**0.610**	–0.082
15	I like to rely on my intuitive impressions	**0.501**	–0.121
16	Using my gut feelings usually works well for me in figuring out problems in my life	**0.606**	0.169
17	I believe in trusting my hunches	**0.772**	–0.050
18	Intuition can be a very useful way to solve problems	**0.765**	–0.059
19	I often go by my instincts when deciding on a course of action	**0.642**	–0.216
20	I trust my initial feelings about people	**0.497**	–0.162
	% of variance	20.80	18.79
	Cronbach's α	0.809	0.827

Description: (R) – reverse coded item; 7 point Likert scale: 1 – I definitely disagree, 7 – I definitely agree.

Source: own elaboration with using SPSS 24.

The consistency of the rankings obtained by different methods is measured using the tau Kendall rank correlation coefficient. The average values of the tau Kendall coefficient are presented in Figure 1.



Description: I – individual ranking, D – DR method, T – TOPSIS method, A – AHP method, K – tau Kendall coefficient.

Fig. 1. The consistency of rankings obtained by different methods measured by the tau Kendall coefficient

Source: own elaboration.

The best average consistency was noted between the rankings obtained by individual evaluation and the DR method (0.533), as well as DR and TOPSIS (0.542). The lowest average consistency was noted for the rankings obtained by individual evaluation and AHP (0.054), as well as AHP and DR (0.095).

To answer our research question *RQ*1, we first checked the Pearson coefficients between the variables representing the rational/intuitive style and the tau Kendall correlation coefficients for the rankings obtained by means of different methods.

Table 3. Relationship between average value of decision style and Kendall's correlation coefficients

Pearson coefficient	K(A,I)	K(I,D)	K(I,T)	K(A,D)	K(A,T)	K(D,T)
AvR	0.104*	0.014	0.067	0.096*	0.145**	0.023
AvI	–0.046	–0.034	–0.012	–0.052	–0,011	–0.040

Description: I – individual, D – DR, T – TOPSIS, A – AHP, K – tau Kendall coefficient, AvR – average value for answers from 10 questions describing the intuitive style, AvI – average value for answers from 10 questions describing the intuitive style, $^{*}p < 0.05$; $^{**}p < 0.01$.

Source: own elaboration.

The results presented in Table 3 show a weak but statistically significant relationship between the analytical style and the tau Kendall coefficients K(A,I), K(A,D), K(A,T), which shows the degree of concordance of rankings obtained using AHP and one of the other methods.

Next, for a more detailed analysis, three classes of respondents were distinguished: with a low, medium and high level of analytical style (L_R, M_R, H_R) and three classes of respondents with low, medium and high levels of intuitive style (L_I, M_I, H_I). The legitimacy for this approach is confirmed by the fact of the orthogonal

Table 4. The numbers of respondents in decision style classes

H_I	37	45	35
M_I	48	80	50
L_I	40	45	38
	L_R	**M_R**	**H_R**

Source: own elaboration.

character of the decisionmaking constructs observed earlier. As a criterion of belonging to the appropriate classes, quartile values of the relevant variables were adopted: no more than Q1 for the low level, between Q1 and Q3 for the medium level, and not less than Q3 for the high level. Considering the co-occurrence of both decision styles, nine classes were finally distinguished: K1: L_R & L_I; K2: M_R & L_I; K3: H_R & L_I; K4: L_R & M_I; K5: M_R & M_I; K6: H_R & M_I; K7: L_R & H_I; K8: M_R & H_I; K9: H_R & H_I. The numbers of respondents allocated to the described class of the decision style are shown in Table 4.

Table 5 presents the average values of the tau Kendall's correlation coefficient in the described classes. In addition, the dark gray color indicates the classes for which this coefficient takes the highest values, the light gray – the classes with the middle values, while the white – the lowest values of the Kendall coefficient.

Analyzing the results presented in Table 5, quite large differences between the average values of K(A,I), K(A,D) and K(A,T) can be noticed, as well as the relatively small differences in the average values of the other coefficients among the classes of decision styles. The highest concordance of the K(A,I), K(A,D) and K(A,T) rankings was obtained for respondents for whom the level of analytical style exceeds their level of intuitive style, i.e. respondents from the K2, K3 and K6 classes, and the lowest concordance for respondents with a low level of analytical style and a low or medium level of intuitive style, i.e. respondents from classes K1 and K4.

Table 5. Relationship between decision style class and Kendall's correlation coefficients

K(A,I)			
H_I	0.06	0.02	–0.02
M_I	–0.11	0.06	**0.16**
L_I	–0.03	**0.20**	**0.14**
	L_R	**M_R**	**H_R**

K(A,D)			
H_I	0.15	0.00	0.03
M_I	–0.05	0.07	**0.21**
L_I	–0.01	**0.25**	**0.22**
	L_R	**M_R**	**H_R**

K (A,T)			
H_I	0.24	0.22	0.26
M_I	0.01	0.25	**0.32**
L_I	0.14	**0.36**	**0.29**
	L_R	**M_R**	**H_R**

K (I, D)			
H_I	**0.56**	0.52	0.46
M_I	0.48	**0.57**	0.54
L_I	0.52	**0.56**	0.55
	L_R	**M_R**	**H_R**

K (I, T)			
H_I	**0.49**	0.47	0.43
M_I	0.35	0.48	**0.48**
L_I	0.41	**0,50**	0.44
	L_R	**M_R**	**H_R**

K (D,T)			
H_I	0.50	0.47	0.53
M_I	0.46	**0.58**	**0.55**
L_I	0.54	**0.56**	0.49
	L_R	**M_R**	**H_R**

Description as in Table 3.

Source: own elaboration using SPSS 24.

The general observations are confirmed by the U Mann-Whitney test (M_W test), where the average values of all the Kendall tau coefficients between any two classes were compared. Table 6 contains the significance level values for the M_W test for these classes and the Kendall tau coefficients (K(A,I), K(A,D), K(A,T)) for which the differences in average values turned out to be statistically significant.

Table 6. Comparison of decision style classes due to values of the Kendall tau coefficients – values of the significance level of the U Mann Whitney test

Class comparison	Tau Kendall coefficient		
	K(A,I)	K(A,D)	K(A,T)
K4:K2	0.008**	0.012*	0.001**
K4:K3	0.017*	0.015*	0.007**
K4:K6	0.011*	0.030*	0.004**
K2:K1	0.044*	0.028*	0.060
K2:K8	0.120	0.025*	0.230
K3:K1	0.085	0.046*	0.126
K3:K8	0.219	0.031*	0.331
K4:K5	0.118	0.252	0.017*
K4:K8	0.406	0.735	0.032*
K4:K9	0.444	0.512	0.035*

Description as in Table 3. $^{*}p < 0.05$; $^{**}p < 0.01$.

Source: own elaboration using SPSS 24.

There were statistically significant differences between class K4, which contains the respondents with a low level of analytical style and a medium level of intuitive style, and classes K2, K3, K6, i.e. with classes in which the level of analytical style exceeds the level of intuitive style. Statistically significant differences were also observed between class K2 and classes K1, K8 and class K3 and classes K1 and K8 with respect to K(A,D) and between class K4 and classes K5, K8, K9 with respect to K(A,T).

Deriving from the results obtained above, two groups of respondents were distinguished: X and Y. The first one is composed of respondents for whom the level of rational style is higher than the intuitive, i.e. X = K2∪K3∪K6, the other remaining respondents, i.e. Y = K1∪K4∪K5∪K7∪K8∪K9. Table 7 presents the average values of the tau Kendall coefficients in the analyzed classes and the significance level of the M_W test.

The analysis of Table 7 shows that respondents from class X were characterized by the greater concordance of the rankings obtained by means of any two methods; but only in the case of the rankings obtained by the AHP method and one from the remaining these differences were statistically significant ($p < 0.001$; M_W test).

Table 7. Comparative analysis of the consistency of rankings obtained by various methods in the *X* and *Y* classes

Tau Kendall coefficient	Average tau Kendall coefficient in class		U Mann-Whitney test (p)
	X (N = 133)	Y (N = 285)	
K(A,I)	0.168	0.001	0.001^{**}
K(A,D)	0.229	0.032	$<0.0001^{**}$
K(A,T)	0.328	0.187	0.006^{**}
K(I,D)	0.549	0.526	0.634
K(I,T)	0.478	0.439	0.498
K(D,T)	0.535	0.519	0.765

Description as in Table 3. $^{**}p < 0.01$

Source: own elaboration using SPSS 24.

Now we can answer the second research question *RQ2*. The usefulness of the method declared by the respondent was related to post-questionnaire question *Q*. The majority of respondents 174 (41.6%) chose the TOPSIS method, the AHP and DR method were chosen by a similar number of respondents: AHP-124 (29.7%) and DR 114 (27.3%). Six respondents (1.4%) did not indicate any of the analyzed methods. The relationship between the rational and intuitive style and the recommended method by the respondents is presented in Figure 2.

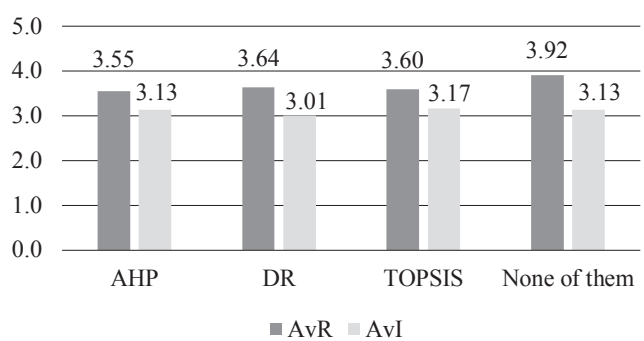


Fig. 2. The relationship between the decision style and the usefulness of the multiple criteria method declared by the respondents

Source: own elaboration using SPSS 24.

By using the M_U test a significant statistical difference (p = 0.042) was found only for the level of intuitive style for the respondents who chose TOPSIS and DR, while there was no statistically significant relationship between the rational style and the choice of multiple criteria decision aiding method. It is also worth noting that by

using the Wilcoxon test, the significant difference ($p < 0.001$) between AvR and AvI values within each method was found.

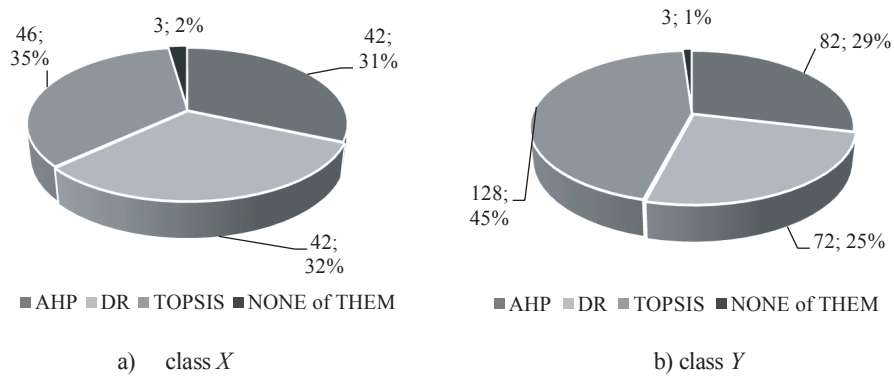


Fig. 3. The structure of recommended methods by respondents in class *X* and *Y*

Source: own elaboration using SPSS 24.

Let us observe that in class X containing the respondents for whom the rational style is higher than the intuitive 35% respondents recommended TOPSIS, 32% DR and 31% AHP; while 45% of the respondents from class Y recommended TOPSIS, 29% AHP and 25% DR (Figure 3).

5. Conclusions

The results presented in this work are part of a comprehensive study related to the analysis of the usefulness of selected MCDA methods for decision support, in particular in the context of supporting negotiations (see: [Roszkowska, Wachowicz (eds.) 2016; 2014a; 2014b; Roszkowska et al. 2017]). The project concerns the identification of a recommendation system of appropriate methods and procedures for supporting a pre-negotiation analytical and decision-making process, dependent on the negotiator's perception and cognitive abilities. Discovering the association of the effectiveness of multiple criteria methods with the personality and decision profile gives the possibility of personalizing the tools for decision support and building precise systems of contract valuation or supporting the negotiation process in a manner convenient for the user, taking into consideration their level of perceptual abilities.

The preliminary results obtained in the experiment presented in this paper indicate the small but statistically significant influence of the decision style on the mechanism of linguistic evaluation of the option pairs carried out on the basis of the AHP procedure. This method requires a greater cognitive effort from the decision--maker, it is also more labor-intensive and time-consuming [Roszkowska et al.

2018]. However, no effect of the level of the decision style on the concordance of the rankings obtained by methods other than AHP was found.

We also found the weak impact of the intuitive style on the effectiveness of the multiple criteria decision aiding method declared by the respondents. More precisely, we found that those who recommended the TOPSIS method are more intuitive than those who recommended DR.

We need to emphasize that the research we conducted was based on the dataset of a very homogenous group of respondents (students), hence the results obtained cannot be directly mapped on other types of decision-makers. However, it should be noted that these are only the preliminary results of the research that will be continued in the context of the analysis of relationships between the personality, decision making profile, heuristic based thinking and the usefulness of multiple criteria methods to support negotiations.

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WPŁYW PROFILU DECYZYJNEGO NA ZGODNOŚĆ RANKINGÓW OTRZYMANYCH ZA POMOCĄ WYBRANYCH METOD WIELOKRYTERIALNYCH – ANALIZA BADANIA EKSPERYMENTALNEGO

Streszczenie: W pracy podjęto problematykę wpływu profilu decyzyjnego na zgodność pomiędzy subiektywnymi preferencjami decydenta a rankingami otrzymanymi za pomocą trzech metod wielokryterialnych, tj. DR, AHP, TOPSIS. Do badania wykorzystano kwestionariusz ankiety elektronicznej będącej hybrydą klasycznego internetowego systemu sondażowego i systemu wspomagania decyzji. Uczestnikami eksperymentu było 418 studentów polskich uczelni. Do opisu profilu decyzyjnego zastosowano test REI, który umożliwił wyodrębnienie dwóch stylów decyzyjnych: racjonalnego oraz intuicyjnego. Do badania zgodności rankingów otrzymanych wybranymi metodami zastosowano współczynnik korelacji rang Kendalla. Stosując różne metody grupowania, starano się znaleźć związki między profilem decyzyjnym a umiejętnością wyrażania swoich preferencji za pomocą metod różniących się wymaganiami poznawczymi. Wyniki badań mogą być pomocne w wyborze metody wsparcia decydenta przy wspomaganiu decyzji z uwzględnieniem profilu decyzyjnego.

Słowa kluczowe: wspomaganie podejmowania decyzji, profil decyzyjny, metody wielokryterialne, analiza preferencji, analiza danych.