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Structuring E-Learning Multi-Criteria Decision Making Problems

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Abstract - roblem structuring is one of the most critical phases of decision ma ing process. A well-posed problem has direct impact on effective decision ma ing, especially when we use the multi-criteria decision ma ing methods. There are different decision ma ing methods that have been used for decision ma ing on e-learning issues in higher education, but the most suitable method for this ind of problems is the Analytic etwor rocess A . A meets all the theoretical requirements of decision ma ing in higher education, but policy ma ers use it very rarely in practice because of its implementation wea nesses. ne of the wea nesses is a lac of support in structuring problem in the form of a networ . This paper brings an overview of several problem structuring methods and approaches, such as simple top-down and bottom-up approaches, the r ACT approach, nterpretative tructural odelling , AT ecision a ing Trial and valuation aboratory and the A A structuring method. t also brings analysis of how those structuring methods and approaches help overcome some of the A wea nesses. inally, we provide some recommendations of how to design a new problem structuring method that fits the A needs.

I. INTRODUCTION

The following quote "*A good solution to a well posed pro lem is almost always a smarter choice than an e cellent solution to a poorly posed one.*" [1] is a very popular quote in decision making field. It highlights the importance of good decision making problem analysis before making any strategic decision. When we make decisions on different strategic e-learning issues and challenges, a real problem analysis before decision making is also requested in the e-learning field.

There are different approaches that we can use for decision making problem structuring. Depending on characteristics of the field in which we make decisions, different problem structuring method(s) are appropriate. E-learning belongs to the field of education in general, but here it will be related to the higher education (HE) field. To identify the most suitable method for decision making on e-learning issues, we follow the next steps:

(1) firstly, we analyse characteristics of decision making in e-learning and HE,

(2) secondly, we analyse the characteristics of decision making methods to be applicable in e-learning and HE field, and

(3) finally, we analyse decision making methods that shall apply in HE and e-learning field to identify their demands regarding structuring of decision making problem.

Some of those steps are already partly investigated. In [2] author identified characteristics of decision making in e-learning and HE. In [3], [4] authors identified characteristics of decision making methods which would be applicable in the area of HE and e-learning. These features are: problem structuring when multiple perspectives and levels of decision making have to be involved, modelling influences between decision making elements, supporting both – qualitative and quantitative scales (criteria), supporting group decision making, enabling sensitivity analysis including risk, opportunities, benefits and costs. The only method that fits all the demands and characteristics is the Analytic Network Process (ANP) [3], [5].

ANP is a multi-criteria decision making method introduced by Saaty [6] as a generalisation of the Analytic Hierarchical Process (AHP). AHP method is one of the most widely exploited multi criteria decision-making methods in cases when the decision (the selection of given alternatives and their prioritising) is based on several tangible and intangible criteria (sub-criteria). The process of complex decision problem solving is based on the problem decomposition into a hierarchy structure which consists of the goal, the criteria, the sub-criteria and the alternatives. In ANP, decision making problems are structured in the form of a network. The basic structure of ANP is an influence network of clusters and nodes (criteria) contained within the clusters [7]. A network has clusters of elements, with the elements in one cluster being connected to elements in the other cluster (outer dependence) or the same cluster (inner dependence). In outer influence one compares the influence of elements in a cluster on elements in the other cluster with respect to a control criterion; and in inner influence one compares the influence of elements in a group on each other.

Priorities in a network are established in the same way as in AHP using pairwise comparisons and judgments based on the Fundamental Scale (1 to 9 scale of absolute numbers) [6] and deriving priorities as the eigenvector of the judgment matrices. The outline of the ANP steps can be found in [7].

II. KEY FEATURES OF PROBLEM STRUCTURING METHODS TO FIT THE ANP NEEDS

Even though in the ANP general directions are given of how to structure decision making problem, in practice

policy makers often experience some issues related to problem structuring as well as applying other ANP steps. According to the literature and authors' experience in the ANP implementation, some of those issues are:

- Structuring decision making problem into optimal number of clusters and elements in clusters is a challenge,
- Problem structuring procedures in the ANP do not include identifying the weights of influences between criteria which makes criteria pairwise comparisons difficult, sometimes not even understandable for decision makers,
- Similarly, on cluster level, the cluster pairwise comparisons are also difficult, especially in the situations when policy makers have to pairwise compare same clusters with respect to several different clusters [8], [9],
- Problem structuring can result with clusters which are strongly inter-connected (many influences between criteria of various clusters), but weakly intra-connected (small number of influences between criteria in the same cluster). That makes cluster comparison more confusable (see Figure 1: pairwise comparison of clusters 1-2-3-4-5 and A-B-C is more confusable in the second example than in the first),

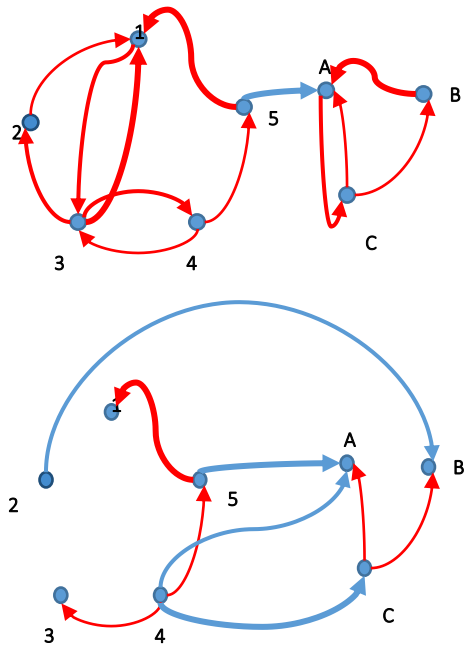


Figure 1. Some possible inter- and intra- connections between clusters 1-2-3-4-5 and A-B-C

- Decision making problem structuring can result with clusters which contain criteria that belong to different fields of expertise. Policy makers cannot make accurate pairwise comparisons and judgements if they are not experts in all needed fields of expertise, e.g. it is difficult to compare ICT and accounting criteria for expert in the ICT field. So, we would like for clusters to contain same-profession criteria, like in the paper [10],
- Finally, decision making problem structure has a direct influence on the number of pairwise comparisons [11].

To conclude, we identified several key features of problem structuring features to fit the ANP needs. These features are:

(1) identifying criteria (nodes in clusters);

(2) modelling influences between criteria (causality);

(3) identifying weights of influences between criteria;

(4) forming network structure;

(5) forming clusters;

(6) forming clusters with strong inter-connection and weak intra-connection; and

(7) forming same-profession clusters.

Some of the examples of the ANP problem structures can be found in [12] (case: strategic planning and decision making on e-learning implementation on the institutional level), [13] (case: evaluating e-Learning platform) and [14] (case: ODL system selection). The above mentioned decision making problem structures are created based on the literature analysis and brainstorming. Details about that approaches will be given in III.-A.

In next section of the paper, we will present several structuring methods and approaches, describe how to use them and analyse them regarding the ANP needs. In section 4 we will summarise results of analyses from section 3 in table form. Finally, in section 5 we will give some recommendations of possible structuring method which will combine advantages of the existing structuring methods.

III. Analysis of Different Problem Structuring Approaches and Methods

Problem structuring methods that we will analyse in this paper are (1) general top-down and bottom-up approach, (2) the PrOACT approach, (3) the Interpretive structural modelling (ISM), (4) the Decision making trial and evaluation laboratory (DEMATEL) and (5) the PAPRIKA structuring method.

A. eneral top down and ottom up approaches

Top-down and bottom-up are basic and the simplest approaches of decision making problem structuring:

- By using a top-down approach, first, we identify the decision making goal. Then we choose networks that will be analysed. Decision making problems can be analysed from a position of four merits: benefits (B), opportunities (O), costs (C) and risks (R); and depending on the problem we can analyse one or more networks. Then we identify control criteria for each merit (and sub-criteria, if applicable), clusters for each control (sub-) criterion and finally identify criteria for each cluster [7].

- Opposite approach, bottom-up approach means doing all steps like in top-down approach, but in reverse order, starting from criteria, through clusters, control (sub-)criteria and merits to goal.

Decision makers often combine those two approaches and structure problem in both directions simultaneously. Structuring procedure finishes when results from applying both approaches "meet each other". Depending on e-learning problem complexity, some levels of problem structure will or will not be present. More complex problems might have all mentioned levels, but less complex problems might not contain e.g. control criteria (or sub-criteria).

When we analyse BOCR aspects of decision making problem, some of those aspects can be modelled as networks and some as hierarchies. For example, benefits (B) can be modelled as a network, and costs can be modelled as a hierarchy, like in [15]. Of course, the ANP method will be applied to network models and the AHP to hierarchy models.

Regarding fitting the ANP needs, we can conclude that top-down, bottom-up or combined approaches fit some of the ANP needs. Firstly, we can identify decision making criteria, but we cannot be sure that we covered all the important criteria. Secondly, we can model influences between criteria, but not determine the weights of those influences. Criteria are formed into clusters by the decision maker. There are no procedures that will ensure an appropriate number of criteria per cluster, consider influences between criteria when forming clusters or group same-profession criteria in the same cluster. All of this depends on the decision maker and his/her e-learning problem knowledge, analytics capabilities and how much knowledge (s)he has on the ANP method.

B. The r ACT approach

The PrOACT approach (also known as a proactive approach) represents decomposition of decision making problem on several main elements [1]:

1. Pr (Problem). Problem is an entity which poses a barrier for a particular group of people in certain time and place;
2. O (Objectives). Objectives are goals that we want to achieve by solving the problem. Objectives can be created by using top-down or bottom-up approaches. Also, a method called problem tree can be used in a way that for the defined problem (Pr) we identify problem-sources and problem-consequences. When we get the whole list of problems, then we can define objectives which we will respond to problems. Finally, after objectives are defined, the criteria such as measures of objectives and their scales are determined.
3. A (Alternatives). Alternatives are possible decisions, choices and between them, we want to choose the best one. Some decision making problems have clear alternatives, and in some cases, we must analyse the problem and goal deeply to make the right definition. Methods that can be helpful in the phase of creating alternatives are: brainstorming/brainwriting, case studies, focus groups, nominal group technique, DELPHI, morphological analysis, Theory of Solving Inventive Problems (Russian: *Theoria esheneyva so retatels ehuh adach*, TRIZ).
4. C (Consequences). Consequences are values that alternatives achieve per each criterion. Usually, multi-criteria decision making problem structures are described in a table form (decision making matrix or table of values).
5. T (Trade-offs). Trade-offs mean expressing the values of a certain criterion in terms of another criterion. Trade-offs are mainly used in Even Swaps method [1].

The PrOACT approach has been introduced by authors of Even Swaps method, and it has been designed for purposes of Even Swaps method [1]. However, this approach can be used with other methods which require decision making table as their input. For example, Electre, Topsis, Promethee and some other methods can benefit from applying PrOACT in the problem structuring phase. Still, most of them would also need some additional data that is not already provided in the table of values that was formed as a result of applying the PrOACT approach.

The PrOACT approach can be used for identifying criteria, and similarly to top-down, bottom-up and combined approaches. However, we cannot be sure that we covered all the criteria. Regarding fitting of the ANP needs, the PrOACT approach is not very useful, especially not for complex decision making problems such as strategic e-learning decision making problems. Namely, the PrOACT approach is a one-level approach: there are no procedures that will guide us to define merits, control criteria, clusters, and criteria. Also, the PrOACT approach does not model influences between criteria which means that the resulted model is not the network. All generated criteria form one cluster.

C. nterpretative tructural odelling

The ISM method is almost always combined with Delphi method. Therefore, Delphi can be considered as the first step in the ISM process. The role of Delphi in the ISM process is to ensure a complete list of criteria that describe strategic e-learning decision making problem [16]. Conducting the ISM includes active involvement of decision making problem experts and literature review.

The ISM is useful for analyzing the complex socioeconomic systems. It also helps to impose order and direction on the complexity of relationships among elements of a system. The ISM has two components [16]:

1. Building the hierarchical relationship – modelling influences between elements by using basics of graph theory.
2. Analysis using the MICMAC matrix (fra. *atriced' Impacts Croise s ultiplication Appliquée a UN Classement*) which consists of ties between elements (criteria). It is used to analyse the driving power and dependence power

of elements (criteria). It further helps to find the key criteria that are driving the whole process. MICMAC provides valuable insights about the relative importance and interdependencies among the criteria.

Steps of ISM (shortened according to [16], [17], [18]):

1. Identification of decision making elements – conducting Delphi method with experts and literature review to get a full list of criteria.
2. The creation of Reachability Matrix - this is a quadrate matrix of criteria with influences between them. In the matrix, on the address (x, y) can be 0 or 1. If there is 1, it means that criterion x has an influence on criterion y, and if there is 0, it means that x has no influence on x. Also, the concept of transitivity is applied.
6. Partitioning the Reachability Matrix- Reachability Matrix is partitioning into levels (clusters) to get a hierarchy of relationships between criteria.
7. MICMAC analysis: for each criterion, we should calculate *driving power* (summing rows) and *dependence power* (summing columns in Reachability Matrix).
8. Building ISM model – a hierarchy of relationships in decision making problem is built.

The main advantages of the ISM are [19]: systematic procedure; efficiency (when the ISM is software-supported); the ISM results and the model are understandable to users; it focuses users to think about only one aspect of the problem at the time. Disadvantages are: in the case of a vast number of elements, the process of conducting the ISM can be very tiring; experts from decision making problem domain are mandatory.

ISM becomes very desirable regarding fitting the ANP needs, but does it fit all the needs? Surely, it identifies the criteria, and here users are advised to conduct Delphi and literature review to be sure that they covered all decision making problem aspects (criteria). Also, systematically we can identify influences between criteria, but the weights of those influences are still missing. On the other hand, the ISM model is not a network structure with a cluster that is required in the ANP. However, the partitioning procedure can be interesting regarding creating clusters with strong inter-connection and weak intra-connection. However, to achieve that, a further adaption of the method is needed. Finally, the process of partitioning of Reachability Matrix does not consider the field of expertise (profession) of criteria when levels are created; so, it is not ensured that levels contain same-profession criteria.

D. The Decision a ing Trial and valuation a oratory D AT

There are some similarities between ISM and DEMATEL [20]. The main goals of DEMATEL method are similar to the purpose of ISM. There are two main results of DEMATEL:

1. Casual diagram (also known as impact-relation map, [21]) – diagram of only significant influences between elements (criteria in decision making problem), which shows only influences that are over threshold value [22].
2. Relation Matrix – describes influences between criteria. Weights of influences are included now. In most often cases, five-scale 0-4 is used: 0, 1, 2, and 3 represent 'No influence', 'Low influence', 'High influence', and 'Very high influence' respectively [23].

Like ISM, DEMATEL has also been already applied in combination with ANP. DEMATEL and ISM provide a systematic, logical reasoning process to determine causality. They clearly delineate the relationships of the complex elements at the system level, direction and impact [20]. DEMATEL can propose the most important criteria which affect other criteria. DEMATEL can reduce the number of criteria [24].

Regarding fitting the ANP needs, by applying DEMATEL, we can model influences between criteria, as well as calculate weights of influences between criteria. Like in top-down, bottom-up and combined approaches, as well as in the PrOACT, we cannot be sure if we covered all the relevant criteria. The result of DEMATEL, impact-relational map (IRM), has a network structure, but this structure is not usable for ANP. However, network structure that would come as a result of drawing relation matrix would be very interesting regarding ANP. On the other hand, the procedure of how input data for IRM are calculated might be helpful in creating a cluster with strong inter-connection and weak intra-connection relationships because in IRM we draw only the strongest relationships. Other procedures for forming cluster are not available, and neither are procedures for creating same-profession clusters.

. The A A method

1000Minds applies patented PAPRIKA method – an acronym for *otentially All airwise an ings of all possi le Alternatives* [25]. This method requires special decision making problem structure, so we will explain it here and later analyse in related to ANP. 1000Minds is an online suite of tools and processes to help individuals and groups make decisions, and also to understand other people's choices. 1000Minds has tools for decision-making, prioritisation and discovering stakeholders' preferences via conjoint analysis [25]. Depending on the application, 1000Minds can also help the user to think about the value for money of alternatives and allocate budgets or other scarce resources.

To be able to apply PAPRIKA method, structuring of a decision making problem consists of several steps:

1. identifying all criteria for decision making,
2. identifying all values that some alternative can achieve per certain criterion,
3. making pairwise comparisons of all possible pair combinations of possible alternatives' values (e.g. what do you prefer: a hypothetical alternative with values on criterion 1 and y on criterion 2 OR a hypothetical alternative with

values on criterion 1 and *v* on criterion 2) to get criteria weights and alternative priorities.

This decision making problem structuring reminds on modelling in Dex method. DEX is a qualitative multi-criteria method, in which all criteria are represented by qualitative (symbolic, verbal) attributes. The attributes are structured into a hierarchy, and the evaluation of alternatives is governed by decision rules [26].

This problem structuring method has many weaknesses regarding fitting the ANP needs. First of all, just like the PrOACT, criteria are identified in one-level approach. Then, there are no hierarchical or network levels. Finally, this method does not fit most of the ANP demands, and the features of the method do not contribute to the ANP needs.

IV. Results: How Different Problem Structuring Methods Fit the ANP Needs

In Table II we have summarised how different problem structuring methods and approaches fit the ANP needs.

TABLE II. How different decision making methods fit HE and e-learning demands

A demands	**Top-down, bottom-up**	**r ACT**		**A T**	**inds**
Identify criteria	+/-	+/-	+	+	+/-
Modelling influences between criteria	+/-	-	+	+	-
Weights of influences	-	-	-	+	-
Network structure	+	-	+	+	-
Hierarchy of criteria sets	+/-	-	-	-	-
Forming clusters	+/-	-	+/-	+/-	-
Strong inter- and weak intra-connection	-	-	+/-	+/-	-
Same-profession clusters	+/-	-	-	-	-
Cluster size	+/-	-	-	-	-

If we simply count number of fits, we can say that the method that the best fits the ANP needs is DEMATEL. Also, if the top-down or bottom-up approach is implemented by experts in both, decision making problem field and ANP method, the results might be even better than in DEMATEL - if experts pay attention to (1) profession of criteria (create same-profession clusters) and (2) connections between criteria when forming clusters (strong inter- and weak intra-connection). On the other hand, there is room for improvement of the structuring method.

V. Recommendations for Upgraded Problem Structuring Method

In this section, we give some recommendations for upgraded problem structuring method which will combine good sides of the presented model structuring approaches and upgrade them with some additional features:

1. The starting point of the upgraded method is Delphi and literature review. Those methods ensure a list of all criteria that are relevant for certain e-learning problem.
2. All identified criteria will be grouped by experts or Q-sorting into several groups that are related according to four merits: B, O, C and R, and further analysis goes separately for each merit.
3. To all identified criteria, we join a profession (field of expertize). A profession will be considered in step 5 as a factor for creating same-profession clusters.
4. Now, in each merit, we identify influences between criteria and calculate their weights (as in DEMATEL).
5. This step requires the development of clustering procedure that will separate weighted network of criteria into clusters. Those clusters will consist of same-profession criteria (as a feature with the highest priority) and will have weak inter- and strong intra- connection between criteria. Cluster size should be between 5 to 9 (number of criteria in the cluster) in most of the clusters. To develop that procedure, algorithms that resulted in ISM model and IRM model can be analysed and possibly reused, as well as different cluster algorithms, such as algorithms in the Pajek [27], an algorithm for affinity analysis [28] and others.

After developing the method, it should be evaluated by using qualitative and quantitative analysis, including software implementation which will simplify new structuring method applications. The proposed method will fit the best into ANP needs, but it requires considerable resources in expertize (use of experts), time and professional guidance.

VI. Conclusion

Dealing with different e-learning challenges systematically requires making the proper strategic decisions related to those challenges. Prerequisite for making a right decision requires a good structure of decision making problem. The method that meets the most characteristics of decision making in HE is the ANP method.

In this paper, we presented several problems structuring approaches and described how they fit the ANP needs. We conclude that the most suitable structuring method regarding the ANP needs is the DEMATEL. However, the DEMATEL still has weaknesses, so we gave some recommendations for upgraded problem structuring method that will be based on the DEMATEL.

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