# Using ELECTRA MLO multi-criteria decision making method in stepwise Benchmarking. Application in higher education.

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This paper describes multi-criteria decision making as a tool for stepwise benchmarking. The ELECTRE MLO ranking method is used. I give a mathematical theorem with a proof which is the answer to the question whether it is better to progress gradually or "to skip steps". In chapter 3 ELECTRE MLO method is applied to benchmark teaching assistants of one faculty, University of Belgrade according to the marks given by their students.

Keywords: multi-criteria decision making, ELECTRA , benchmarking, evolution path, higher education

## Introduction

Benchmarking is a management tool which represents a systematic process of measuring the quality of a product or services against those which are the best in the observed area. This process includes the comparison with the direct competitor on one hand and we have the comparison according to definite benchmark that is, something we want to achieve on the other hand. In this paper I will illustrate and give the example of the comparison of teaching assistants of one faculty, the University of Belgrade, according to the marks given to them by students. The marks were based on ten criteria.

Benchmarking is mostly used in an international level in comparison to the state policy. Benchmark is always represented by the most developed countries. There are a lot of studies on this topic (Arrowsmith, Sisson, & Marginson ,2004; M. Petrović, Bojković, Anić, D. Petrović, 2012; P. Hong, S. W. Hong, Jungbae Roh, & Park, 2012; Petrović, Bojković, Anić, Stamenković, &Tarle , 2014). The socio-economic, geo-strategic and cultural influence of one country is often neglected during the mutual comparison, so the question is whether the measures transferred from other countries are always applicable (Dolowitz&Marsh , 1996; Bauer, 2010; Lundvall & Tomlison, 2012). In spite of the differences it is clear that the leaders of the countries, especially those which are in the same region, or in the European Union, or they tend to enter the European Union, can follow one another (Rose, 1991). The International benchmarking is widely applied even in information and communication technology.

The process of benchmarking includes making different decisions, from the way of choosing the most relevant statistical data to the way of role model and thus improve certain characteristic. The main questions is „who or what you should look up to in order to became better". It is not always the best option to learn from the best one in certain area. We should also include real abilities. The main purpose of this paper is to consider this topic and give answer to the question whether it is better to progress gradually or „to skip steps". The answer can be clearly guessed from the very introduction and mathematical explanation is the central theorem of this paper. There are so many studies about tendency towards the similar that is about the gradual progress towards (Moore, 1999; Hambelton & Gross, 2008; Lim, Bae, & Lee, 2011). We search for someone or something a bit better i.e. benchmark in each step of progress and thus we come to so called evolution of progress. The most important thing here is to choose the best evolution path. In chapter 3 of this paper I give the example of the teaching assistant who obtained the worst marks. He should first look up to the colleague who is a bit better than hi, then he should gradually improve until he reaches the level of the best marked teaching assistant. If we make a continuous progress, we have the ideal evolution path. That path is difficult to achieve in practice because we always have a real data. Since, it is often about the choice that is making decisions the methods of operational research are used in benchmarking DEA (Data Envelope Analysis) method is often used. It is based on the linear programming and was created in papers (Charnes, Cooper,& Rhodes, 1981). With DEA method we make evaluation of efficiency finding alternatives on pareto limit. DEA is applied in many areas. Except this one, we use the methods of multi-criteria decision making among which the most popular is the family of ELECTRE methods. In this paper I will use one modification of ELECTRE I method which is developed to serve as a tool in Benchmarking. This is ELECTRE MLO method which first appeared in study (Petrović et al, 2012). ELECTRE I method is introduce by Roy in book (Roy, 1968). The method now has only historical importance, as the method representing the base on which the other more useful methods were created.  The most popular and the most frequently used modification of ELECTRE I are ELECTRE Iv (Greco, Figueira, & Ehrgott , 2005), and ELECTRE Is (Roy & Skalka, 1987). The family of ELECTRA solves three very important problems: choice, ranking and sort. Methods which solve the problem of ranking alternatives are especially important for benchmarking. ELECTRE III method deals with this issues (Bouysson & Roy, 1986; Papadopulos & Karagiannidis, 2008; Ishizaka & Giannoulis, 2010). Before ELECTRE MLO method appeared the alternatives which formed a cycle were thought to be indifferent and we ranked in same hierarchical level. This view can lead to imprecise levels (one level contains more alternatives than the other ones). According to the important result from the study (Anich & Larichev, 1996) ELECTRA MLO method solves the problem of acyclic. The problem of acyclic is solved by introducing modified concordans index and AST (absolute significance threshold) which represent the limit after which no cycle will appear in a graph. ELECTRE MLO method will help us find the best evolution path. This method ranks alternatives into levels so that we clearly see hierarchy between them. By applying this method we obtain the tree (the graph without cycle). The best alternative i.e. the one which represents the benchmark to all other is on top of the tree. The worst candidate needs to make progress gradually towards the top choosing the best benchmark in every moment. He looks for the optimal path, the path which is closest to the ideal one. Although benchmarking is mostly used in foreign policy, in section 3 we will see a specific application in higher education. Different research about lecture quality, lecturer's capability and students evaluation of lecturer in higher education were conducted (Millis & Cottell, 1997; Ramsden, 2003; Wei, 2007). Their aim was to improve the quality of higher education facilities. Arguments ‘’for” and “against” students evaluating their lectures were given in paper (Wachtel, 1998). In (Sullivan& Skanes, 1974) authors pay special attention to characteristics that have lecturers with successful academic carriers and that were excellently graded by students.

## Methodology

As in introduction told the ELECTRA MLO is the best tool in benchmarking. We define now sets of criteria $G_{ij}^{+}$, $G_{ij}^{-}$, $G_{ij}^{=}$ for two alternatives $A_i$ and $A_j$ in following way:

$G_{ij}^{+}=\{g_k \,|g_k(A_i)>g_k(A_j)\}$,

$G_{ij}^{-}=\{g_k \,|g_k(A_i)<g_k(A_j)\}$,

$G_{ij}^{=}=\{g_k \,|g_k(A_i)=g_k(A_j)\}$, $g_k(A_i)$ is marks for alternative $A_i$ and criteria k. The $\omega_k$ is weight factor for criteria k. Let $I_{1,\dots,}I_m$ set of marks for any criteria and $|I_k|=\max I_k-\min I_k$ is scaled score range of criterion k. Let us define normalization value of marks and normalization value of weight factor on following way:

$$\omega_k=\frac{\omega_k}{\sum_{k=1}^{n}\omega_k} \qquad g_k^{*}\,(a_i)=\frac{g_k}{|I_k\,|}$$

For ELECTRE I method concordans and discordans index define:

$$C(a_{i,}\ a_j) = \frac{\sum_{g_k \in G_{ij}^{+} \cup G_{ij}^{=}} \omega_k}{\sum_{k=1}^{n} \omega_k}$$

$$d(a_{i,}\ a_j) = max_{g_k \in G_{ij}^{-}} \frac{g_k\,(a_j) - g_k\,(a_i)}{|I_k\,|}$$

Modified concordans index given by formula: $C(a_{i,}\ a_j)^* = \frac{\sum_{g_k \in G_{ij}^{+}} \omega_k}{\sum_{\{k|g_k \in G_{ij}^{+} \cup G_{ij}^{=}\}} \omega_k}$

Let us define a parameter l(i,j) on following way:

$$l(i.j) = \frac{d(a_{i,}\ a_j)}{\sum_{\{k|g_k \in G_{ij}^{+}\}} \omega_k\,(g_k^*\,(a_i) - g_k^*\,(a_j))} \sum_{\{k|g_k \in G_{ij}^{+}\}} \omega_k^*$$

**Theorem 1** (Anić, Larichev): The parameter λ is chosen so that for each arranged pair alternatives:

$\{(a_i\,, a_j\,) \in A \times A|(a_i\,\mathrm{S} a_j\,) \wedge \neg(a_j\,\mathrm{S} a_i\,)\}$ holds inequality :

$$\lambda < \frac{l(a_i, a_j)}{l(a_i, a_j) + 1}$$

Parameter λ is limit value of modified concordans index, there is not cycle. Also, there isn't relation indifferent between alternatives.

The modified performance indicator scores $a_{i_s k}^* = \begin{cases} a_{i_{s-1}k}^* \ if \quad a_{i_{s-1}k}^* > a_{i_s k}^* \\ \quad a_{i_s k}^* \ otherwise \end{cases}$

$R_{sk}^{\pi}$- for each criterion k, the difference between scores of the alternatives from the adjacent levels of performance is calculated:

$R_{sk}^{\pi} = a_{i_{s*1}k}^* - a_{i_s k}^*$

Ideal step:

$\mu_k^\pi = \frac{\sum_{s=1}^{m-1} R_{sk}^\pi}{m-1}$

For each criterion k on path π we depict the variation measuring the mean-squared difference from the increment step thus giving us the distance from ideal path:

$$DPV_{ik}^\pi = \frac{1}{m-1}\sum_{s=1}^{m}(R_{sk}^\pi - \mu_k^\pi)^2$$

The overall value of the variation for all criteria:

$$DPV_i^\pi = \frac{\sum_{k=1}^{n} DPV_{ik}^\pi \omega_k}{\sum_{k=1}^{n} \omega_k}$$

$DPV_i^w$ is the worst path that is the path where the total difference between scores of alternatives $a_i$ and target $a_m$ for each criterion k is obtained when moving only at one level.

$\rho_i^\pi$ is the relative measure of evolution path π.

$\rho_i^\pi = \frac{DPV_i^\pi}{DPV_i^w}$

Now we examine the difference between scores of the alternatives from two concrete levels:

$R_{j-1k}^\pi = a_{i_jk}^* - a_{i_{j-1}k}^* = a$

$R_{jk}^\pi = a_{i_{j+1}k}^* - a_{i_jk}^* = b$

$R_{j+1k}^\pi = a_{i_{j+2}k}^* - a_{i_{j+1}k}^* = c$

$\mu = \frac{\sum_{s=1}^{m-1} R_{sk}^\pi}{m-1}$

Following inequalities stand: $a \le a + b \le a + b + c$

**Theorem 2**: If alternatives are compared by one criterion, it is better to go in order one level at a time then to jump over next one and then take a 'pause'.

**Proof**:

Using previous labels, next inequality should be proven:

$$\frac{1}{m-1}\left(\sum_{s=1}^{j-1}(R_{sk}^{\pi}-\mu)^2+(a-\mu)^2+(b-\mu)^2+(c-\mu)^2+\sum_{s=j+2}^{m-1}(R_{sk}^{\pi}-\mu)^2\right)$$
$$\leq\frac{1}{m-1}\left(\sum_{s=1}^{j-1}(R_{sk}^{\pi}-\mu)^2+(a+b-\mu)^2+\mu^2+(c-\mu)^2\right.$$
$$\left.+\sum_{s=j+2}^{m-1}(R_{sk}^{\pi}-\mu)^2\right)$$

From the right side of inequality addend $(a+b-\mu)^2$ represents skipped step and addend $\mu^2$ pause.

Except for two, addends from the left and right side are equal and by solving we get:

$$(a-\mu)^2+(b-\mu)^2\leq(a+b-\mu)^2+\mu^2$$

$a^2-2a\mu+\mu^2+b^2-2b\mu+\mu^2\leq a^2+b^2+2\mu^2-2a\mu-2b\mu+2a$

$0\leq 2ab$

This makes claim proven.

Remark 1: It is proven that step skipped in j-th moment is equivalent for any moment.

Remark 2: If the modified performance indicator scores are greater in next level according to this criterion, that case should not be considered, according to 1.

**Application**

By human resources, we mean to the sum of all knowledge and skills of a certain group of people. These skills and knowledge should be a product of education, especially higher education in today's developing world. It is very important that students, during their educational process, have high quality lecturers, who will prepare them for further advancement.

The students of one faculty, University of Belgrade evaluated their teaching assistants by ten criteria, on a scale one to five. I accessed and used the data, the average marks of teaching assistant for each of the ten criteria. Teaching assistants of this faculty are marked with good grades in general so normalization of marks is done in the following way: all marks which are lower than three are one, and I made the uniform integer scale from two to nine for values from three to five.

The example included only the teaching assistants who were evaluated by more than fifty students so that the marks can be considered realistic. The evaluation criteria and obtained marks can be seen in the table 1. Each criterion is given the appropriate weight factor according to its importance (the second column of the table). Since the faculty on which our research took place is a technical science faculty and teaching assistants hold practical classes, the most important criteria are (in this following order): encouraging students to be more active, the importance of practice, comprehensibility and manner of exposure. Regularity of practice and consultation is a duty of everyone employed at faculty, but it doesn't affect much the quality of lecturers.

Table 1.

The specialized software applied the method ELECTRE MLO ranking on these data. I choose the value of modified concordans index as 0,85. The AST is 0,75. The result of ELECTRA MLO method applying is the tree in picture 1. We can clearly see the hierarchy among the alternatives. The aim of weaker candidates is to make the most possible uniform progress. Since the data are realistic the ideal evolution path does not exist. But the candidates need to choose the optimal evolution path in order to achieve the level of the teaching assistant who got the highest marks.

Figure 1.

In every educational institution cooperation among colleagues is advisable. I considered the evolution paths for alternative five. I calculated $\rho_i^\pi$ for each of those paths (picture 2) according to the already mentioned way. We shouldn't be surprised that we obtained the same value ρ for two paths since they differ only in one alternative 15 or 16 (these two alternatives have marks which are different for one only in few criteria and these two alternatives are in same level of tree). The teaching assistant number five should choose one of the first two paths because of the lower value of ρ. I suggest that teaching assistants attend each other's practices to be able to take example from a better-evaluated colleague. Workshops without students could be organized in order to improve their personal teaching method.

Figure 2.

**Conclusion**

There is a saying: "if you don't became better you will became worst". A constant tendency for progress exists among people. This research has shown that ELECTRE MLO ranking method is a good tool in stepwise Benchmarking.

In the Methodology chapter there is a detailed description of ELECTRE methods of multi-criteria decision making, especially ELECTRA MLO method and how to apply this method in Benchmarking. It describes how to pick the best evolution path off all possible paths in the graph by calculating ρ, which is very important for very day praxis. Very often people want to advance as fast as they can to become the best in a certain area. The main contribution of this paper is Theorem 2 which shows how one should behave in regard to general progress. This theorem shows us that "skipping steps" is worst choice than advancing gradually. The best thing to do is always take example from a slightly better colleague than us.  ELECTRE MLO ranking method helps us to plan how to prosper i.e. '' who or what you should look up to in order to became better".

Decision making using this method was illustrated by this higher education example. In this example it was concluded that for every teaching assistant there is an optimal development path. Also, all possible evolution path for teaching assistant number 5 (A5) were considered. The best evolution path was chosen. Since we have realistic data the result was that two equally good evolution paths exist. The same calculation (which is described in chapter 2 in detail) can be applied for any other alternative. This model and approach to the problem could also be useful in other areas of planning of business progress.

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Table 1.

| **Criteria** | $\omega$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ | $A_9$ | $A_{10}$ | $A_{11}$ | $A_{12}$ | $A_{13}$ | $A_{14}$ | $A_{15}$ | $A_{16}$ | $A_{17}$ | $A_{18}$ | $A_{19}$ | $A_{20}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Regularity of practice | 1 | 7 | 7 | 8 | 7 | 6 | 6 | 8 | 9 | 8 | 8 | 9 | 9 | 9 | 6 | 9 | 9 | 9 | 6 | 6 | 8 |
| Regularity of consultation | 1 | 7 | 7 | 7 | 7 | 7 | 4 | 7 | 8 | 7 | 7 | 9 | 9 | 8 | 6 | 9 | 9 | 8 | 5 | 6 | 8 |
| Comprehensibility and manner of exposure | 4 | 7 | 5 | 7 | 3 | 4 | 3 | 7 | 8 | 6 | 7 | 8 | 9 | 4 | 5 | 9 | 8 | 8 | 3 | 5 | 6 |
| Encouraging students to be more active | 5 | 6 | 6 | 6 | 4 | 4 | 2 | 7 | 7 | 3 | 6 | 8 | 9 | 6 | 4 | 8 | 8 | 7 | 3 | 5 | 5 |
| The importance of practice | 4 | 7 | 6 | 7 | 4 | 4 | 2 | 7 | 8 | 5 | 7 | 8 | 9 | 5 | 5 | 8 | 9 | 8 | 3 | 5 | 4 |
| Providing useful information | 3 | 7 | 6 | 6 | 4 | 5 | 2 | 7 | 8 | 4 | 7 | 8 | 9 | 6 | 4 | 8 | 8 | 8 | 3 | 5 | 7 |
| Assistant responds to student questions | 3 | 7 | 6 | 6 | 5 | 5 | 3 | 7 | 8 | 5 | 7 | 8 | 9 | 6 | 5 | 9 | 8 | 8 | 3 | 6 | 5 |
| Professional and ethical in communication | 2 | 6 | 6 | 6 | 5 | 5 | 3 | 7 | 8 | 5 | 7 | 8 | 9 | 7 | 4 | 9 | 8 | 7 | 3 | 5 | 6 |
| Objective and impartial in evaluation | 2 | 7 | 6 | 7 | 5 | 6 | 3 | 7 | 8 | 5 | 7 | 8 | 9 | 7 | 5 | 9 | 8 | 8 | 3 | 5 | 6 |
| Overall impression | 3 | 6 | 6 | 7 | 4 | 5 | 2 | 7 | 8 | 4 | 6 | 8 | 9 | 6 | 5 | 9 | 8 | 8 | 3 | 5 | 6 |

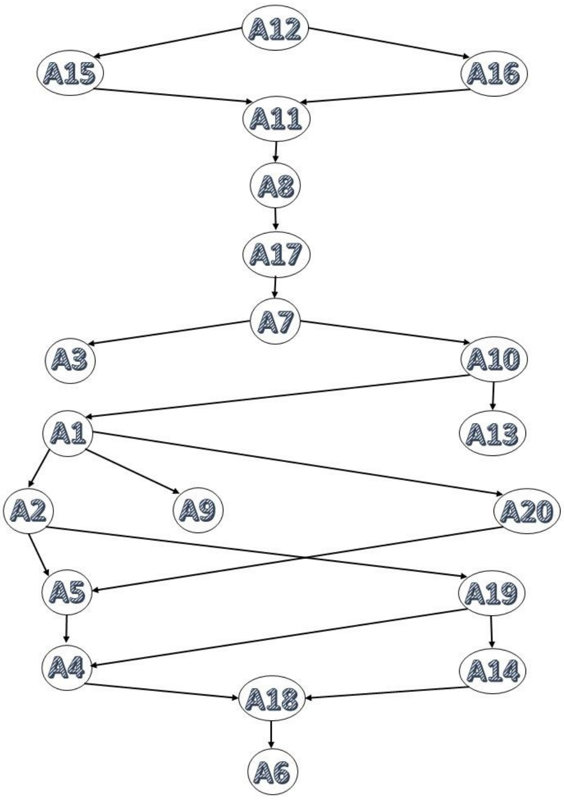


Figure 1

Figure 2

| Path | $\rho_i^\pi$ |
|---|---|
| A5 → A2 → A1 → A10 → A7 → A17 → A8 → A11 → A15 → A12 | 0.1837 |
| A5 → A2 → A1 → A10 → A7 → A17 → A8 → A11 → A16 → A12 | 0.1837 |
| A5 → A20 → A1 → A10 → A7 → A17 → A8 → A11 → A15 → A12 | 0.2091 |
| A5 → A20 → A1 → A10 → A7 → A17 → A8 → A11 → A16 → A12 | 0.2091 |
| A5 → A10 → A7 → A17 → A8 → A11 → A15 → A12 | 0.3402 |
| A5 → A1 → A10 → A7 → A17 → A8 → A11 → A15 → A12 | 0.2970 |