Metamodeling SNAP, a Multi-Criteria Method for Effective Strategic Decision Making on e-Learning Issues

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Abstract - **Many e-learning decision-making problems are multi-criteria problems, and their analysis requires the application of appropriate decision-making method. Since e-learning is a domain which is characterised by the existence of influences and dependencies between the decision-making elements, some of the most suitable methods for the multi-criteria analyses are the Analytic Network Process (ANP), Weighted Influence Non-linear Gauge System (WINGS) and Social Network Analysis Process (SNAP). ANP is the most well-known and most often used multi-criteria decision-making methods appropriate for the domains which are characterised by the existence between influences and dependencies between the decision-making elements, such as the e-learning domain. This paper presents the basic steps of the relatively new method, SNAP method, and its ERA metamodel. The SNAP method combines two methods, ANP and Social Network Analysis. (SNA) The integration of those two methods diminishes some of the weak-points that appear in the application of the ANP. The role of the ERA metamodel of SNAP is double: it helps in the understanding of the SNAP steps, and it is a base for potential SNAP software support development.**

Keywords - e-learning, decision making, ANP, SNAP, ERA, model

I. INTRODUCTION

Strategic planning on e-learning requires multi-criteria analysis of many aspects of e-learning. The decision-making analysis of e-learning issues often requires the application of specific multiple-criteria decision-making (MCDM) methods. There are many MCDM methods, and firstly, we have to decide which one of those to apply.

From the position of this paper, we will divide MCDM methods into two groups:

- MCDM methods that do not enable modelling influences and dependencies between the elements of decision-making problem,

- MCDM methods that support modelling influences and dependencies between the elements of decision-making problem.

Elements of the decision making structure are decision-making goals, criteria (grouped) into clusters and the alternatives. Examples of the MCDM methods from the first group are Analytic hierarchy process (AHP) [1], [2], Electre, Topsis, Promethee, and many others. Examples of MCDM methods from the second group are Analytic Network Process (ANP) [3]–[5], Weighted Influence Non-linear Gauge System (WINGS) [6], and Social Network Analysis Process (SNAP). The number of methods in group 1 is much higher than the number of methods in group 2.

Let's see a simple example presented in Figure 1. The figure shows a simple decision-making problem that is consist of four criteria (1, 2, 3, 4) and the task is to determine the weights of the criteria.
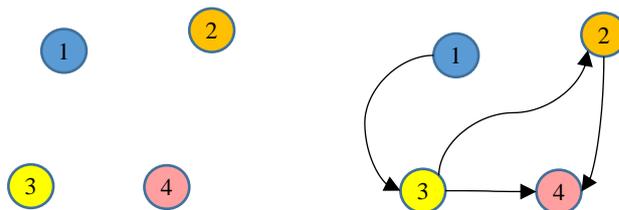
Figure 1. Decision making problem without (left) and with (right) influences between decision-making problem elements [7]

If we have the situation as presented at Figure 1 (left), then any decision-making method can be applied, and if we have the situation as in Figure 1 (right), then we should not apply the decision-making methods from group 1, but only decision-making methods from group 2. If we apply MCDM methods from group 1 in this situation, then we will get the results that are not accurate.

When talking about e-learning decision-making problems, some previous researches discussed that most of them are similar to the fight situation in Figure 1 [8], [9]. Criteria in MCDM problems influence each other and to get accurate results which should apply the method that will take into account those influences. However, in many situations, actually, in most situations, when e-learning issues were discussed, some method from group 1 has been applied. In most cases, this was the AHP method [10].

The most well-known method that enables modelling influences between the elements in decision-making structure is the ANP. However, this method has many characteristics that are not favourable and because of which users avoid application of ANP and use AHP instead.

Those characteristics are discussed in detail in [11]. They are primarily related to the complexity of the ANP, but also some other features. One of those is that the ANP models influences between criteria, but does not take into account their strength (general importance of the criteria with respect to the goal).

Newly developed method called SNAP (Social Network Analysis Process) has the feature that both components are incorporated into criteria weighs: (internal) strength/importance of the criteria and the intensity of affecting/influencing other criteria.

In the next section, we will present SNAP method and demonstrate it on one example, and after that, we will present the ERA model of this method and compare it to ANP ERA model.

II. SOCIAL NETWORK ANALYSIS PROCESS (SNAP)

SNAP method has been developed as the alternative to the ANP method which has many weak-points regarding complexity. SNAP combines ANP (AHP) with SNA in a way that weak parts of the ANP are replaced with specific steps of the SNA which have lower complexity. Those two methods are first time combined in the paper [9] where just the idea of integrating those two methods has been presented. After that, a full first version of the SNAP method has been presented in paper [12].

The steps of the decision-making method SNAP are [12]:

- Component 1: identify the strength of each criterion (AHP) (adapted from [13], [1]):
  - Create matrix A, dimension is $n \times n$, where n is the number of criteria
  - Do pairwise comparisons of each two criteria with respect to the goal by using Saaty's scale and fill the matrix A, $a = \frac{1}{a_{ji}}$ holds
  - Calculate $\sum_{i=1}^{n} a_{i1}, \sum_{i=1}^{n} a_{i2}, \dots \sum_{i=1}^{n} a_{in}$,
  - Make matrix B, the dimension is $n \times n$,
  $$b_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}$$
  - Create matrix C, dimension is $n \times 1$, $c_{i1} = \frac{\sum_{k=1}^{n} b_{ik}}{n}$
  - The strength of criterion i is in the i-th row of matrix C
  - Calculate inconsistency (calculate $CR = \frac{CI}{RI}$, where RI is a random index defined as the consistency index of the matrix randomly generated by pairwise comparisons; CI is the consistency index calculated as $CI = \frac{\lambda_{max} - n}{n-1}$ and λ_{max} is the biggest eigenvalue of the matrix A)
- Component 2: identify the intensity of the influences between criteria:
  - Create a matrix of influences, D, D_{ij} represents the influence between criteria i and j; if there is more than one decision maker who gave their input in terms of influences (values 0, 1, 2, 3 and 4 represent the range from "no influence" to "very high influence"), we can average them

- Calculate $P_D I(N_i)$ and $P_D O(N_i)$ [14]
$$P_D I(N_i) = \sum_{j=1}^{N} w_{ji}, (i \neq j)$$
$$P_D O(N_i) = \sum_{j=1}^{N} w_{ij}, (i \neq j)$$
  - Calculate $P_D O(N_i) - P_D I(N_i)$
  - Normalise the $P_D O(N_i) - P_D I(N_i)$
- Aggregate the strengths of criteria (from Component 1) and intensities of the influences between criteria (from Component 2) to final criteria weights.

To demonstrate SNAP method and compare it to ANP, we will use an example presented in [12], but it will be changed in a way that two clusters of criteria will be formed to describe the difference between ANP and SNAP better. The example is related to the case *evaluation of the scientists*, and the problem structure is consist of three clusters: goal, cluster of criteria related to the teaching (courseware – co, grades from students – gr) and cluster of criteria related to the science (papers – pa, projects – pr, citations – ci). The structure is presented at the Figure 2. The black arrows represent dependencies of five criteria on decision making goal (G), and red arrows represent dependencies between the criteria.
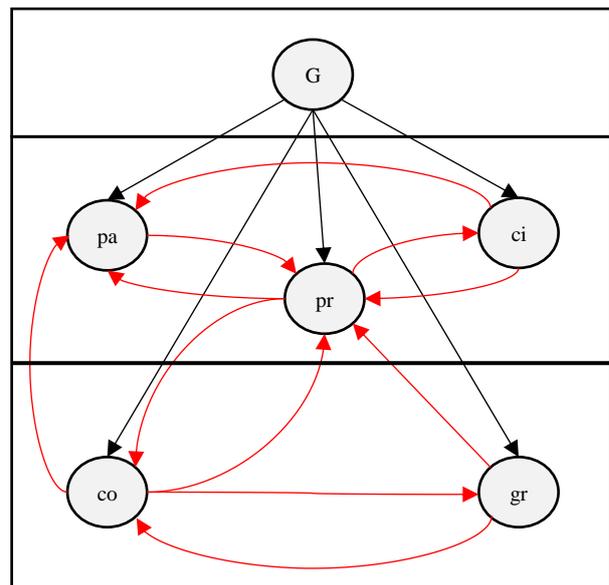
Figure 2. Decision making problem structure – evaluation of the scientists (adapted from [12])

Methods from group 1 (a division of MCDM methods in the Introduction part of this paper) takes into account the black arrows when calculating the criteria weights. On the other hand, the ANP takes into account the red arrows. Finally, the SNAP method takes into account both, red and black arrows. Actually, the ANP can obtain data about black arrows as well, but in future ANP steps those data do not have any influence on the finale criteria weights (to understand this better, you can consult the paper [11], section 4.2.).

After the problem has been structured (Figure 2), in ANP we should do the following steps in terms of giving inputs:

1. Comparisons on the node level using the Saaty's scale:

   a. Comparing criteria in cluster *teaching* with respect to the goal,

   b. Comparing criteria in cluster *science* with respect to the goal,

   c. Comparing *pa* and *pr* with respect to the *co*,

   d. Comparing *pa* and *pr* with respect to *ci*,

   e. Comparing *pa* and *ci* with respect to *pr*,

2. Comparisons on the cluster level using the Saaty's scale:

   a. Comparing *science* and *teaching* with respect to *goal*,

   b. Comparing *science* and *teaching* with respect to *teaching*,

   c. Comparing *science* and *teaching* with respect to *science*.

For users, especially complex and fuzzy are the comparisons 1cde and 2bc. It is often hard to understand for the user what they are comparing. In step 2, we have to three times compare the same two clusters, every time with respect to a different cluster and users often do not differentiate those three comparisons.

In SNAP, for this example, we have to do the following to give inputs about the decision-making problem:

1. Steps 1ab and 2a from the ANP steps list,

2. Identify the intensities of influences between criteria (red arrows at Figure 2).

We can see that step 2 in SNAP replaces the most misunderstanding steps of the ANP. The result of the SNAP step 2 is presented in Figure 3.
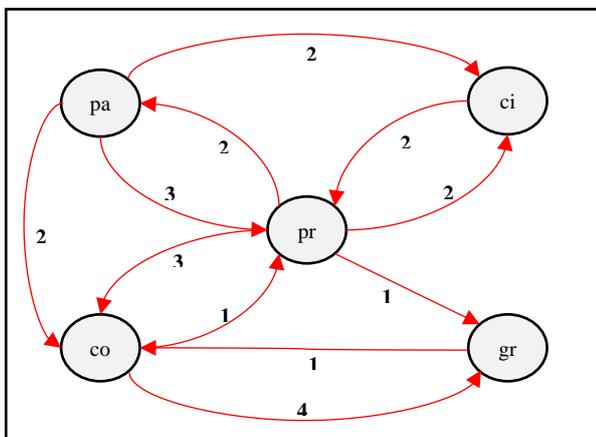
Figure 3. Influences between the criteria in the problem evaluation of the scientists ([12])

After the inputs are identified, other steps of the ANP and SNAP can be automatically implemented. Finally, we will get the results that are presented in Table 1.

TABLE 1. CRITERIA WEIGHTS BY SNAP AND ANP

Criteria	SNAP	ANP
pa	0.2794809	0.305
pr	0.2535056	0.418
gr	0.1557129	0.013
co	0.1706002	0.095
ci	0.1407004	0.167

III. METAMODELLING SNAP

The research of SNAP and detailed comparison with ANP can be found in the paper [15]. In this paper, we will present ERA metamodel of both methods, ANP and SNAP and compare them and finally, evaluate their complexities.

Metamodeling is the analysis, construction and development of the frames, rules, constraints, models and theories applicable and useful for the modelling in a predefined class of problems. This concept is composed of the notions of the terms *meta* and *modelling*. Thus, metamodeling is the construction of a collection of concepts within a certain domain, a precise definition of the constructs and rules needed for creating semantic models [16].

In Figure 4 we can see the ERA metamodel of the ANP method. The ERA metamodel is consist of the following tables:

1. *Goal* – it contains data about the decision-making goal,

2. *Clusters* – this table contains data about the clusters of criteria in the decision-making problem,

3. *Criteria* – this table contains data about the criteria in each cluster,

4. *CompGoal* – this table contains data about the comparisons of both, criteria and clusters, with the respect to the decision-making goal (analogy with steps 1ab, and 2c in the previous section)

5. *CompCriteria* – this table contains data about the pairwise comparisons of criteria with respect to other criteria considering the dependencies between the criteria (red arrows in Figure 2) (analogy with steps 1cde from the previous section). This Table is connected with the table of Clusters because, in ANP, we compare the criteria from the same cluster only.

6. *CompClusters* – this table contains data about pairwise comparisons of clusters with respect to other clusters (analogy with steps 2bc in the previous section).

There are eight relationships in the ERA model. The data about the decision-making problem that is the most confusable for users to input are written in tables *CompCriteria* and *CompClusters*.
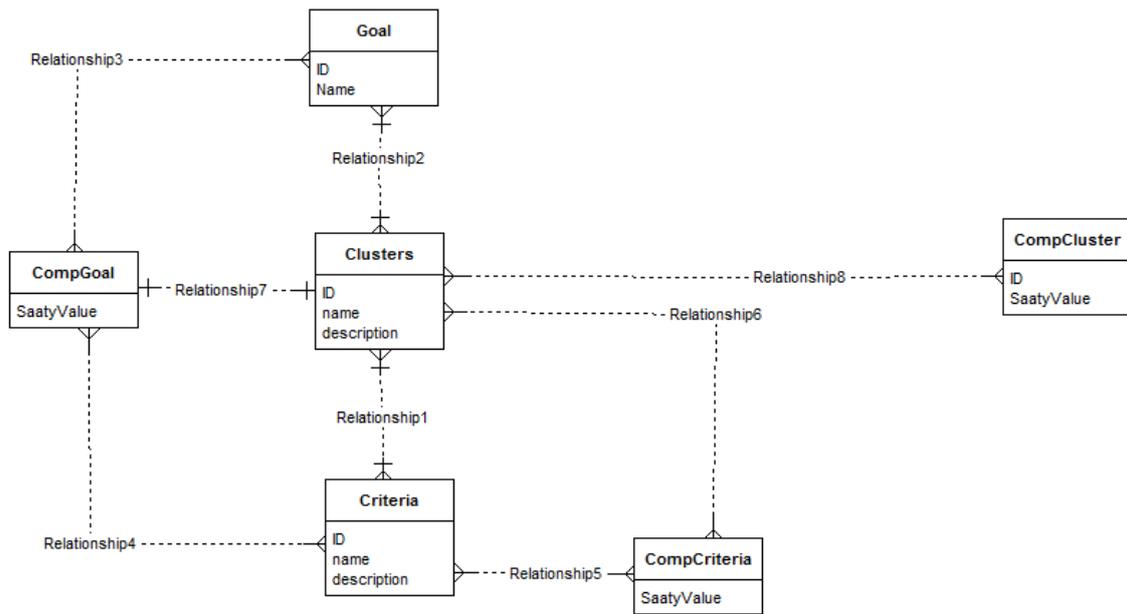
Figure 4. ERA model of the ANP method

The ERA model of the SNAP method is presented in Figure 5. This model includes four tables from ANP ERA model – the first four tables from the previous list. In addition to that, SNAP ERA model contains a table *Influences* which covers the data about absolute influences between the criteria (analogy with Figure 3) that are needed for calculating priorities for Component 2 of the SNAP method. The concept of influences is opposite to dependencies – this is why arrows in Figure 3 have the opposite direction than the arrows in Figure 3. In the ANP, we model dependencies, in SNAP we model influences.

The table *Influences* is prerequisite for applying the SNA part of the SNAP method – calculating the incoming and outcoming centrality degree of specific criterion in the decision-making model. The procedure of giving inputs for this table replaces all steps in the ANP that are misunderstood to the users – steps 1cde and 2bc from the previous section. The reason why this table can replace those steps in ANP is in the fact that - when we make comparisons of the criteria with respect to other criteria (1cde) and comparisons of the clusters with respect to other clusters (2bc), our reasoning should start from the intensities of the influences between the criteria.

Finally, when comparing the raw number of the tables and relationships of presented two ERA metamodels, we can see that the number of both, tables and relationships, is
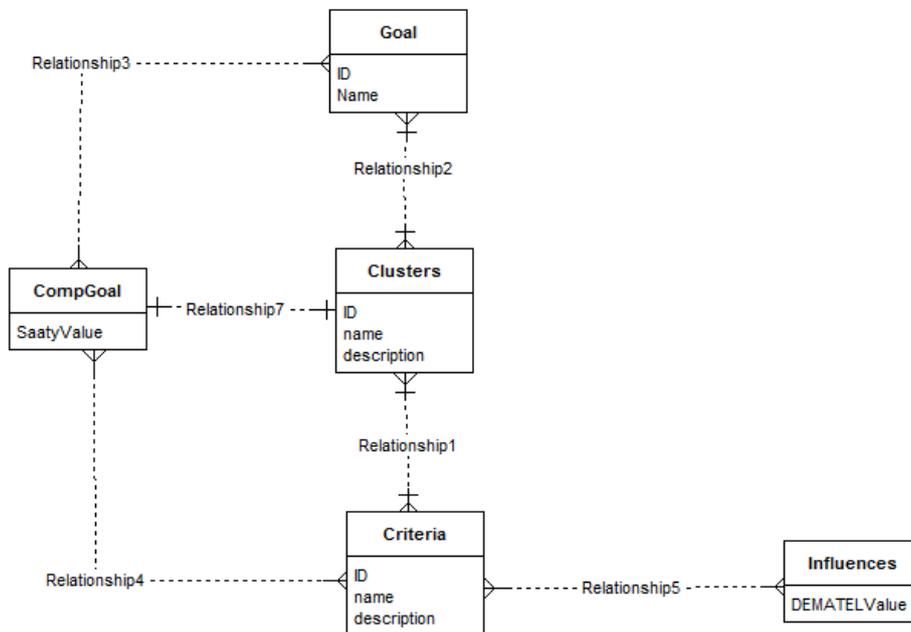
Figure 5. ERA model of the SNAP method

lower in SNAP metamodel which additionally proves the lower complexity of the newly developed method when comparing to the ANP.

IV. CONCLUSION

Many e-learning decision-making problems are multi-criteria problems. Their analysis requires appropriate methods. Since there are influences and dependencies between decision-making elements in e-learning problems, methods that support this feature are welcome. The most well-known method with this feature is ANP. However, there are some weak-points of ANP which demotivates users to use it. This is why the SNAP method has been developed. SNAP is an integration of ANP method with SNA method which is less complicated than the original ANP method.

In this paper, we presented the method SNAP and gave its metamodel. The metamodel is essential because of several reasons:

1. ERA metamodel can help us to understand the SNAP method better,

2. By comparing the ERA model of SNAP with ERA model of ANP, we can additionally argument the lower complexity of the SNAP considering the ANP.

3. The provided ERA metamodel can be a starting point in developing software support for the SNAP. Of course, additional modification will be required.

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