Czech Economic Review 7 (2013) 55–67
Acta Universitatis Carolinae Oeconomica

Possible Modifications of the Multiple Criteria Assignment Method

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Received 17 September 2012; Accepted 17 February 2013

Abstract The paper introduces the multiple criteria decision making method using one of basic problems of linear programming as its computational principle; thus, the algorithm is based on the assignment problem enabling the assignment of alternatives and rank. The known basic algorithm of the assignment method is described and some modifications are proposed that take into account differences among criterial values or some stochastic elements. Finally, the article offers some practical application in investment decision making process in the field of capital market with shares funds.

Keywords Assignment method, difference, shares fund
JEL classification C63, G11

1. Introduction

The reader can see two important missions in this article. Firstly, we propose the multiple criteria decision making (MCDM) method based on the assignment problem. The basic idea is described in a formally modified form compared to Bouška et al. (1984). This approach does not take into account the differences among criterial values; thus, the method modification will be projected to improve the current algorithm. Furthermore, an involvement of some stochastic elements will make the procedure more realistic. Secondly we can meet the application of proposed methods in terms of the capital market. A potential investor wants to choose a suitable investment shares funds managed and offered by Investment company Česká spořitelna. We will obtain a few different results and compare them.

2. Basic form of the assignment method (AM)

The assignment method is described in Bouška et al. (1984) or Hwang et al. (1981). We will use a rather formally modified basic algorithm and then propose deeper modifications in order to afflict the importance of criterial values and also some stochastic elements in the decision making process. First of all, we look at the basic idea of this method in the following several steps.

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Step 1. Observe the matrix of valuations of all alternatives according to particular criteria $\mathbf{Y} = (y_{ij})$, where y_{ij} $(i = 1,2,\ldots,p; j = 1,2,\ldots,k)$ represents the evaluation of the i-th alternative by the j-th criterion. The vector of criteria weights $\mathbf{v} = (v_1, v_2, \ldots, v_k)$ is defined by decision maker in agreement with his preferences. For example, the weight vector can be established on the basis of the scoring method (see Fiala 2008).

Step 2. For each alternative i we create the ranking vector $\mathbf{a_i} = (a_{i1}, a_{i2}, \ldots, a_{ik})$, where the component a_{ij} $(i = 1,2,\ldots,p; j = 1,2,\ldots,k)$ presents unambiguous sequence of the i-th alternative according to the j-th criterion. Then we can identify the set A_{ij} $(i, j = 1,2,\ldots,p)$ containing the indices of criteria according to which j-th alternative is placed in the i-th position. If more than one alternative has the same rank according to some criteria, we specify the sets E_{ij}^n $(i, j = 1,2,\ldots,p)$ including the indexes of criteria by which the j-th alternative shares the i-th position with n others. For instance, when the j-th alternative shares the 5-th place with two others by the k-th criterion, we create three sets for the j-th alternative as $E_{5j}^3 = E_{6j}^3 = E_{7j}^3 = \{k\}$. In this particular situation, the index of k-th criterion is not included in the set A_{5j},A_{6j},A_{7j}, respectively.

Step 3. In the next step, the matrix $\mathbf{B} = (b_{ij})$ is designed where it must hold

$$b_{ij} = \sum_{g \in A_{ij}} v_g + \sum_{g \in E_{ij}^n} \frac{v_g}{n}, \quad i, j = 1,2,\ldots,p.$$

Thus, the item b_{ij} characterizes the sum of weights corresponding to such a criteria that assign the i-th place to the j-th alternative. If we had no weights of characteristics, the formula would be computed as a sum of according to the particular criteria. In the case of indifferent relations among alternatives by concrete criteria, the component b_{ij} does not include a whole value of weight v_g, but only its relative part v_g/n, where n denotes the number of alternatives placed in the same position. The value b_{ij} actually expresses the fitness of assignment of the i-th position to the j-th alternative.

Step 4. The final ranking of alternatives is set as a solution of the following assignment problem (see Jablonský 2007; Ramamurthy 2007; Sharma 2009; or Burkard et al. 2009).

$$z := \sum_{i=1}^{p} \sum_{j=1}^{p} b_{ij} x_{ij} \rightarrow \max$$

$$\begin{aligned} \text{s.t.} \quad & \sum_{i=1}^{p} x_{ij} = 1 \qquad j = 1,2,\ldots,p \\ & \sum_{j=1}^{p} x_{ij} = 1 \qquad i = 1,2,\ldots,p \\ & x_{ij} = \{0,1\} \quad i, j = 1,2,\ldots,p, \end{aligned}$$

where x_{ij} takes the value 1 if the j-th alternative is placed in the i-th place, otherwise it equals 0. Because the higher value of b_{ij} represents that the ranking of the j-th alternative in the i-th place is better, the objective function has to be maximized.

The basic form of the assignment method provides full ranking of alternatives. The indisputable advantage of this method is that the criterial values may not be standardized. On the other hand, we should not forget that the differences among alternative's criterial values according to particular criterion are not taken into account in the described algorithm.

3. Assignment method with differences (AMD)

As mentioned above, the modified algorithm of method accepts the distances among criterial values. Therefore, this approach becomes more complicated, eventually in virtue of data standardization. The modified method principle will be introduced during in the following steps (AMD).

Step 1. We set the matrix of criterial values $\mathbf{Y} = (y_{ij})$ with size $p \times k$ and the weight vector $\mathbf{v_j} = (v_1, v_2, \ldots, v_k)$. It is necessary to transform all minimized criteria to the maximized form according to

$$q_{ij} = \max_i(y_{ij}) - y_{ij} \quad \forall j(\min),$$
$$q_{ij} = y_{ij} \quad \forall j(\max).$$

As in the basic algorithm, we create the ranking vector $\mathbf{a_i} = (a_{i1}, a_{i2}, \ldots, a_{ik})$, where the component a_{ij} $(i = 1,2,\ldots,p; j = 1,2,\ldots,k)$ presents a rank of the i-th alternative according to the j-th criterion and the set A_{ij} $(i, j = 1,2,\ldots,p)$ containing the indices of criteria by which the j-th alternative is placed in the i-th position in the case of no indifferent references according to all examined characteristics. If more than one alternative has the same rank according to the some criteria, we specify the sets E^n_{ij} $(i, j = 1,2,\ldots,p)$ including the indexes of criteria by which the j-th alternative shares the i-th position with n others.

Step 2. We create two sets for $i = 1,2,\ldots,p,\ j = 1,2,\ldots,k$

$$C^l_{ij} = \{r, q_{ij} > q_{rj};\ r = 1,2,\ldots,p,\ i \neq r\},$$
$$C^h_{ij} = \{r, q_{ij} < q_{rj};\ r = 1,2,\ldots,p,\ i \neq r\},$$

containing all indexes of alternatives r which are evaluated worse, or better than the i-th alternative by the j-th criterion. Afterward, we can define two matrices $\mathbf{Q^l} = (q^l_{ij})$ and $\mathbf{Q^h} = (q^h_{ij})$, where

$$q^l_{ij} = \frac{\sum_{r \in C^l_{ij}} (q_{ij} - q_{rj})}{\left|C^l_{ij}\right|} \quad i = 1,2,\ldots,p,\ j = 1,2,\ldots,k,$$

$$q^h_{ij} = \frac{\sum_{r \in C^h_{ij}} (q_{rj} - q_{ij})}{\left|C^h_{ij}\right|} \quad i = 1,2,\ldots,p,\ j = 1,2,\ldots,k,$$

expressing the average distance from alternatives that are evaluated worse, or better than the i-th alternative by the j-th criterion. The expressions $|C_{ij}^l|, |C_{ij}^h|$ denote the cardinality of sets C_{ij}^l, or C_{ij}^h.

Step 3. Now the values q_{ij}^l and q_{ij}^h must be standardized as follows

$$t_{ij}^l = \frac{q_{ij}^l}{\max_i (q_{ij}^l)} \quad i = 1,2,\dots,p, \; j = 1,2,\dots,k,$$
$$t_{ij}^h = \frac{q_{ij}^h}{\max_i (q_{ij}^h)} \quad i = 1,2,\dots,p, \; j = 1,2,\dots,k.$$

Step 4. In the next step, we construct the matrices $\mathbf{B^l} = (b_{ij}^l)$ and $\mathbf{B^h} = (b_{ij}^h)$, where the following formulas must hold

$$b_{ij}^l = \sum_{g \in A_{ij}} v_g t_{jg}^l + \sum_{g \in E_{ij}^n} \frac{v_g}{n} t_{jg}^l \quad i,j = 1,2,\dots,p,$$

$$b_{ij}^h = \sum_{g \in A_{ij}} v_g t_{jg}^h + \sum_{g \in E_{ij}^n} \frac{v_g}{n} t_{jg}^h \quad i,j = 1,2,\dots,p.$$

The components b_{ij}^l, or b_{ij}^h $(i,j = 1,2,\dots,p)$ represent the sum of weighted average distances from worse, or better alternatives in the case of assignment of the j-th evaluated alternative to the i-th place according to all criteria. In the case of indifferent relations among alternatives by particular criteria, the component b_{ij} does not include a whole value of weight v_g, but only its relative part v_g/n, where n denotes the number of alternatives placed in the same position as in the basic algorithm. The greater b_{ij}^l, or lower b_{ij}^h means the major fitness of the assignment of the j-th alternative to the i-th position.

If there are no assignments of the i-th order to the j-th alternative according to all criteria, the values b_{ij}^l will be low enough, on the contrary b_{ij}^h must be positive or at least equal zero as follows

$$b_{ij}^l = -big\,M \quad i,j = 1,2,\dots,p \quad A_{ij}, E_{ij}^n = \emptyset,$$
$$b_{ij}^h = big\,M \quad i,j = 1,2,\dots,p \quad A_{ij}, E_{ij}^n = \emptyset.$$

These values are stated in sufficient size in comparison with other elements in the matrices $\mathbf{B^l}$ and $\mathbf{B^h}$ not to take place unsolicited assignment of the i-th place to the j-th alternative.

Step 5. We again apply the assignment problem for the creation of the final ranking of alternatives. In this time, we use two assignment problems. First of them finds the ranking according to the average deviations from worse alternatives

$$z_1 := \sum_{i=1}^{p} \sum_{j=1}^{p} b_{ij}^l x_{ij}^l \to \max$$

$$\text{s.t.} \quad \begin{array}{ll} \sum_{i=1}^{p} x_{ij}^{l} = 1 & j = 1,2,\ldots,p \\ \sum_{j=1}^{p} x_{ij}^{l} = 1 & i = 1,2,\ldots,p \\ x_{ij}^{l} = \{0,1\} & i,j = 1,2,\ldots,p, \end{array}$$

where x_{ij}^{l}, takes value 1 if the alternative j is placed in the i-th position, otherwise it equals 0.

The second model finds the ranking according to the average deviations from better alternatives

$$z_2 := \sum_{i=1}^{p} \sum_{j=1}^{p} b_{ij}^{h} x_{ij}^{h} \rightarrow \min$$

$$\text{s.t.} \quad \begin{array}{ll} \sum_{i=1}^{p} x_{ij}^{h} = 1 & j = 1,2,\ldots,p \\ \sum_{j=1}^{p} x_{ij}^{h} = 1 & i = 1,2,\ldots,p \\ x_{ij}^{h} = \{0,1\} & i,j = 1,2,\ldots,p, \end{array}$$

where x_{ij}^{h} takes value 1 if the alternative j is placed in the i-th position, otherwise it equals 0. As we try to reach the assignment as efficient as possible in the sense of values b_{ij}^{l}, or b_{ij}^{h}, the objective function z_1 is maximized, z_2 minimized.

Step 6. The two given alternative ranks may not be the same. The final order will be obtained as an average of both rankings as follows

$$k_j = \frac{d_j^{l} + d_j^{h}}{2} \qquad j = 1,2,\ldots,p,$$

where d_j^{l} and d_j^{h} is the fractional place of the j-th alternative according to the assignment problems mentioned above. The final rank is stated on the basis of upwardly ordered values k_j.

The described method takes into account the differences among the criterial values, unlike the basic form. On the other hand, its computational procedure becomes more complicated. The final ranking can also contain indifferent relations.

3.1 Assignment method for stochastic parameters (AMDS, AMDSSimple)

In real applications we can often consider that the decision maker (investor) could not be able to evaluate criteria and also their weights exactly. In our case, the return of shares funds is a random variable with some continuous probability distribution (uniform, normal, logistic, etc.). Probability distribution is determined by *Kolgomorov-Smirnov test* (see Hindls et al. 2006; or Rényi 1972). The weights will be also random variables with uniform probability distribution $R(a,b)$, where two parameters represent the lower and upper limit of these estimations.

Now we generate a proper number of scenarios including the values of returns and weights and repeat the whole algorithm AMD for all scenarios. The given number of orders equals the number of scenarios.

To gain the final order, we can apply the assignment problem once again as follows

$$z := \sum_{i=1}^{p} \sum_{j=1}^{p} d_{ij} x_{ij} \rightarrow \max$$

$$\begin{aligned} \text{s.t.} \quad & \sum_{i=1}^{p} x_{ij} = 1 && j = 1,2,\ldots,p \\ & \sum_{j=1}^{p} x_{ij} = 1 && i = 1,2,\ldots,p \\ & x_{ij} = \{0,1\} && i,j = 1,2,\ldots,p, \end{aligned}$$

where x_{ij} $(i,j = 1,2,\ldots,p)$ denotes the assignment of the j-th alternative to the i-th place in the case value 1, on the contrary case it is 0, d_{ij} expresses how many times the j-th alternative is placed in the i-th position. If one position is shared by several alternatives, it is included only partially to d_{ij}. In other words, when the j-th alternative shares the i-th position with m other alternatives, then $d_{ij}, d_{i+1j}, \ldots, d_{i+mj}$ contain average rank number. Therefore, the following formula must hold

$$\sum_{i=1}^{p} d_{ij} = q \qquad j = 1,2,\ldots,p,$$

where q is the number of scenarios. To obtain the most acceptable assignment, the objective function of the assignment problem is maximized. This approach will be labelled as AMDS.

Another way how to set the final order of alternatives is using a simple average of fractional ranking. We label this approach as AMDSSimple. We formulate the following expression

$$r_j = \frac{\sum_{s=1}^{q} h_{js}}{q} \qquad j = 1,2,\ldots,p,$$

where h_{js} $(j = 1,2,\ldots,p; s = 1,2,\ldots,q)$ is the position of the j-th alternative within the scope of the s-th scenario. If more alternatives share only one position, h_{js} must be calculated. Imagine the j-th alternative placed in the a-th position with m others. This means that they occupy a-th as far as $(a+m)$-th place together. Then, the individual "standing" of the j-th alternative the h_{js} is set as an average by following form

$$h_{js} = \frac{\sum_{k=0}^{m} p_{a+ks}}{m+1},$$

where p_{a+ks} $(k = 0,1,\ldots,m)$ are common occupied standings $a, a+1, \ldots, a+m$ in the s-th scenario. For instance, the j-th alternative shares the fifth place with two others, so the position of the j-th alternative will be six as well as for two others (for some scenario s). The final rank is stated on the basis of uplink ordered values r_j.

The AMDSSimple has one disadvantage the final rank allows the indifferent references.

4. Software used

Before the practical application of methods mentioned earlier, it is suitable to briefly introduce software applied for all processes mentioned in this article.

LINGO is an optimization program that is able to solve linear and nonlinear programming problems. The student version is accessible through the developer's website: a stateside company LINDO. The program was used for solving assignment problems.

Sana is a supplement to MS Excel. It is also freeware that enables to solve multicriteria problems using several basic methods (WSA, TOPSIS, ELECTRE I and III, etc.). We applied the program in order to evaluate criteria weights via the scoring method.

Crystal Ball is an Oracle spreadsheet-based application for predictive modeling, forecasting, simulation, and optimization. The software is used in order to make the *Kolgomorov-Smirnov test* for the determination of probability distribution of shares fund returns.

SPSS is statistical software produced by the company IBM. It was used for generating random numbers of logistic and normal distribution for shares fund returns and uniform probability distribution for criteria weights.

5. Practical application

The investor wants to invest his or her free financial resources in some open shares fund. A *shares fund* is an inside organizational entity of an investment company without a legal identity (Valach 2007). An *open shares fund* is a fund whose administering investment company must buy back allotment certificates by request of the shareholder in a particular term for an actual value of fund property accordant with one allotment certificate (Veselá 2011). As a long-term client of Česká spořitelna, the person chooses the shares funds provided by the Investment company Česká spořitelna offering four basic groups of funds, namely *money-market funds*, *mixed funds*, *bond funds* and *stock funds*. The list of these funds is showed in Table 1.

The investor wants to gain the ranking of all open shares funds in order to make the right investment decision. Three criteria are set by the investor (decision maker), *return*, *riskiness*, and *costs*. We use average monthly returns from 1st April 2009 to 1st December 2011. Only for mixed shares funds *Personal portfolio 4* and *Plus* is used shorter time period due to their latter foundation. The *risk* is stated as a standard deviation of fund returns, *costs* include the entry fees. Standard deviation is comprehended as the root-mean-square average of all deviations from the mean. It can be formulated

Table 1. List of shares funds offered by the Investment company Česká spořitelna

Money-market funds	Mixed funds	Bond funds	Stock funds
Sporoinvest	Personal portfolio 4	Sporobond	Sporotrend
	Plus	Trendbond	Global Stocks
	Controlled yields fund	Bondinvest	Top Stocks
	Conservative MIX	Corporate debenture	
	Balanced MIX	High Yield debenture	
	Dynamic MIX		
	Stock MIX		

Source: Investment company Česká spořitelna (2012b) (http://www.iscs.cz/web/fondy/).

as in Chikkodi and Satyaprasad (2010)

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}},$$

where x_i is monthly return of the i-th shares fund, $\bar{x}$ denotes the average monthly return of the shares fund and n expresses the number of monthly periods. The useful data are reported in Table 2.

The investor also determines the weights of all criteria by the help of the scoring method. From the interval $\langle 0, 10 \rangle$, he or she gives 10 points to *riskiness*, 8 points for *return* and 3 to *costs*. The resulting criteria weights are displayed in the Table 3. It is obvious that the investor is quite risk-averse, on the other hand, costs are not a very important factor.

5.1 Stochastic elements

According to the *Kolgomorov-Smirnov test*, we can claim that the returns of most shares funds have a normal probability distribution except *Sporoinvest*, *Corporate debenture*, *High Yield debenture*, *Controlled yields fund*, and *Sporotrend*, for which the logistic distribution is shown as more acceptable. The full report about distribution is displayed in the Table 4.

The investor is not able to set the weights of criteria exactly, but he/she has only general image about their values according to his or her preferences. Once again, *riskiness* will be the most essential characteristic, *costs* the least. The decision maker states an interval of weight values for each criterion. The probability distribution of weights is uniform with two parameters $R(a,b)$ as the Table 5 shows.

Ten scenarios are generated with the values of *returns* and weights according to stated particular possibility distribution.

Table 2. Return, riskiness, and costs of shares funds

Shares fund	Return (%)	Riskiness (%)	Costs (%)
Sporoinvest	0.15	0.27	0.3
Personal portfolio 4	0.25	0.72	1.5
Plus	−0.07	0.75	1.5
Controlled yields fund	0.19	0.59	1
Conservative Mix	0.45	1.06	1
Balanced Mix	0.57	2.08	1.5
Dynamic Mix	0.76	3.14	1.5
Stock Mix	0.84	4.46	3
Sporobond	0.53	1	1
Trendbond	0.22	1.39	1
Bondinvest	0.44	1.12	1
Corporate debenture	1.07	2.56	1
High Yield debenture	1.32	4.54	1
Sporotrend	2.20	15.05	3
Global Stocks	0.88	4.45	3
Tops Stocks	2.62	8.52	3

Source: Investment company Česká spořitelna (2012a) (http://www.csas.cz/banka/content/inet/internet/cs /RR_SK.VIII..xml) and self-calculation in MS Excel.

Table 3. Weights of criteria

Return	Riskiness	Costs
0.38	0.48	0.14

Source: The Sanna within the MS Excel software.

5.2 Results

Now we can apply four methods described above—AM, AMD, AMDS and AMDSSimple. The overall results are in the Table 6.

According to basic algorithm AM, the first investment alternative is represented by *Sporoinvest*. This option has the best values of criteria riskiness and costs. Despite its worse return, it is in the first place. The other end of the list shows stock shares funds due to their very high rate of riskiness and costs. Their very good return did not help to their better rank. In the middle of the table, there are shares funds whose values of all examined characteristics are more or less not extreme in the context of all other assessed open shares funds.

It is obvious that the AMD method does not give the same ranking as AM. However the first place was not threatened, the same as the last one. The shares funds *Trendbond* and *Plus* represent the biggest shift in ranking in comparison to AM result. It is caused due to the differences among criterial values. The drop of the *Plus* fund

Table 4. Probability distribution of shares fund returns

Shares fund	Prob. dis.	Mean	St. dev.	Scale
Sporoinvest	logistic	0.131		0.135
Personal portfolio 4	normal	0.253	0.724	
Plus	normal	−0.073	0.747	
Controlled yields fund	logistic	0.146		0.299
Conservative Mix	normal	0.449	1.064	
Balanced Mix	normal	0.574	2.082	
Dynamic Mix	normal	0.761	3.137	
Stock Mix	normal	0.841	4.460	
Sporobond	normal	0.532	0.995	
Trendbond	normal	0.224	1.389	
Bondinvest	normal	0.441	1.116	
Corporate debenture	logistic	0.987		1.299
High Yield debenture	logistic	1.179		2.372
Sporotrend	logistic	1.561		7.641
Global Stocks	normal	0.877	4.454	
Top Stocks	normal	2.615	8.517	

Source: Crystal Ball supplement within the MS Excel software.

Table 5. Parameters of uniform distribution of criteria weights

	Return	Riskiness	Costs
a	0.3	0.4	0.1
b	0.4	0.5	0.2

Source: Self-designed in MS Excel.

is influenced by the long distances from the better alternatives due to solitary negative return. On the contrary, the rise of *Trendbond* fund reflects small differences from the better alternatives, especially in risk and costs, despite a comparatively worse order.

Finally, we are applying the modified assignment method with stochastic parameters AMDS and AMDSSimple. As we can see in the Table 6, the AMDSSimple approach can give the ranking with indifferent relations. This is not possible in the AMDS, because the final order is made as a solution of the assignment problem. It is obvious that worse position of the *Plus* shares fund is confirmed, the better position of *Trendbond* as well in comparison to AM. Regarding AMD, we note a significant worse position of two shares funds—*Personal portfolio 4* and *Bondinvest.* This fact is mainly caused by generated values of returns of these two funds that are significantly below their mean value in most scenarios. To eliminate this fact it is necessary to generate more scenarios.

The results can be also summarized graphically in Figure 1.

Table 6. Final ranking of open shares funds according to all applied methods

Shares fund	AM	AMD	AMDS	AMDSSimple
Sporoinvest	1	1	1	1
Controlled yields fund	2	2	2	2
Personal portfolio 4	3	6	9	9
Plus	4	7–8	8	8
Sporobond	5	3	4	3
Conservative Mix	6	5	7	6–7
Bondinvest	7	7–8	3	4
Trendbond	8	4	6	5
Balanced Mix	9	10	11	11
Corporate debenture	10	9	5	6–7
Dynamic Mix	11	12	12	12
Global Stocks	12	13	14	14
Stock Mix	13	15	13	13
High Yield debenture	14	11	10	10
Top Stocks	15	14	15	15
Sporotrend	16	16	16	16

Source: LINGO optimization software.

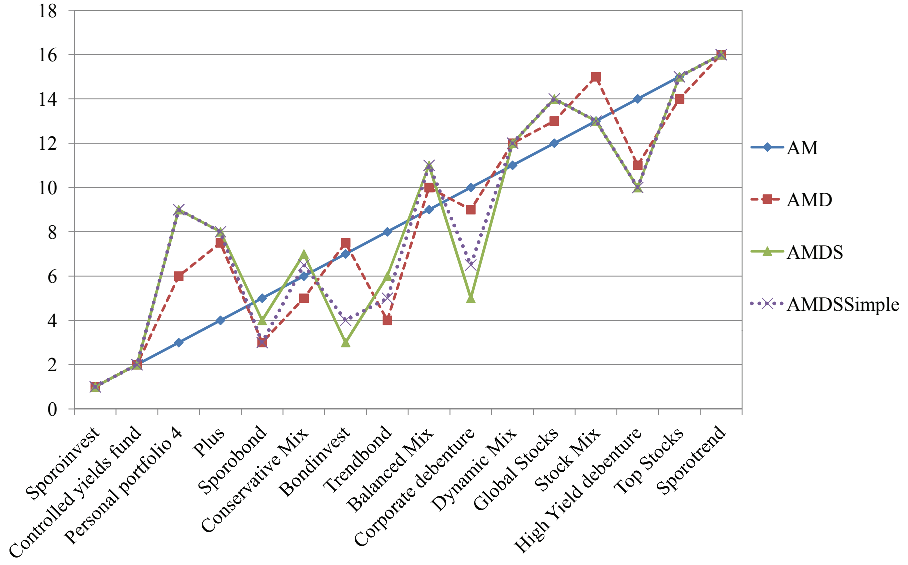

Figure 1. Final ranking of open shares funds according to all applied methods

The graph clearly shows the result of all used methods which were closely commented. We can see that the front and rear positions are actually unchanged according to all methodical approaches. Significant differences are rather perceptible in the middle of the ranking. The shares funds at the beginning of the final rankings have very good or the best values of the most important criterion, on the contrary the shares funds at the end give very bad or the worst values of this criterion. The open shares funds in the middle do not have extreme criterial values, so that their positions are changeable.

We can generally say that the first position is unchanged according to all used algorithms. The potential investor would invest a selected amount of money in the *Sporoinvest* open shares fund. If this fund mainly has a low level of risk, the result is not surprise according to the investor's preferences.

It is no doubt that the result of the assignment method and their modifications described in this article actually do not allow the creation of an entire investment portfolio. The investor will probably invest in the shares fund ranked first, or he or she can eventually choose a few funds in first three or four positions and invest money in particular shares. But which shares? This question can be answered by an application of multiple objective decision making methods that are able to set the whole portfolio with specific shares of particular choice assets. Borovička (2012) describes this problem and its possible solution.

6. Conclusion

This paper offers three new concepts of multiple criteria decision making method based on the assignment methods. Modifications of the basic algorithm are proposed in order to cover up the differences among criterial values in the computational algorithm, involving some stochastic elements as well.

From the practical point of view, the results, in accordance with all method modifications described above, are expectantly different. The modified algorithm becomes more complicated, namely the AMDS and AMDSSimple, due to scenario generation. On the other hand, both procedures become more accurate and realistic.

As the practical application shows, the results of proposed methods can help the investor to make the right investment decision in the field of capital market with open shares funds. But we should not forget that the analysis is based on the historical data which may not ensure the same development in the future. Thus other supportive analytic instruments and perceptive insights are recommended.

Acknowledgment The research project was supported by grant no. 13-07350S of the Grant Agency of the Czech Republic and by grant no. F4/16/2011 of the Internal Grant Agency, Faculty of Informatics and Statistics, University of Economics, Prague.

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