COMPARISON OF AHP AND ANP METHODS FOR RESILIENCE MEASUREMENT IN SUPPLY CHAINS

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Abstract

The paper presents the utilization possibilities of multi-criteria decision-making methods for supply chain resilience measurement. Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) designed by Saaty are used for this purpose. The aim of this paper is to make a comparative analysis of the methods and point out the main differences between them, to identify the advantages, disadvantages, risks and limitations in the application of these methods in supply chain resilience measurement and to show the usefulness of these procedures for application on a simplified case study.

Keywords: supply chain resilience, Analytic Hierarchy Process, Analytic Network Process, measurement system

1. INTRODUCTION

The first comprehensive concept of resilient supply chains was designed in 2004 by Christopher and Peck [1]. They define resilience as „the ability of a system to return to its original state or move to a new, more desirable state after being disturbed“. Their work was followed by a number of authors and the most prominent publications are [2], [3], [4], [5], and [6]. Each team of authors defines resilience of supply chains in another way and also suggests different capabilities that will help supply chains to increase their resilience against negative factors causing serious disruptions in the supply chain. According to the World Economic Forum [7], the major factors include: natural disasters, extreme weather changes, conflicts and political troubles, terrorism and sudden radical changes of demand. Practical implementation of the suggested capabilities, which include especially [8], [9], [10], [11]: Adaptability, Agility, Anticipation, Capacity, Collaboration, Dispersion, Efficiency, Financial Strength, Flexibility, Market Position, Organization, Quick Response, Recovery, Security, Visibility, have to face various problem. The fundamental problem is finding a suitable instrument for determining the degree of current and required resilience of the supply chain. The measurement providing such information is a complicated and complex process. At present, there is only a limited number of tools relying on the utilization of quantitative approach [12], [13], [14]. The authors of the article have developed their own methodology based on multi-criteria decision-making, the essence of which was published in [15], [16], [17]. These publications are followed by other authors, for example [18], [19]. The basic features are the methods of Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) designed by Saaty, allowing you to prepare and evaluate a structure representing the supply chain resilience. The aim of this paper is to make a comparative analysis of the methods and point out the main differences between them, to identify the advantages, disadvantages, risks and limitations in the application of these methods in supply chain resilience measurement and to show the usefulness of these procedures for application on a simplified case study. The creation and evaluation of the structure (hierarchy in case of AHP and network in case of ANP) takes advantage of SuperDecisions software.

2. CHARACTERISTICS OF AHP AND ANP

The AHP and ANP methods are multistage decomposition methods used to solve decision-making problems involving more than one criterion of optimality. The basic idea is to create a decision-making structure and the

subsequent evaluation of importance of the individual links among the interconnected elements. These evaluations are represented by weights, which can be determined on the basis of Saaty method of pair comparison or by normalizing direct measurements. The basic differences between the two methods are represented by the options and rules applied during the creation of a decision-making structure.

The AHP method [20], [21] is a specific case of ANP method, in which the structure is formed as a hierarchy. The hierarchy is always linear and may contain any number of levels and elements. The arrangement of levels in a hierarchy goes from the general (higher level) to the specific (lower level). There are certain links and relations between the elements in successive levels. The intensity of these relations is expressed numerically. The procedure used for obtaining the final results contained in the practical part can be found in article [16].

The ANP method [22] is a general procedure, in which the structure is created as a network. The network may consist of any links among all the elements. The ANP does not limit human understanding and experience to force decision-making into a highly technical model that is unnatural and contrived. It is in essence a formalization of how people usually think, and it helps the decision-maker keep track of the process as the complexity of the problem and the diversity of its factors increase [23]. The procedure used for obtaining the final results contained in the practical part can be found in article [17].

3. SUPER DECISIONS SOFTWARE

The SuperDecisions software implements the Analytic Network Process for decision making with dependence and feedback developed by Dr. Thomas Saaty. The program was written by the ANP Team, working for the Creative Decisions Foundation. The software allows you to create any network characterizing the examined problem. You can also set graphical illustrations of the individual elements, allowing for easier orientation in the studied problem. When determining the importance of the mutual links, you can use different types of methods of entering the values, including: graphical, verbal, matrix, questionnaire and direct. This decision-making process automatically involves the calculation of inconsistency and, in case of a negative outcome, the software marks the problematic elements and recommends changes. The partial and final results of the decision-making problem are characterized by the following outcomes:

- Unweighted Super Matrix
- Weighted Super Matrix
- Cluster Matrix
- Limit Matrix
- Priorities
- Synthesize

The software also makes it possible to perform a complex sensitivity analysis which, however, will not be applied in the case study.

4. SIMPLIFIED CASE STUDY

The concept of the measurement system of industrial supply chain resilience is based on the decomposition of resilience, as the ability of a supply chain to return to its original state in case of its serious disturbance, to such a level of resilience sub-abilities, which will allow defining the tangible and measurable indicators for evaluation of resilience of the entire supply chain. The basis is to determine the key resilience sub-abilities, which will enable effective protection of the supply chain against anticipated vulnerability factors [16], [17].

The selected key resilience sub-abilities are [14]:

- Adaptability (AD) - ability to modify operations in response to challenges or opportunities:
    - Elements selected for (AD) measurement: Lead time (LT), Frozen planning period (FP).

- Financial Strength (FS) - capacity to absorb fluctuations in cash flow:
    - Elements selected for (FS) measurement: Liquidity (LR), Profitability (PR).
- Collaboration (CO) - ability to work effectively with other entities for mutual benefit.

A hierarchical structure of AHP method created in SuperDecisions software is illustrated in **Fig. 1**. The calculation procedure is described in [16].

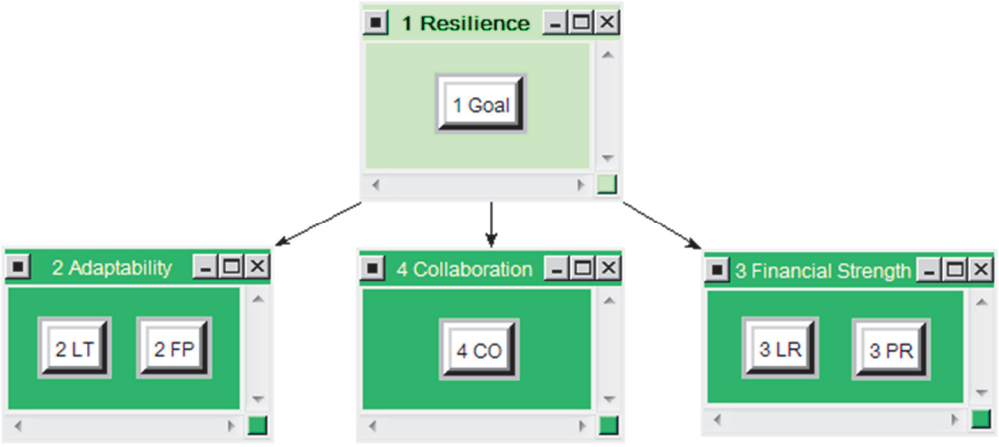

Fig. 1 Hierarchy structure of metallurgical supply chain resilience

Network structure for ANP method created in SuperDecisions software is shown in **Fig. 2** (calculation procedure is described in [17]).

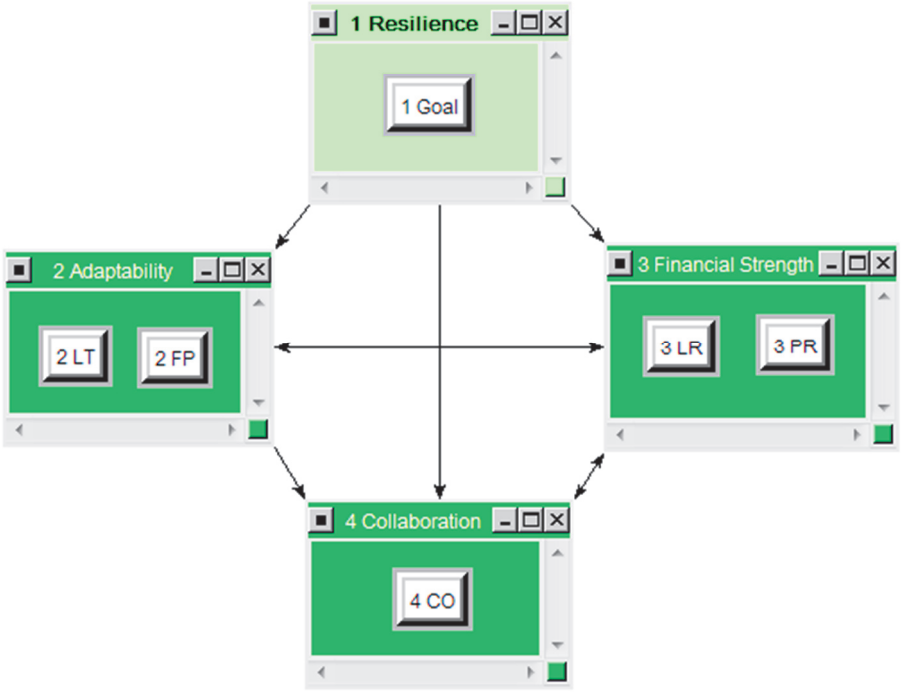

Fig. 2 Network structure of metallurgical supply chain resilience

The difference in comparison with AHP is in the addition of links between the selected elements. The links have been determined on the basis of an expert assessment in the following manner:

- Lead time (LT) is influenced by Collaboration (CO), Liquidity (LR) and Profitability (PR).
- Frozen planning period (FP) is influenced by Collaboration (CO), Liquidity (LR) and Profitability (PR).
- Collaboration (CO) is influenced by Profitability (PR).
- Liquidity (LR) is influenced by Collaboration (CO) and Lead time (LT).
- Profitability (PR) is influenced by Collaboration (CO), Lead time (LT), Frozen planning period (FP).

5. RESULTS AND THEIR DISCUSSION

The final results used to determine the weights of the individual elements in the structure of resilience measurement can be shown in two versions, when SuperDecisions software is used:

1. by means of Limit Matrix,
2. by means of a table of Priorities.

When applying the AHP method, the most important sub-ability was Collaboration (CO), which gained the weight of almost 66%. The second place was taken by Financial Strength (FS) with a gain of 26%, and the least important factor was Adaptability (AD) with 8%. The resulting values of the specific indicators are shown in **Fig. 3** (the last column marked Limiting).

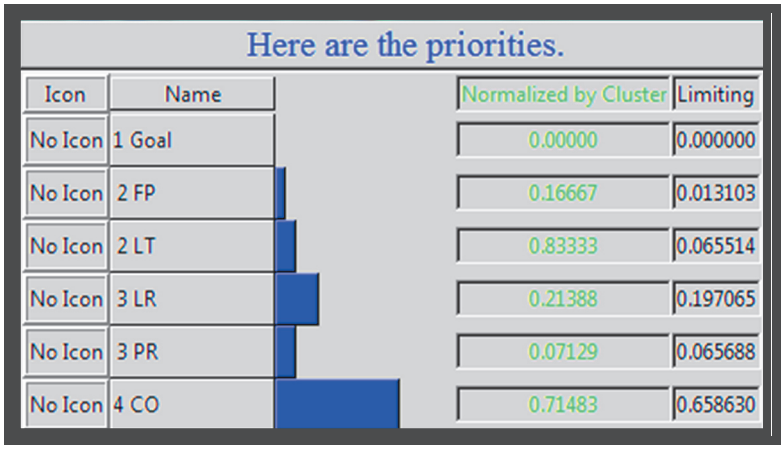

Fig. 3 The final weights of AHP application

When applying the ANP method, the most important selected sub-ability was Financial Strength (FS), which gained the weight of almost 44%. The second place was taken by Collaboration (CO) with a gain of 41% and the least important was Adaptability (AD) with less than 15%. The resulting values of specific indicators are shown in **Fig. 4** (the last column marked as Limiting).

The final weights of the individual indicators during the application of the AHP and ANP methods are significantly different. The main difference is the high increase in the importance of Profitability indicator, whose priority was higher by 37% when the ANP method was applied. The reason is that it takes into consideration the real interdependence among the individual indicators when measuring the supply chain resilience by means of the given method. The expert assessment has shown that all indicators are influenced by the Financial Strength, and always much more by Profitability than Liquidity. The reason is the necessary condition to have sufficient investment capital for building the remaining abilities increasing the supply chain resilience.

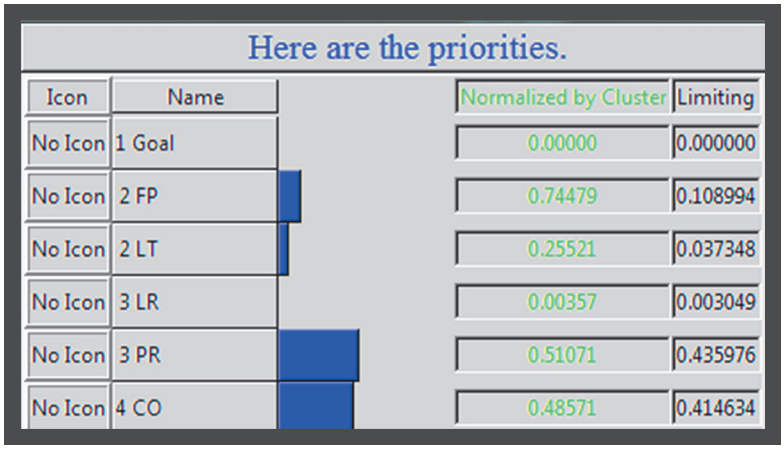

Fig. 4 The final weights of ANP application

CONCLUSION

Both methods of multi-criteria decision-making have confirmed their applicability in evaluating and measuring the resistance of a supply chain:

- The advantage of AHP method is its simplicity, which makes its applicability in managerial practice in supply chain management easier.
- The advantage of ANP method is its complexity, which allows you to capture the complex structures of real interconnections during the assessment of the supply chain resilience.

The decision on the choice of method always depends on the supply chain management, which must take into account the reasons, circumstances and source options of the performed evaluation and measurement.

Further research must focus on creating a complex taxonomy of the abilities increasing the resilience of the supply chain and the possibilities of the final evaluation of the determined results.

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