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A new method for strategic decision-making in higher education

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Abstract Using the appropriate methodology for strategic decision-making in higher education is crucial to make effective decisions. In this paper, the analytic network process (ANP), one of the most suitable decision-making methods in terms of higher education issues, is presented and evaluated from the position of the user. After recognising some characteristics of the ANP that can be improved, the main objective of this research was to develop a new method based on the characteristics of the ANP and social network analysis (SNA). The research methodology used in this paper is the design science research process (DSRP), which is often used to design new artefacts, such as models, methods and methodologies. The main phases of this approach include problem identification, objectives of a solution, design and development, demonstration of the artefact, evaluation and dissemination. By using the DSRP, a new decision-making method is designed and proposed. The new method has two components that are based on the ANP and SNA. The first component is related to determining the importance of criteria with respect to the goal of decision-making. The second component is related to modelling influences/dependencies between criteria, and identifying criteria that strongly influence others, as well as criteria that others depend on. A measure that describes how strong a particular criterion is in terms of influences/dependencies is based on the centrality degree, one of the most fundamental centrality measures. In this paper, the new method, which was evaluated on several

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cases, is demonstrated with example of evaluating scientists, and a comparison of the new method's results and the ANP method's results is presented.

Keywords ANP · SNA · Decision-making · Higher education

1 Introduction

This paper was prepared under the project, "Development of a methodological framework for strategic decision-making in higher education—a case of open and distance learning (ODL) implementation". The project's structure had four phases: (1) Intelligence—problem identification and research; (2) Design of decision-making methodology; (3) Implementation and monitoring of strategic decisions; and (4) Evaluation of effects of strategic decisions (Divjak and Project Associates 2017). This paper's research is related to the second of the four phases, of which the main goal is to design a new decision-making methodology that will be appropriate for strategic decision-making in the area of higher education.

Using an appropriate method for strategic decision-making is crucial to make effective decisions. Influences/dependencies between criteria are characteristic of strategic decision-making problems in the area of higher education. Therefore, to successfully deal with these problems, we need a method that supports modelling influences/dependencies (Divjak and Begicevic 2015). The most popular method to support this feature is the analytic network process (ANP). In addition, the ANP enables group decision-making, sensitivity analysis, risk analysis, and cost and benefit analysis. These are important characteristics, especially from the perspective of the higher education field, because strategic decisions are highly uncertain and risky, and have long-term consequences. Furthermore, they are largely brought about by higher management, i.e. a group of participants who influence the decisions, and more importantly, in terms of the actions taken, the human, material and financial resources that are committed (Divjak 2016). The authors of this paper (Kadoić et al. 2016) conducted a systematic literature review on the methods, methodologies and approaches practically used in the higher education field. They concluded that the method used most often is the analytic hierarchy process (AHP), which does not support modelling influences/dependencies between criteria. The AHP is more often used in decision-making than the ANP, because the latter is more complex in its implementation, the duration of the decision-making process takes longer, and users often misunderstand some of the method's steps. These findings were the motivation to create an alternative decision-making method that will support modelling dependencies between criteria. The new method is based on the ANP and social network analysis (SNA). In addition to applying the new method to the higher education field, it can be used in other fields and for decision-making problems in which there are influences between the criteria.

In Sect. 2, we discuss the research methodology. Section 3 is dedicated to the ANP and its steps. This section also includes a short analysis from the perspective of the users to determine the criteria that will be used when comparing the new method with the ANP. In Sect. 4, the main centrality measures of SNA are presented. The new method, its components and steps are described in Sect. 5. This section also contains an example of an implementation of the new method, as well as an evaluation of the method.

2 Research methodology and paper objectives

According to the types of research designs (Creswell 2009), the design of this research is mixed method research. It is a pragmatic research philosophy, and the research methodology follows the design science research process (DSRP). The phases of this research, adapted from Peffers et al. (2006) and Vaishnavi and Kuechler (2004), are:

1. *Problem identification and motivation* The problem identified in this research is the difference between decision-making methods that should be used and those that are practically used in strategic and tactical decision-making in higher education. As stated earlier, in decision-making in higher education, dependencies/influences exist between criteria. Some of the methods that support modelling dependencies between the criteria are the ANP (Wudhikarn 2016) and the weighted influence non-linear gauge system (WINGS) (Michnik 2013). In practice, the most often used method is the AHP. Electre, Promethee, Topsis and some others are also used (Kadoić et al. 2016), but those methods do not support modelling dependencies between criteria. Instead, criteria weights are calculated by only determining the importance or strength of criteria with respect to the decision-making goal. By including dependencies between criteria, we obtain more accurate criteria weights (Begičević 2008). This phase is related to the first goal of the paper (see below).
2. *Objectives of the solution* The solution to the problem is to create a new artefact, a multi-criteria decision-making method that enables modelling influences/dependencies between criteria in the decision-making problem. In the previous phase, the criteria to compare the new method with the ANP will be identified. They will be created by analysing the ANP and identifying the characteristics that can be improved. The objectives of the solution will be set as better (more favourable) values of the new method than the values of the ANP.
3. *Design and development* A new artefact, i.e. new decision-making method, will be presented in this phase. The new method will be based on the ANP and SNA. The method has two components. One is related to the importance of criteria (strength), and the other to influences/dependencies between criteria. The first component will be modelled by using the AHP, and the second by using SNA.
4. *Demonstration of the artefact* The new method will be implemented in a case from the area of higher education, namely, the evaluation of the scientists. Criteria weights will be calculated.
5. *Evaluation of the artefact* The ANP will be implemented in the case from the previous phase. Furthermore, the results (criteria weights) of both methods will be compared and the Spearman's rank correlations will be calculated. In this way, the new method will be evaluated on a specific case.
6. *Dissemination phase* This paper is a way of disseminating information. The idea of connecting the ANP and SNA, without detailed analysis, has already been presented in our paper (Kadoić et al. 2017c). Now, we bring the method's details,

some examples, and a comparison with the ANP results related to the selected case.

The objectives of the research are:

1. To present and analyse the characteristics of the ANP and SNA;
2. To develop and present a new method that is based on the characteristics of the ANP and SNA;
3. To demonstrate a new method for calculating criteria weights by using a case of scientist evaluations; and
4. To compare the implementation results of the new method and the ANP for calculating criteria weights in a case related to the evaluation of scientists.

3 The analytic network process (ANP)

The ANP is a generalisation of the AHP. The ANP supports modelling dependencies between criteria as well as modelling feedback (Saaty 2001). Our research is limited to the criteria level, and alternatives have not been included thus far.

According to our experience, the concept of dependency is sometimes confusing to the user. The concept is often connected with the concept of influence: if a criterion influences another, it means that the second criterion depends on the first criterion (Kadoić et al. 2017a). If a criterion significantly influences other criteria, its weight increases (when compared to a state without influences), as shown in Fig. 1.

However, if a criterion is highly dependent on other criteria, its weight decreases. If, on the right side of the picture, we modelled the dependencies instead of the influences, the final weights of K1 and K2 would be lower than 0.24 and the weight of K3 higher than 0.52.

Therefore, we have to be careful with the interpretation of what we are modelling. For a graphical representation of a decision-making problem, we often use nodes to present criteria and arcs (directed arrows) to represent dependencies/influences between criteria. In the ANP, we model dependencies (Saaty 2001), but in interpretative structural modelling (ISM) or the decision-making trial and evaluation laboratory (DEMATEL), we model influences between criteria (Attri et al. 2013; Bhadani et al. 2016; Falatoonitoosi et al. 2014; Shao et al. 2014; Sharma et al. 2013; Shih-Hsi et al. 2012). Often, either ISM or the DEMATEL, or even both simultaneously, have been used in conjunction with the ANP. In those implementations, ISM and/or DEMATEL are mainly used to structure the decision-making problem, and then the ANP is

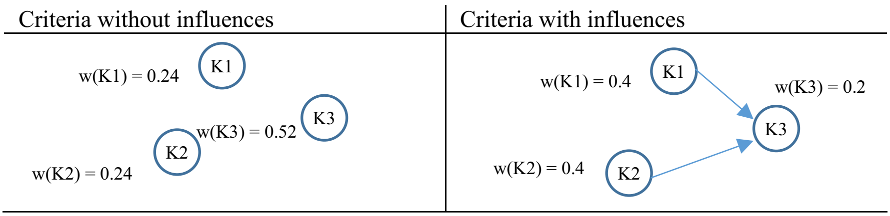

Fig. 1 Decision-making criteria with and without influences

applied on the obtained decision-making structure. In some papers, it is difficult to determine if the arcs in the ISM/DEMATEL structure have been properly interpreted and "converted" for the ANP implementation.

After explaining the main concepts—dependencies and influences—we will describe the ANP method with an example and analyse their characteristics.

3.1 The ANP steps

Step 1 Decision-making problem structuring. This is the step in which a decision-making problem has been structured through merits, control criteria and subcriteria, clusters and criteria. These elements are presented in Fig. 2, the ANP general decision-making problem. First, we have to decide which networks (merits) of the problem will be examined. For each chosen merit, we have to define control criteria (and subcriteria, if the decision-making problem is more complex), KK. For each control criterion, we have to identify clusters and elements of the clusters–criteria. In addition, dependencies between criteria have to be identified (blue arcs). Automatically, dependencies between the clusters are created (red arcs).

A review of possible problem structuring methods can be found in Belton and Stewart (2010), and Kadoić et al. (2017b). The structuring process highly depends on the decision-making method that will be applied. The selection of criteria and sub-criteria is a crucial step in the process of applying decision-making method. Selected criteria and influences/dependencies between them must realistically represent the

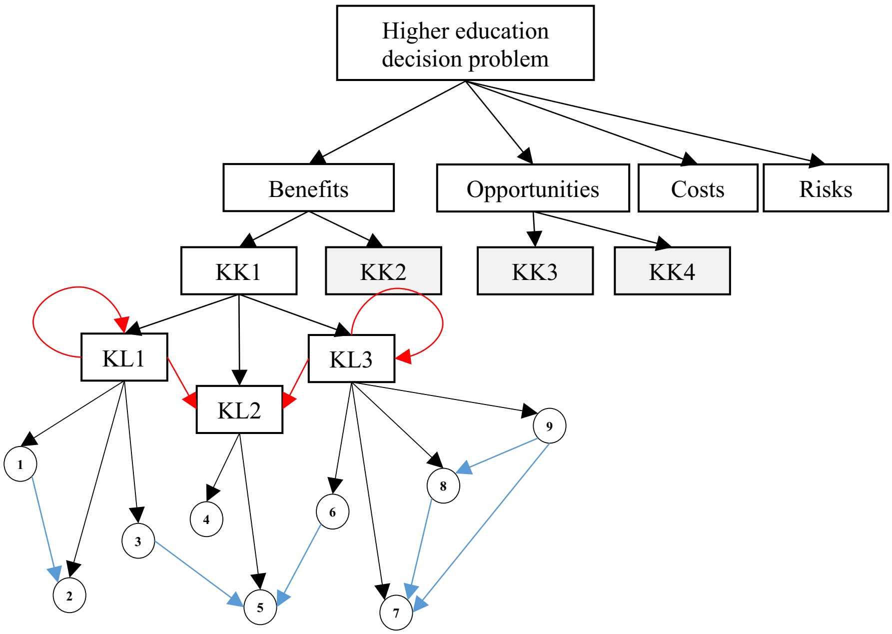

Fig. 2 The ANP general decision-making problem

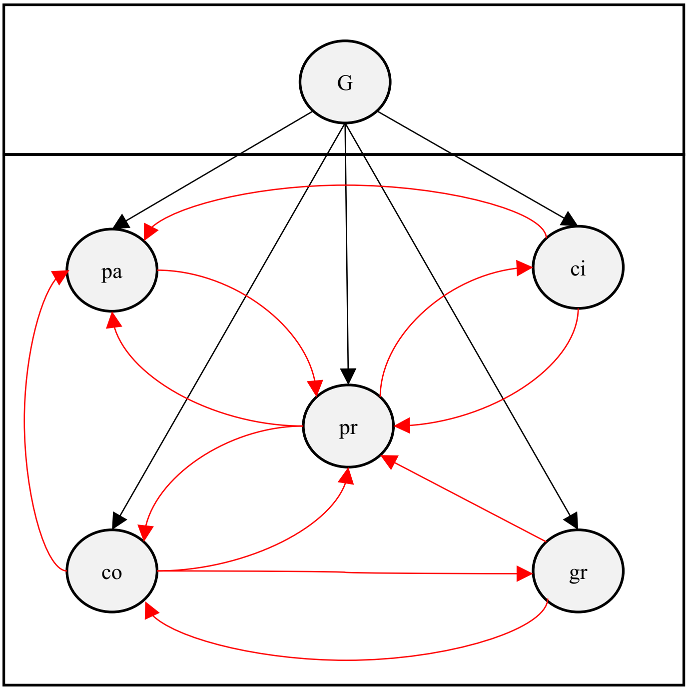

Fig. 3 Structure of decision-making model; case: evaluation of the scientists

problem area. The decision makers have to cover all the criteria relevant for the specific problem. Sometimes different institutions have similar or even the same decision-making problem but their lists of relevant criteria are not necessarily the same. Within the ANP, it is also important to identify all influences/dependencies between criteria. It is desirable to include experts relevant to the problem area field, as well as experts in the decision-making field (that are familiar with the appropriate methods).

Our example in Fig. 3 contains two clusters: a cluster of the goal and a cluster of five criteria. The decision-making problem is related to the evaluation of scientists. The criteria in the decision-making problem are papers, projects, citations, development of teaching materials (courseware) and students' evaluations (grades). The dependencies between criteria are also defined. Some of the identified criteria can be deconstructed to elements on lower levels. In this case, during the pairwise steps, decision makers will include the complexity of criteria in their judgements.

Black arcs are related to dependencies of the goal on criteria, and red arcs are related to dependencies between criteria.

Step 2 Pairwise comparisons and weighted supermatrix. In these steps, we have to perform several pairwise comparisons:

- Comparisons of all criteria with respect to a goal (to get the importance/strength of criteria)
- Comparisons of criteria that depend on the same criterion or that influence the same criterion. We have to compare papers and projects with respect to citations; course-

Table 1 (Un)weighted supermatrix

	G	Citations	Courseware	Grades	Projects	Papers
G	0	0	0	0	0	0
Citations	0.08128	0	0	0	0.4	0
Courseware	0.14189	0	0	0.8571	0.2	0
Grades	0.33412	0	0.1429	0	0	0
Projects	0.28975	0.33333	0.5714	0.1429	0	1
Papers	0.15296	0.66666	0.2857	0	0.4	0

ware and projects with respect to grades; papers, grades and projects with respect to courseware; and papers, courseware and citations with respect to projects.

When doing pairwise comparisons, Saaty's scale is used. This scale is relative and has degrees of 1 to 9: 1 means that two elements in the pair are equally important; 3 means weak domination of one element to another; 5 means strong domination; 7 means very strong domination; and 9 means extremely strong domination (Saaty and Vargas 2006; Sayyadi and Awasthi 2013). In addition, all real numbers on the scale are used. According to the axiom of reciprocity, if one element is n times more important than another (n is a number from Saaty's scale), then the other element is $1/n$ times more important than the first one.

This step is time-consuming, complex and often not understood by the users because they have to compare the same two criteria several times, each time with respect to some other node. In this case, for example, papers and projects need to be compared with respect to the goal, and then with respect to citations, and finally with respect to courseware. The questions that are asked each time are: (1) To achieve the goal of decision-making (select the best scientist), which criterion is more important—papers or projects, and to what degree on Saaty's scale? (2) Between papers and projects, which element has a higher influence on citations, and how much higher (or which element is the citations criterion more dependent on)? and (3) Between papers and projects, which element has a higher influence on courseware, and how much higher (or which element is the courseware criterion more dependent on)?

Calculating the priorities from the judgements has been described in basic ANP literature (Harker and Vargas 1987; Saaty 2001, 2008; Saaty and Cillo 2008; Saaty and Vargas 2006). After calculating the priorities, we get the unweighted supermatrix. The weighted supermatrix is then calculated by comparing clusters in pairs. Considering that our decision-making problem is not very complex, our supermatrix is already weighted (Table 1). Previously mentioned problems related to the complexity of implementation, duration and misunderstanding some criteria comparisons are highlighted even more in cluster comparisons.

Step 3 Calculating limit matrix. The weighted supermatrix has been multiplied with itself. This repeats until we get a matrix that equals its factors. This is the limit matrix. The characteristic of the limit matrix is that its columns are equal. This is how we get the final criteria weights. In our example, the weights of the criteria are presented in Table 2.

Table 2 The ANP priorities

Name	Limiting
G	0.000000
Citations	0.167207
Courseware	0.095269
Grades	0.013610
Projects	0.418017
Papers	0.305898

Step 4 Sensitivity analysis. In this step, we analyse how small changes in inputs (comparisons) affect the final ANP priorities.

3.2 The analysis of the ANP implementation

The most important steps of the ANP method have been summarised. However, this is enough to identify some critical moments that form the criteria for comparing the ANP with the new method. These criteria are:

- Complexity (from the perspective of the user), measured by the number of inputs (comparisons) that have to be put into model;
- Duration, measured by the time spent to give all inputs (comparisons); and
- Understanding the process of giving inputs.

In addition, we will compare the results of both methods (calculating differences in final criteria weights between the ANP and the new method, and calculating Spearman's rank correlation).

At the end of this section, we point out some other conclusions of our analysis of the ANP method, which might be useful later to explain some differences between the two methods' results.

- First, in the ANP, it is possible to get a final weight of 0 for some criteria. This can happen when we have criteria without an incoming arc. For example, in terms of the AHP (only comparisons with respect to the goal), a criterion can have a weight of 0.6 (the most important criterion). Later, if that same criterion does not have any input influence arc (meaning that it does not influence any other criterion, or no other criterion depends on it), its final weight will be 0. In the ANP, feedback (arcs from alternatives to criteria) ensure that each criterion will have at least one input arc, but sometimes we just need the criteria weights (maybe we do not yet know the alternative). The new method will be more focused on calculating criteria weights without knowing the alternatives.
- Second, when doing comparisons with respect to other criteria, we have to consider the *intensity* of influences/dependencies between criteria. This is why some pairwise comparisons will be 2, 4, 5 or some other value on Saaty's scale. However, if we look at the situation where the paper criterion depends on the projects criterion, we do not have to identify the intensity of that influence. We just write 1 in the supermatrix, independently of how strong the influence is.

- Connected to the previous point, through pairwise comparisons and creating eigenvectors in the ANP, the intensities of the dependencies are relativized in general.

4 Social network analysis (SNA)

Social network analysis (SNA) is a methodology for the visualisation and research of structures and relationships in a social network. Its aim is to analyse the structure of a social network so that researchers can make conclusions about the individual or group and understand the behaviour of the social network.

The social network structures that SNA studies may vary in form, so it is possible to have a structure in which two entities are not associated/connected (the network consists only of nodes), or in which each two entities are related in some way. These are two extreme situations; the most common form of network is one that belongs to the spectrum of the two extreme situations described (Knoke and Yang 2008).

In each network, the primary task is to determine its most important actors, whether it is a social network of individuals or groups. Here, we use the concepts of centralism and prestige (reputation). These measures aim to quantify the importance of actors in a complete network, taking into account the sociometric characteristics of the received and sent (for directed networks) and the structure of unbound links. Below, we will clarify the centrality measure. This measure consists of three main components: the centrality degree, the closeness centrality and the betweenness centrality.

1. The centrality degree is the simplest measure of centrality. The node degree in the network is equal to the number of lines associated with the top if it is a non-directional zero-scale graph. Therefore, the formula for calculating the degree of centrality in the non-directional unweighted graph (matrix notation) is:

$$C_D\left(N_i\right) = \sum_{j=1}^{N} x_{ij}, \left(i \neq j\right) \tag{1}$$

where $C_D\left(N_i\right)$ is the centrality degree of node N_i, and the right part of the equation calculates the number of connections of node i. Here, we look at the neighbourhood matrix (which is in the unweighted graph equal to the matrix of the connections) and simply sum the rows or columns (since the matrix is symmetric) and, thus, get the centrality degrees. In the directed graph, there are other in-degree and out-degree measures of centrality, and they are counted by counting the links entering or exiting the node:

$$P_D I\left(N_i\right) = \sum_{j=1}^{N} x_{ji},\ \left(i \neq j\right) \tag{2}$$

$$P_D O\left(N_i\right) = \sum_{j=1}^{N} x_{ij},\ \left(i \neq j\right) \tag{3}$$

In our case, the nodes in the graph will be criteria, and the connections (ties) will be influences between criteria. The decision-making problem network will be directed and weighted. This is why we need incoming and outgoing centrality measures for weighted graphs. Some authors define incoming/outgoing centrality measures for weighted graphs as the arithmetic (or weighted arithmetic) mean of the regular centrality degree and the total sum of the weights that income/outgo in some node (Opsahl et al. 2010). In our case, we will use weights that income/outgo in some node:

$$P_D I\left(N_i\right)=\sum_{j=1}^{N} w_{ji},\ (i \neq j) \tag{4}$$

$$P_D O\left(N_i\right)=\sum_{j=1}^{N} w_{ij},\ (i \neq j) \tag{5}$$

2. Closeness centrality is a measure that shows how close some node is to other nodes in the network. Unlike the centrality degree that considers the number of direct connections of the observed node with other nodes, the closeness centrality is a measure that takes into account even the indirect connections between nodes—two nodes can be connected through the third node. The formula for calculating the closeness centrality is:

$$C_C\left(N_i\right)=\frac{1}{\sum_{j=1}^{N} d\left(N_i, N_j\right)}\ (i \neq j) \tag{6}$$

   where $d\left(N_i, N_j\right)$ is a geodesic distance between two nodes.
   Characteristics of a node with high centrality are quick access to other network nodes, short walk to other peaks, closeness to other entities, and high familiarity with current events in the network. The presented formula can also work with directed weighted graphs.
3. Betweenness centrality is related to how many other actors mediate in geodesic paths between pairs of actors in the network. The importance of the node is determined by its position in the network in relation to the other nodes in the net. This measure is based on the concept of the path in the network. The nodes that lie on the path between the other peaks have high betweenness centrality, and they have control over the resources, and are strong mediators and pass guards. Characteristics of nodes with high betweenness are that they have a privileged or influential position in the network, represent a unique breakpoint (cut-point), and have a big impact on what is going on in the network.
   The measure is calculated according to the following formula:

$$C_B=\sum_{j<k} \frac{g_{jk}\left(N_i\right)}{g_{jk}} \tag{7}$$

   where g_{jk} is a number of geodesic paths between nodes j and k, and $g_{jk}\left(N_i\right)$ is a number of geodesic paths between j and k that include a node i.

5 A proposal of a new decision-making method

As mentioned earlier, the new method is based on the characteristics of two presented methods—the ANP and SNA. The new method will model two *dimensions* of each criterion—the strength of the criterion (importance with respect to the goal) and the intensity of influences (between criteria). In one paper (Michnik 2013), this observation is compared using some specific cases. For example, in physics, the magnitude of the force on each of two elements depends on two elements—masses or electric charges and the distance between them. Similarly, in an elastic collision, the effect of the collision depends on both mass and the velocity of the colliding bodies. Some other examples in other fields are also presented in that paper.

5.1 Methodology of the new method SNAP

The new method has been named SNAP (as a combination of SNA and ANP). The method has two components, of which each is related to one of two *dimensions* of criteria. We determine each dimension separately, and then aggregate them to the final criterion weight. When creating the new method, we were mindful of the complexity of the new method and users' understanding of it.

As previously stated, a systematic literature analysis about the usage of different methods, methodologies and approaches resulted in the conclusion that the method used most often is the AHP. Therefore, we want to take this on board and the importance of the criteria with respect to the goal model by using AHP. This is a well-known method that users understand, and which they do not experience significant problems when applying. Alternatively, methods that can be used for determining the strength of the criteria can be direct judgement, the SMART method or the SWING method (Sikavica et al. 2014).

To model influences/dependencies between criteria, we will use centrality measures from SNA. For this proposal, we will mainly use centrality degree for directed weighted graphs (prestige). The goal is to measure the influence of one criterion to others, and vice versa from the others to it. Outgoing influences will increase the total influence intensity of certain criteria, and incoming influences will decrease the total influence intensity of certain criteria.

It is important to discuss the role of the decision-making problem structuring method and calculating the intensity of influences of some criteria. In the ANP, when the structuring procedure is performed, we identify criteria and dependencies between them. Instead of dependencies in the new method, we can identify influences between them. If we model dependencies, then outgoing connections will decrease the total intensity of certain criteria, and incoming dependencies will increase the total intensity of influences of certain criteria. In the example, we will use instructions from the combined DEMATEL and ISM approaches. First, we will identify all criteria relevant to the problem (the Delphi method can be used in this step; Sharma et al. 2013). The next step is to establish contextual relationships between criteria and to create a matrix of influences. This includes incorporating the transitivity concept (Bhadani et al. 2016). Now we have a 0–1 matrix, which describes all influences between criteria.

The next step is to measure the influences between criteria. This is done by experts. We assume that the scales 0, 1, 2, 3 and 4 represent the range from “no influence” to “very high influence”. The reason for applying ISM before DEMATEL is to identify all the influences. This is why we will not do the rest of the DEMATEL steps, which will ensure in some different way that the transitivity concept will be applied.

The steps of the decision-making problem structuring are:

1. Identify the criteria;
2. Identify the influences between criteria (if there is or is not an influence between each two criteria);
3. Incorporate the transitivity concept; and
4. Measure the influences between criteria.

The steps of the decision-making method SNAP are:

- Component 1: identify the strength of each criterion (AHP) (adapted from Begičević et al. 2007; Saaty 2008):
  - 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 $\sum_{i=1}^{n} a_{i1}$, $\sum_{i=1}^{n} a_{i2}$, … $\sum_{i=1}^{n} a_{in}$,
  - Make matrix B, 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 ith row of matrix C
  - Check 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 (scales 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 $P_D O\ (N_i)$ (Eqs. 4 and 5)
  - 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 weight.

5.2 Application of the SNAP on a case study of evaluating scientists

In this chapter, we present the application of the new method in a case of evaluating scientists. The decision-making problem structure is given in Fig. 4.

The first part of the SNAP is to do the AHP. Pairwise comparisons of the criteria with respect to the goal are given in Table 3.

The second part of the SNAP is to apply SNA. We will apply a centrality degree formula for directed weighted graphs and calculate incoming and outgoing centralities.

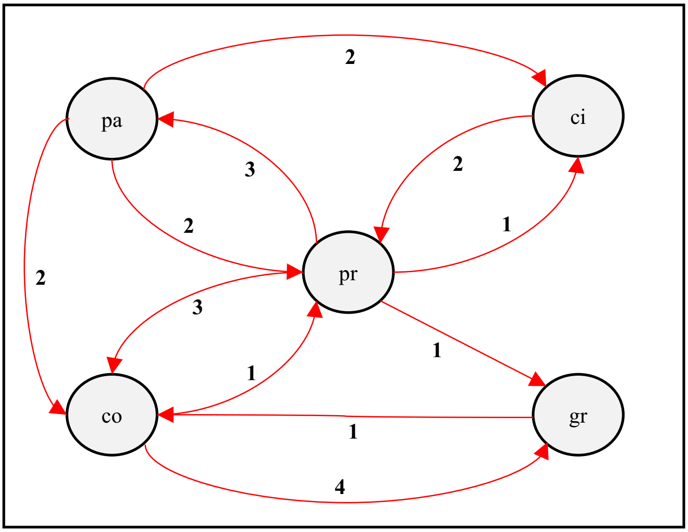

Fig. 4 Influences between criteria with weights

Table 3 Pairwise comparisons with respect to the goal and priorities

	Citations	Courseware	Grades	Projects	Papers	STRENGTH
Citations	1	1/2	1/4	1/3	1/2	0.08128
Courseware	2	1	1/3	1/2	1	0.14189
Grades	4	3	1	1	2	0.33412
Projects	3	2	1	1	2	0.28975
Papers	2	1	1/2	1/2	1	0.15296

After applying the normalisation process, we will get the final intensities of criteria influences on other criteria. Finally, we will then calculate the final weights of criteria.

Explanation of Table 4. Columns PO and PI are related to the centrality degree formula from Eqs. 4 and 5. After that, the difference of those two values is calculated to identify how much higher/lower the influence is on other criteria to the observed one. This procedure relies on calculating the net effect in DEMATEL (Shao et al. 2014). After conducting the normalisation procedure (normalisation by sum), we get the final intensities of the influences of criteria. Then, we calculate the final new method weights as weighted averages of strengths (AHP, 1) and influence intensities (Normalisation, 4).

5.3 Evaluation of the SNAP and discussion

To evaluate the method on a case of evaluating scientists, we will compare its results with the ANP results and calculate Spearman's correlation rank (the usual proce-

Table 4 Calculating final criteria weights by the new method

	pa	pr	gr	co	ci	PO	PI	PO-PI	Normalisation		AHP	New method
pa		2		2	2	6	3	3	11	0.262	0.153	0.2401
pr	3		1	3	1	8	4	4	12	0.286	0.29	0.2865
gr				1		1	5	−4	4	0.095	0.334	0.1430
co		1	4			5	5	0	8	0.191	0.142	0.1808
ci		2				2	3	−1	7	0.167	0.08	0.1496
PI	3	5	5	6	3			8	42			

Table 5 Calculating Spearman's rank correlation

	New method	ANP	Rank New method	Rank ANP	Diff	Diff^2	Spearman
pa	0.2401	0.305	2	2	0	0	0
pr	0.2865	0.418	1	1	0	0	0
gr	0.1430	0.013	5	5	0	0	0
co	0.1808	0.095	3	4	−1	1	0.00833
ci	0.1496	0.167	4	3	1	1	0.00833
							0.9

dure for calculating Spearman's rank correlation is used; Spearman Rank Correlation Coefficient 2017).

In this case, the Spearman's rank correlation was favourable at 0.9 (calculation of the rank correlation is presented in Table 5). The new method has been applied in several other cases, mostly with similar results. In some cases, the Spearman's rank correlation was lower. The reason for this can be found in Sect. 3.2 where we gave a short ANP analysis. Even though both methods support modelling influences (or dependencies) between criteria, each method has its own specifics. The second component of the new method has more similarities with the DEMATEL than with the ANP in terms of structuring decision-making problems. The DEMATEL itself starts with the same, or at least a very similar step (structuring), while in the ANP, we model dependencies (through the unweighted graph), and then later, the intensities of influences are taken into account, but only with respect to one criterion at a time.

We also applied the WINGS method in the case of evaluating scientists, which returned different results than both the new method and the ANP.

The selected case, like many others on which we tested the new method, is not a very complex example. The reason for this is that the number of criteria in the model decreases the possibility of high differences between criteria. Thus, in terms of comparing results with other methods, less complex examples are more welcome. In terms of demonstrating the new method, a less complex example is also preferable.

Finally, we have to evaluate SNAP in terms of the three criteria we presented in Sect. 3.2. The analysis is given in Table 6.

Table 6 Comparing the SNAP and the ANP

Criterion	SNAP	The ANP
Complexity	10 pairwise comparisons with respect to a goal	In the ANP, we have to know all data, plus generate judgements in terms of pairwise comparisons of criteria with respect to the criterion they have influence on; similar conclusions can be generated in general
	25 influence intensities between criteria	
Duration of the process	Taking into account previous comparisons, it is obvious that the procedure in the ANP has a longer duration than the new method. In both methods, we perform 10 pairwise comparisons with respect to the goal. To be able to do pairwise comparisons between criteria that influence the same criterion, we first have to identify influence intensities between them and then transform them into comparisons; thus, doing those comparisons lengthens the process	
Understanding	The pairwise comparisons between criteria that influence the same criterion confuse users. In the new method, that issue is eliminated	

6 Limitations of the research and future work

Currently, the research is related to criteria level only. The alternatives were not included in the model. Also, the evaluation has been only partially done in several examples (and one case is presented in the paper). The presented case is not related to a specific situation or institution. The lists of criteria in the problem *evaluation of scientists* are different considering the scientific field (social science, STEM, medicine…). Also, the strengths of criteria, influences between criteria as well as final criteria weights are consequentially different considering the scientific field.

The main goal was to demonstrate the application of the proposed method on the case by avoiding the usage of general labels of criteria $(c_1, c_2, \ldots, c_n)$. However, even in this general and straightforward case, it was possible to determine influences/dependencies between criteria.

In the future, we will continue the research by implementing the simulation, which will generate general decision-making problems (different combinations of comparisons of criteria with respect to the goal and different combinations of influences/dependencies between criteria), and which will be solved by both, the SNAP and the ANP. The purpose of the simulation is to identify classes of the decision-making problems in which the final criteria weights are similar.

Also, as a part of the new method evaluation, the method will be applied to several specific strategic decision-making problems in higher-education institution(s):

- Problem area experts will identify criteria important in decision-making problem
- Experts will evaluate dependencies/influences between criteria and their weights
- Criteria weights by using SNAP will be calculated
- Experts will make related pairwise comparisons (needed for the ANP)
- Criteria weights by using ANP will be calculated
- Comparisons of final criteria weights by both methods will be done, and differences will be interpreted.

Moreover, besides comparing ANP and SNAP results in terms of the criteria weights, it will be possible to compare methods in terms of three criteria in Table 6: complexity, duration of the process and understanding.

After that, the SNAP will be upgraded with steps for identifying the priorities of the alternatives.

One of the assignments of the future work is to come up with the proposals related to the decision-making problem structuring, specifically for SNAP.

7 Conclusion

In this paper, a new decision-making method that, besides identifying the strength of the criteria (with respect to the goal), enables modelling the influences/dependencies between criteria has been presented. The new method was developed in the framework of the HigherDecision project, and it is focused on strategic decision-making in higher education. The field of higher education is characterised by existing influences/dependencies between criteria in decision-making problems. Using decision-making methods that do not take into account the influences between criteria can guide decision makers to make decisions that are not the best.

The number of decision-making methods that enable modelling influences/dependencies is much lower than the number of methods that do not enable that feature. In this paper, two methods are mentioned—the ANP and the WINGS. The ANP, as the most well-known method from this group, has been described and analysed. It is not used in practice as often as, for example, the AHP, because users find it more complex. In that direction, our method contributes to the list of decision-making methods that support modelling influences between criteria. It can be used as an alternative to the other methods. The methodology used in the research was design science research process (DSRP), which is often used when researchers create new artefacts, such as algorithms, methods, procedures, etc.

The new method (SNAP) is based on the ANP and SNA. We used incoming and outgoing centrality degree (prestige) to measure influences between criteria and after normalisation. In addition, by aggregating the strength of the criteria, final criteria weights were calculated. To make the method implementation more successful, it is important to structure the decision-making problem precisely, considering all specifics of the problem and its' context.

The SNAP was compared with the ANP in terms of the two methods' results (on a presented case), and in terms of the complexity of implementation, the duration of giving inputs, and understanding the process of giving inputs. In those comparisons, the new method has shown favourable results.

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