A REVIEW AND CRITIQUE OF MADM METHODS AND APPLICATIONS IN BUSINESS AND MANAGEMENT

Jiri Franek[1]
jiri.franek@vsb.cz
Faculty of Economics, VSB – Technical University of Ostrava, Sokolska trida 33, 701 21 Ostrava, Czech Republic

Katerina Kashi
katerina.kashi@vsb.cz
Faculty of Economics, VSB – Technical University of Ostrava, Sokolska trida 33, 701 21 Ostrava, Czech Republic

ABSTRACT

Since their introduction, the multiple attribute decision making (MADM) techniques have witnessed great development and popularity among scholars. Their applications range from very basic to more sophisticated using mathematical optimization linear programming (MOLP) and fuzzy operations. Even though many scholars and authors have researched various possibilities for the practical use with MADM, it seems the same enthusiasm has not taken root in real business environments. Hierarchical and network thinking is very important for any strategist and entrepreneur. The most frequent plea is that speed and efficiency should prevail, when in reality the business environment is much more dynamic and turbulent. Often entrepreneurs and managers have difficulty filling out the questionnaires for comparing the criteria and alternatives. The lack of agreement in the criterion evaluation and compromise thus limits the application of MADM techniques. Another problem is associated with the large number of evaluation criteria that are often needed and the network of interdependencies. This paper reviews applications that can be considered useful in real business, and based on empirical research proposes a suggestion of specific tasks that could be used and accepted in the business environment.

Keywords: AHP, ANP, DEMATEL, TOPSIS, VIKOR, decision making, management.

---

[1] Acknowledgement: This paper is supported by SGS of the Faculty of Economics, VŠB-Technical University of Ostrava; project's registration number is SP2014/126. All support is greatly acknowledged and appreciated. This research was supported by the European Social Fund on VSB-TUO (CZ.1.07/2.3.00/20.0296).

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

1. Introduction

The business environment is experiencing a period of development in the knowledge that has influenced decision making processes of firms, organizations and individuals. However, many important strategic decisions are made on the basis of self-evidence and intuition, and do not always fully comprehend relationships among evaluated factors and criteria. Decision making is an important and demanding part of business economics. When a decision making problem occurs there is usually a limited number of possible alternatives, but a large number of criteria by which the optimal solution is selected. The process of identification and evaluation of criteria (factors) and alternatives should follow a standardized and structured framework that a manager applies to decision making. The manager should be able to use decision support tools that are easy to handle and can be applied to a wide range of problems in a relatively short time. Managerial decision making consists of a large number of conflicting criteria that cannot be assessed, ranked or selected in a straightforward manner. If the manager is overlooking interrelationships or comparing a number of criteria, he can easily make a mistake in judgment. However, there are a number of methods and techniques that can be used to help with the structure and processing of information and data. The multiple criteria decision-making (MCDM) methods have been successfully applied to many business and management decision making problems. MCDM methods can be divided into two main streams: the multiple attribute decision making (MADM) methods with a finite number of alternatives, and mathematical optimization linear programming (MOLP). We will focus on the MADM methods which are more convenient to use in decision making problems within the business domain. The MADM methods are well developed and have a strong mathematical basis. Though several software solutions are available, they are not among the business tools that are frequently used. Non-expert users who deal with relatively complex but straightforward decision making problems should be able to use these software solutions more often. When determining the significance of a particular pair of criteria for the object investigated, an expert should mentally 'weigh' the respective importance of other pairs of the criteria considered. When the number of criteria is large, it is a challenging problem. Practical application of MADM methods has revealed that only a few experts could avoid contradictions in filling out questionnaires (matrices) on which a MADM approach is based (Ishizaka and Labib, 2011). Conversely, MADM approaches demand certain mathematical knowledge and have their own limits.

The aim of this paper is to investigate how MADM methods should be applied and presented to non-expert users in real business environments. Therefore, advantages, disadvantages and practical applications of MADM methods in a real business will be discussed. The research consists of case studies that aim to reveal convenient approaches to the practical use of the MADM method.

2. Review and discussion about MADM applications

In recent years there has been a shift towards a more sophisticated use of decision support tools and methods. Unfortunately, their implementation is still not widespread among small and medium-sized companies. It is not necessary for these companies to purchase expensive software or implement sophisticated decision support processes, but simply to understand some basic decision-making methods that can help make their work more effective. The Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) are among the most widely discussed MADM methods. These methods represent

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

a group of decomposition multiple attribute decision-making approaches that were developed by Saaty (1977, 1996). Decision Making Trial and Evaluation Laboratory (DEMATEL) has been developed to construct the interrelations between factors/criteria to build the impact of a network relation map (Fontela and Gabus, 1976; Tzeng and Huang, 2011). DEMATEL models the influences of components of a system with an initial direct relation matrix. Influences of components can ripple transitively to other components, which is modeled by raising the initial direct relation matrix to powers. These methods are specifically designed for complex decision making problems with a network or hierarchical structure. Other scholars have concentrated their efforts on methods that can deal with larger numbers of criteria and alternatives. One of the basic methods is the WSA (Weighted Sum Approach) developed by Keeney and Raiffa (1976) that is based on comparison of criteria by normalizing evaluations. Alternatives are evaluated and ranked according to the decreasing value of benefit function. The Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) method was proposed by Hwang and Yoon (1981). The compromise solution can be regarded as choosing the solution with the shortest Euclidean distance from the ideal solution and the farthest Euclidean distance from the negative ideal solution. "Vlse Kriterijumska Optimizacija I Kompromisno Resenje" (VIKOR) method was developed for multiple criteria optimization of complex systems (Opricovic, 1998; Tzeng and Huang, 2011).

In this paper we are not focused on mathematical or methodological advances of the above mentioned methods, rather in how practical the application is and how it could help managers in their day-to-day job. The focus is on investigating methodological approaches using MADM that are likely to be effective in certain managerial tasks.

What support should managers expect from MADM? At the very least, it should order the decision making process and evaluation of factors in a way that allows them to provide transparent and more reliable solutions. In this case, pair-wise comparison can serve as a tool and is the basis for the AHP, ANP and DEMATEL methods. The user must break down difficult and complex decisions into small judgments. However, when the number of comparisons is large, it is very time consuming to provide pair-wise judgments for all combinations, and this is discouraging for most managers. Therefore, the manager can use other methods that do not include as much "human" input i.e. WSA, TOPSIS, VIKOR, COPRAS, ELECTRE, PROMETHE, etc. When there is a need for relatively quick ranking and ordering of items, decision makers can rely on TOPSIS and VIKOR. The main advantage of this approach is that its user could directly input judgment data without any previous mathematical calculations and make a list of alternatives that share similar properties. Both methods can be combined with decomposition methods of AHP/ANP and DEMATEL. The aim is to find characteristic applications for such hybrid methods.

Various aforementioned approaches that can deal with multiple and conflicting criteria have been adopted so far. However, they fail to consider the impact of business objectives and the requirements of company stakeholders in the identification of evaluating criteria for strategic decisions. The integrated approach of multiple criteria decision making methods outranks the conventional approaches because they can match criteria importance with priorities derived from the corporate/business strategy. In periods when the business has a shortage of resources and time, they are not willing to accept further difficulty from a decision making method. The aim of scholars is to

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

convince these managers of the advantages of MADM and that they outweigh the shortcomings. To deal with this matter, application of MADMs in business and management can be investigated from three main perspectives: (i) methodological, (ii) areas of application (business domains or industries), (iii) specific management tasks.

2.1 Methodological perspective

From a methodological point of view, MADM methods are most widely used for: expert prioritization, ranking of criteria, selection of alternatives, assessment of multiple variants and assessment of interrelationships between factors. In general, they are used for either quantification of qualitative assessments or as a merger of quantitative and qualitative evaluations. Expert opinions can be gathered by various basic methods. However, the main advantage of using structured and developed MADM approaches is that they try to reduce randomization and subjectivity (Henig and Buchanan, 1996; Yang et al., 2001). In the case of simple pair-wise comparison methods and more sophisticated AHP/ANP methods the consistency of decision making can be monitored and controlled not only for the individual decision maker but also for a group of experts (Saaty, 1986; Saaty & Peniwati, 2007). These methods are well designed for dealing with large numbers of conflicting criteria that cannot be directly ranked easily (McKee, 1992). Human perception and logic of prioritization is more prone to errors starting from 4 criteria to 7 or more (Saaty, 1994). Furthermore, by simple direct ranking it is impossible to consider interrelationships between criteria. The problem can be solved using the network model of ANP. Interrelationships of criteria can be derived from following the DEMATEL method (Hsiao-Chi and Ya-Wen, 2008; Jerry Ho et al., 2011). All three methods are widely used in collaborative decision making. To clearly represent human thinking a semantic fuzzy number can be added to basic AHP, ANP and DEMATEL methods. A manager must apply a structured decision making process preferably based on some MADM frameworks if he is to truly acknowledge his judgment. The network model of decision making, ANP, should always be applied when there is a possibility of interdependency among selected criteria or alternatives. When dealing with multiple alternatives (or variants) pair-wise comparison based methods are falling behind because of the time consuming and complicated process involved with constantly thinking about which alternative is more preferred than the other. This complexity combined with a larger number of criteria could lead to bad decision making due to the weariness of the decision-makers. In this case, certain MADM methods could be less effective because they require too much effort and human input. At this point, the decision-maker has to decide which MADM approach is more suitable when structuring and identifying criteria and alternatives. For problems where the criteria or alternatives can be assessed using representative quantitative metrics, combination of outranking or compromise criteria methods should be applied. The desired methods could be TOPSIS and VIKOR, which use measure of distance towards the basal respectively ideal alternative (Opricovic and Tzeng, 2004) or PROMETHE, ELECTRE and their variations based on outranking (Opricovic and Tzeng, 2007). For estimation of criteria weights the pair-wise or objective weighting methods can be used.

Objective weighting methods (Lotfi and Fallahnejad, 2010) that are being applied in various cases tend to be based on either information science in the form of entropy based on principles of Shannon (1949) or statistics (standard deviation). The difference between these approaches is the perspective with which they look at data. Shannon's entropy is used for estimation of weights in a heterogeneous dataset of measures where the most

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

fluctuating metric gets more priority (Wang and Lee, 2009). Similarly, measure of variance can be used but for homogenous or normalized data.

The aforementioned objective methods are frequently associated subjective approaches in order to combine human perception and experience with hard data. Such combinations can be made by using SAW (Simple Additive Weighting) or the decision maker can select how much emphasis (weight) will be given to subjective or objective priorities.

The final aim is to be able to generalize such methods into a business environment and within the actual organizational structure. This means that collaborative decision-making should be facilitated by using group decision-making approaches to AHP/ANP or DEMATEL (Lee et al., 2013; Tsai et al., 2013) with consistency and consensus measures to check the logic and fragmentation of decisions. It is purely a problem of how the process of such decision-making is implemented within normal business circumstances. The results should be completed with a sensitivity analysis to check if possible changes in opinions or priorities can have certain influence over the final decision. This leads to a question of whether it is more advisable to use specialized software or ordinary suitable computer programs for facilitation, or use group voting and consensus vs. group averages of preferences or weights. Further discussion can also be focused on the use of judgment scales or fuzzy numbers. It should be mentioned that results of the decision making are biased by the methodology and the way the expert opinions are gathered. If the decision-making is based purely on human input it is surely biased, and subjectivity plays a role in the final result. However, decisions are always made under certain conditions and in certain situations, so we must understand this and interpret the results within this framework and understanding. The results will depend on the goal of the decision making, and the numbers and experience of the experts, etc. Saaty (1990) presents a case of a decision making example and notes that a certain number of experts can find the solution that is close to the real world situation. That is the reason why multiple attribute decision-making methods are relevant in practice and should be applied more in business operations.

2.2 Applications of MADM in business domains

Bearing in mind the above section, practical applications of MADM can be found scattered across a wide range of business and management related problems. There are numerous works of scholars that have made inquiries into the scope of MADM applications, especially AHP/ANP and TOPSIS. Furthermore, these works include combinations of AHP/ANHP and TOPSIS and other MADM methods. In general, based on the methodological implications of MADM methods mentioned in the Section 2.1, it can be said that in virtually every problem where a decision is yet to be made some MADM approach can be used. However, the question remains whether it is worth it for the decision-maker to follow a more rigorous process of decision-making or not. In business and management, decisions are often linked with utilization and allocation of resources (time, money, raw materials, human, etc.), and this means that they have a profound effect on the organization or decision-maker himself. So it is only a matter of weighting the costs and benefits of an incorrect decision. Using some kind of structure or methodological approach helps the decision-maker find a solution that is not purely based on intuition or an incomplete thinking process. Given the evidence from various research studies and practical applications, there are serious advantages for the decision-maker when utilizing a MADM method. The business domains concerned with MADM are:

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

personnel management, manufacturing, education, social and political affairs, engineering, industrial processes, logistics, government, banking and finance, sports, commerce, environmental management, project management including R&D.

There are a large number of case studies that were facilitated by scholars or expert users of MADM. The question remains whether MADM methods were adopted by the particular organizations long term or not. From the scholars perspective, MADM methods are relatively easy to apply and do not have any concerns from the methodological perspective. But from the business practitioner's perspective, the right methodological approach to different problems can be quite hard and time consuming. Specialized decision support software often deals with hard data and the human input is restricted. Therefore, it is only the support software that gives the user a ranking or list of suitable alternatives and solutions. The sophistication of the software determines how precise a measure of preference is given toward the best solution. Of course, most of this software is based on linear programming not on multiple criteria decision-making methods. But when the decision-maker (a manager) faces a problem where the hard data are scarce or insufficient the MADM approaches can be helpful. Specialized MADM software can be found and installed even as a package within MS Office. Some scholars point out that when the decision-maker does not understand the methodological background of the software, he can make some procedural mistakes or interpret the results incorrectly. The ideal solution would be to have a person within the organization that is trained in MADM methods applications who can facilitate decision-making processes or facilitate strategically important issues.

Business domain applications vary in their purpose. Based on Vaidya and Kumar (2004), the goals of decision making using AHP/ANP are: selection, evaluation, benefit-cost, allocation, planning and development, priority and ranking estimation, decision making, forecasting, QFD (Quality Function Deployment) and medicine. This leads to further classification of MADM applications into particular business and management tasks with specific combinations of MADM methods. Investigation of particular applications is useful in order to find best practices in MADM application across different management tasks that can be utilized by practitioners as well as scholars. Table 1 summarizes the aforementioned suggestions of MADM applications. The number of criteria characteristic is based on suggestions mentioned in the literature. Table 1includes only selected methods that have been discussed above. The emphasis is on how appropriate each method could be given the number of alternatives

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

Table 1
Summary of applications of selected MADM methods on alternative selection

Alternative selection / *Application perspective*	No. of alternatives	Selection of the best alternative	Evaluation of alternatives	Benefit-cost perspective	Allocation of weights and priorities	Ranking
Decision making	Up to 7	AHP/ANP, DEMATEL, COPRAS-G	AHP/ANP, DEMATEL	AHP/ANP, TOPSIS, VIKOR	AHP/ANP, DEMATEL	All MADM methods
	More than 7	TOPSIS, VIKOR, WSA, ELECTRE, PROMETHE	TOPSIS, VIKOR, WSA, COPRAS-G	TOPSIS, VIKOR	AHP, DEMATEL	
Prediction	Up to 7	AHP/ANP	AHP/ANP	AHP/ANP	AHP/ANP	AHP/ANP,
	More than 7	TOPSIS, VIKOR	TOPSIS, VIKOR	AHP	AHP	TOPSIS, VIKOR
Selection of strategic alternatives	Up to 7	AHP/ANP, DEMATEL	AHP/ANP, DEMATEL	AHP/ANP	AHP/ANP, DEMATEL	AHP/ANP
	More than 7	TOPSIS, VIKOR	TOPSIS, VIKOR	AHP	AHP, DEMATEL	TOPSIS, VIKOR
Alternative development	Up to 7	AHP/ANP, DEMATEL	AHP/ANP, DEMATEL	AHP/ANP	AHP/ANP, DEMATEL	AHP/ANP
	More than 7	TOPSIS, VIKOR	TOPSIS, VIKOR	AHP	AHP, DEMATEL	TOPSIS, VIKOR

3. Application of MADM to specific management tasks

To tackle the problem of MADM application to specific management tasks we must consider two things. First, how should a manager (user) generally approach a problem which he wants to solve using MADM methods? Second, the manager should determine if a suitable best practice exists or even a model application which he can use as a framework. Based on the evidence from applications of MADM the following list of actions can be considered step by step instructions for MADM application in practice. It includes steps that are compatible with pair-wise, compromise criteria function and outranking methods.

The general procedure of MADM application is as follows:

- description of the decision situation, problem definition and explanation of the reason for the decision (goal of the decision) – meaning the weight estimation, priority and ranking estimation, selection, evaluation, allocation, decision making, etc.;
- definition of the objectives of the decision problem – meaning the formulation of a task's goal which will serve as a point of reference in the case of criteria and alternatives identification, questions about preferences and for the final result interpretation;
- specification of the decision-making form - individual, expert or group with possible prioritization of certain individuals within the group;

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

- decomposition of the problem into the following necessary parts: determination of alternatives (e.g, strategy , products , etc.) and definition of criteria and sub-criteria (e.g. factors , attributes, scale);
- outline of the problem structure and graphic design decision problem (hierarchy, network or process diagram);
- quantitative data settings and criteria properties - convert the minimization criteria to maximization, missing data, investigation of the interdependence, multicollinearity, etc.;
- selection of MADM decision making methods (sole method, group of methods or combination i.e. hybrid methods) and appropriate methods of determining the weights (objective and subjective);
- a brief description of the selected methods – so the other decision maker will be aware of their methodological background and conditions of use;
- application of MADM on the decision problem;
- sensitivity analysis – how a change in particular criteria weight can influence the final result;
- appropriate presentation of results - a record in the table (local and global priorities, the calculation of the utility function, ranking of criteria and alternatives) presentation in an appropriate chart or additions to the desired problem structure.

Figure 1 illustrates this list with a diagram of general MADM methods application procedures.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

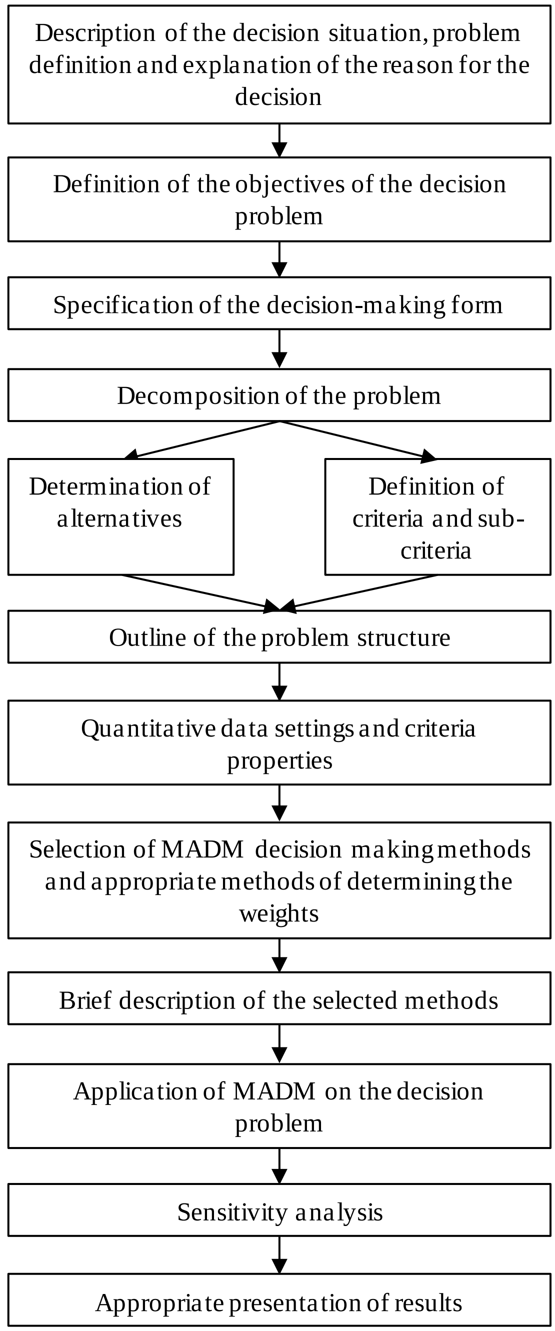

Figure 1. Diagram of general MADM methods application procedure

Considering the scope and variety of managerial tasks the following applications were selected based on their presence in reviewed publications in recent years (2009-2014). Applications of MADM that have been found can be categorized into five main domains:

- allocation of resources and business units,
- partner and supplier selection,
- strategic decision making,

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

- organizational performance assessment,
- human resources management and knowledge management.

Within the aforementioned steps some more modifications have to be made when using particular MADM methods. To begin with, there are a vast number of options for how to estimate subjective and objective weights v_i. In the AHP/ANP, the decision maker can decide upon values s_{ij} of different judgment scales associated with particular verbal expressions, method of weight w_i derivation from the pair-wise comparison matrix (RGMM – Row Geometric Mean Method, eigenvalue, arithmetic mean, quadratic programming, etc.), dependence among criteria (using DEMATEL method), level of desired consistency CR and consensus indicator S^*. DEMATEL method can also be used for calculation of criteria priorities that can be included in ANP. In the DEMATEL method there is an option to reduce or increase the number of interrelations by lowering or raising the limit of a criteria's influences α. WSA, TOPSIS and VIKOR , the methods based on measure of distance from an ideal or basal alternative, have their own options. At first, there is the measure of distance r_{ij} whereas the default Euclidean distance has been used. Furthermore, the decision maker can change its preferences v in the case of VIKOR within its compromise solution Q by increasing or decreasing the weight of each ranking (based on maximum or minimum sum of the whole set of criteria S_j or on maximum and minimum individual criteria values R_j). For example, in the newly developed methods of COPRAS and COPRAS-G (using Grey systems theory) in particular, the decision maker can determine how big the grey intervals should be (Hashemkhani et al., 2012).

3.1 Allocation of resources and business units

When considering the allocation of resources or business units the criteria can frequently be a mix of quantitative and qualitative data. In this case, the decision-maker must carefully select the appropriate combination that reflects both the real measures and expert subjective opinion. However, it is possible to only consider quantitative or qualitative criteria as well. Another option is to structure the criteria as quantitative and qualitative from the beginning with the ability to change the preference of each group based on the decision making conditions. Some scholars admit that quantitative data can be misleading and are often static. On the other hand, the expert's opinion can include even a prediction perspective. Based on findings and evidence from late applications it is better to combine both types of data (criteria).

The analysis of allocation appropriate methods should include subjective estimation of priorities based on the general organization's strategy, objective weighting of alternatives (based on Shannon's entropy or variance) within quantitative criteria (costs, scales of operation, measures concerning demand and supply, distances from the base or to resources, number of staff, etc.) and subjective preferences of predominantly qualitative criteria (stakeholders, environmental impact, organizational demands, business environment, etc.) using AHP/ANP methods in the analysis of allocation (Mu, 2006). It is always hard to distinguish how dependency among criteria plays a role in the decision making, and the application of ANP is more complicated and time consuming. Results are not always much more different if the interdependency concerns only a handful of criteria. It would be best to consider the importance of the task at hand and the scale of the problem, and if the set of criteria is more qualitative in nature then the ANP could be a better option.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

In supply chain optimization of resources, the same aforementioned process applies. However, with regard to manufacturing more quantitative criteria should be used for two reasons. First, the processes are mostly well managed and controlled and thus provide the decision maker with a sufficient number of measures. Second, a manufacturing department is led by hard data oriented experts that put more trust in mathematical optimization than in subjective estimates. However, some criteria can be perceived as qualitative in nature because their quantitative expression can be very complicated and no more efficient (for example, technical state of machines, skill of workers, etc.). In this case of criteria weight estimation, objective approaches can be used together with pair-wise comparison of alternatives according to qualitative criteria. If the number of alternatives is small then AHP/ANP methodology can serve the purpose. If the number of alternatives in both situations is high (see Table 1), then methods that better handle such conditions such as WSA, TOPSIS and VIKOR should be applied instead.

Methodological note on ANP

When using ANP in the aforementioned and later applications the following characteristics should be considered. The relative importance of the element i on the element j is represented by $a_{ij}=w_i/w_j$ in the pair-wise comparison matrix. Following the completion of the matrix A, an estimate of the relative importance of the elements compared is calculated via the equation $Aw=\lambda_{(max)}w$, where $\lambda_{(\max)}$ is the largest eigenvalue of the matrix A w is the desired estimate. This model is described by a supermatrix, Equation 1.

$$W = \begin{matrix} goal \\ criteria \\ sub-criteria \\ alternatives \end{matrix} \begin{bmatrix} W_{11} & \cdots & \cdots & W_{1n} \\ W_{21} & W_{ij} & \cdots & W_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ W_{n1} & W_{n2}\cdots & W_{n(n-1)} & W_{n,n} \end{bmatrix}, i=1,\ldots,n; \quad j=1,\ldots, n., \tag{1}$$

where *Wij* represents all possible and logical pair-wise comparison weights. We can distinguish three main systems of ANP matrices (4 levels hierarchy example): (i) linear AHP/ANP supermatrix, Equation 2; (ii) diagonal ANP with feedback loops on the main diagonal, Equation 3; (iii) cyclical ANP with feedback loops (interdependencies) on the upper part of the supermatrix, Equation 4.

$$W = \begin{matrix} goal \\ criteria \\ sub-criteria \\ alternatives \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & 0 & 0 & 0 \\ 0 & W_{32} & 0 & 0 \\ 0 & W_{42} & W_{43} & I \end{bmatrix}, \tag{2}$$

$$W = \begin{matrix} goal \\ criteria \\ sub-criteria \\ alternatives \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & 0 \\ 0 & W_{32} & W_{33} & 0 \\ 0 & W_{42} & W_{43} & I \end{bmatrix}, \tag{3}$$

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

$$W = \begin{matrix} goal \\ criteria \\ sub-criteria \\ alternatives \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & W_{24} \\ 0 & W_{32} & W_{33} & W_{34} \\ 0 & W_{42} & W_{43} & I \end{bmatrix}. \tag{4}$$

Supermatrices of ANP can be solved using various specialized software, for example SuperDecisions, but it is also practical to use MS Excel to find a solution. The supermatrices (3) and (4) demand more logical thinking and sufficient description of the decision making problem, criteria and alternatives.

3.2 Supplier and business partner's selection

Another important managerial task is the selection of business partners and suppliers and their assessment and performance evaluations. This task and the associated problems are well described in numerous papers and articles. The application of MADM methods is straightforward and often provides an easier and quicker solution to the meticulous process of supplier selection and assessment based on scoring models (e.g. DSCOR). Again, the problems that the decision maker faces are how to assess quantitative and qualitative criteria and how many alternatives (suppliers or business partners) will be considered. Typically in this problem such criteria including experience, financial stability, quality performance, manpower resources, equipment resources, and current workload are considered. In the first step, the critical point is once more the structure of criteria and their priorities. Supplier or business partners are evaluated based on both types of criteria. The nature of the industry, nature of the supply commodity or business exchange decides how much emphasis will be put on qualitative or quantitative criteria. Some supplier performance measures (criteria) can be perceived as variable, thus Grey Systems Theory or fuzzy numbers can be applied in MADM e.g. FAHP/FANP, Fuzzy TOPSIS or COPRAS-G. Another option is to utilize some standard supplier evaluation criteria from scoring models. By using standardized framework combined with methods of WSA, TOPSIS (Behzadian et al., 2012), VIKOR, COPRAS or outranking ELECTRE and PROMETHE, managers can develop their own model of supplier assessment and selection. Such a model is more transparent and methodologically robust. The properties of the aforementioned methods are easy to change making this process reasonably quicker than using the pair-wise comparison methods.

3.3 Strategic decision making

The process of strategic management in business deals with multidimensional problems. These problems stretch across the range of business activities (external factors) and organization (internal factor). The strategic thinker or line manager needs information and a tool which can be used for evaluation of a particular situation or decision making problem. Both external and internal factors have to be considered, but they also exist in the form of qualitative or quantitative information. Multiple attribute decision making methods can be used as tools which can encapsulate both types of factors and both types of information (Tzeng and Huang, 2011). Further, they can prioritize these factors and based on the decision making criteria and chosen methodological approach also select a group of most the favorable alternatives. MADM methods can also serve as a basis for more transparent and traceable decision making. Methods of AHP and ANP can also be considered for group decision making. The ANP model has proven to be more indecisive

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

when the priorities were more equally distributed among alternatives as mentioned in the application on Porter's Five forces analysis, SWOT analysis or performance evaluation. In both cases, the authors have considered and compared results of AHP and ANP approaches. The DEMATEL method is well suited for strategic decision making. It can help to investigate interdependencies for a further ANP approach, and it can also draw an impact-relationship map that reveals which criteria are influencing others and which should be influenced in order to use resources and efforts more efficiently.

Strategic analysis and strategy selection using Porters's Five forces model
In the case of the strategic analysis of the competitive position using the well-known Porter's model of Five, competitive forces have shown how this task could be tackled with a MADM approach. It is not necessary to investigate complicated approaches; the focus should be on those that can be adapted to any business environment and case such as the well-known Porter's Five Forces Analysis (Porter, 1980; 1985). The application of this analysis leads to strategic decision making where three main strategies can be differentiated: cost leadership, differentiation and focus. Recently, there have been numerous applications of such strategic analyses combined with decision making methods in Poveda-Bautista et al.(2011), Saaty and Vargas (2006), Gholami and Seyyed-Esfahani (2012), Görener (2012) with practical results. Some of these cases were also combined with the use of specialized software for AHP/ANP decision making. The decision-making criteria were identified as particular forces and were used for actual analysis. The Five forces analysis has identified 14 criteria (c_1, ..., c_{14}) and three generic strategies (ST_1 - cost leadership, ST_2 - differentiation, ST_3 - focus). The goal of the following AHP method is strategic decision making between proposed strategies. The problem structure is illustrated in Figure 2. All criteria were pair-wise compared and weights have been calculated. In this case, the qualitative approach was chosen to reflect expert opinions of the management board. Decision making criteria according to the Five forces model were:

- Competitors: market share (c_1), product range(c_2), distribution channels (c_3);
- Customers: relationship with current customers (c_4), customer sensitivity on changes and quality of products and services (c_5), potential of new customers (c_6);
- Substitutes: quality of substitutes (c_7), availability of substitutes (c_8), upcoming substitutes (c_9);
- Threat of new entrants: estimated costs of entrance to the market (c_9), other barriers to the entrance (c_{10});
- Suppliers: costs of raw materials (c_{11}), currency risk (c_{12}), reliability of suppliers (c_{13}).

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

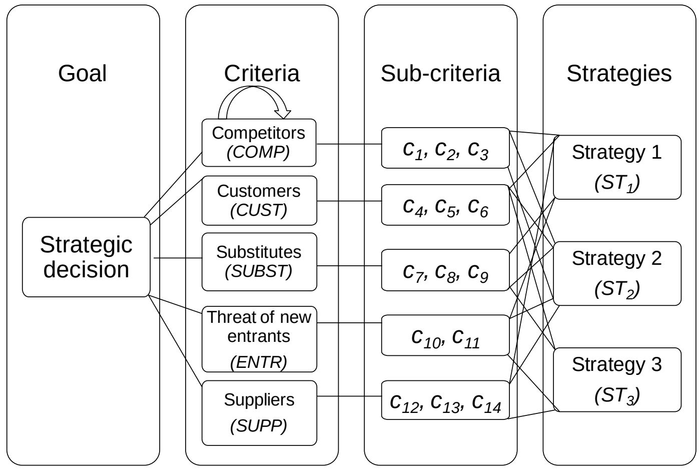

Figure 2. Structure of AHP/ANP model of Porter's Five forces analysis with strategic selection

The result of this approach gives the decision maker (manager) a rank and utility of each alternative and importance ranking of all of the criteria. Performing a sensitivity analysis should reveal how much the criteria weights should be changed in order to influence the ranking of alternative strategies.

Strategic analysis and strategy selection using SWOT model

The problem of AHP/ANP implementation for managerial decision making can be summarized in the following studies of strategic decision-making utilizing ANP techniques and SWOT analysis in particular (internal factors - Strengths, Weaknesses; external factors – Opportunities and Threats). A similar approach has been studied by Zmeskal & Franek (2013) with relation to a company's financial level. Yuksel's study (2007) demonstrated that a process for quantitative SWOT analysis can be performed when there are interdependencies among strategic factors. The proposed model uses the Analytic Network Process (ANP), which allows measurement of the dependency among the strategic factors, as well as AHP, which is based on the independence between the factors. Dependency among the SWOT factors has been shown to influence the criteria and sub-criteria as well as change the strategy priorities. Although the AHP technique removes the deficiencies inherent in the measurement and evaluation steps of the SWOT analysis, it does not measure the possible dependencies among factors. The AHP method assumes that the factors presented in the hierarchical structure are independent; however, this is not always a reasonable presumption. In this study, the interdependency within SWOT factors suggests that opportunities are affected only by the Strengths, no pair-wise comparison matrix is formed for opportunities. Poveda-Bautista et al. (2011) give further applications of the ANP approach in strategic thinking which assesses a companies' competitiveness performance by means of indicators based on the Balanced Scorecard structure. The approach combines the use of the Analytic Network Process (ANP) method with the Balance Scorecard and the information obtained from experts during the decision making process. Sevkli et al. (2012) aimed to provide a quantitative basis to analytically determine the ranking of the factors in SWOT analysis via the Analytic Network Process (ANP) also utilizing the fuzzy sets theory. The proposed SWOT Fuzzy ANP methodology was implemented and tested. The results showed that the SWOT Fuzzy ANP is a viable and highly capable methodology that provided insights for

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

strategic management decisions. The results have shown that a basic ANP approach ranking was similar to Fuzzy AHP and Fuzzy ANP approaches. More application examples and practices can be found in the works of Saaty and Vargas (2006). It shows the versatility of the ANP approach to various strategic decision making tools.

The hierarchy model presented in Figure 3 has four levels including the goal, two main criteria groups of internal and external analysis, SWOT criteria, SWOT sub-criteria and alternatives. The first level of the hierarchy is the goal of the evaluation (selection of the best alternative, rank of alternatives, etc.). The second level of the hierarchy represents the evaluation criteria (the goal of the evaluation depends on which evaluation criteria will be used). The third level of the hierarchy consists of evaluation sub-criteria. The fourth level consists of strategic alternatives.

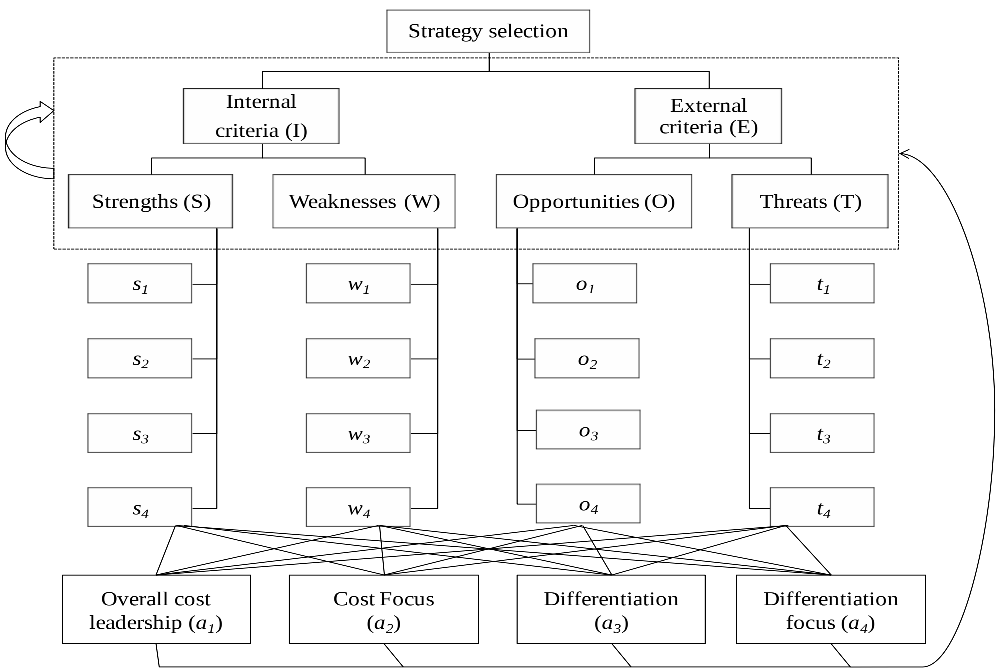

Figure 3. SWOT-ANP model

Then the SWOT-ANP super matrix based on Equation 4, the supermatrix with upper triangle interdependencies (loop), can be drawn as follows, Equation 5:

$$W = \begin{array}{r} goal \\ internal\ /\ external\ criteria \\ SWOT\ sub-criteria \\ SWOT\ sub-sub-criteria \\ Alternative\ strategies \end{array} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ W_{21} & I & 0 & 0 & W_{25} \\ 0 & W_{32} & W_{33} & 0 & W_{35} \\ 0 & 0 & W_{43} & I & 0 \\ 0 & W_{52} & 0 & W_{54} & I \end{bmatrix}. \quad (5)$$

Criteria of the problem are set up in a five level hierarchical form with relevant criteria described in Table 3. These criteria are pair-wise compared and their estimated weights are pasted into the supermatrix (Equation 5). Then the unweighted SWOT-ANP supermatrix is assembled, and the pair-wise comparisons performed between the criteria

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

and alternatives. The loop (interdependency) can be seen between the criteria and sub-criteria (internal and external criteria, SWOT criteria), and between the SWOT criteria and internal and external interdependencies among the alternatives strategies. The results of SWOT-ANP model, as in the Porter's Five forces analysis example, provide the decision maker with a network structure of priorities among criteria and a rank of strategic alternatives evaluated in this case according to interdependencies among them. The ANP approach in SWOT can be considered an important step forward in strategic analysis. Strategic decision making does not have to be based on the presented models, but it often follows a similar approach to identification of strategic alternatives and evaluation criteria.

3.4 Organizational performance assessment

The purpose of MADM utilization in performance assessment (evaluation) is based on similar advantages that MADM gives to strategic decision making. The goal is to find the most important criteria for evaluation and then compare two or more subjects (organizational unit, manufacturing assembly, industries, etc.) according to the criteria and associated preferences. Evaluation, as well as the aforementioned applications, uses a blend of qualitative and quantitative criteria. Thus, it is important that the decision maker thoroughly investigates each of the criteria properties and chooses whether it would be better to follow a qualitative assessment of such criteria using pair-wise comparisons or to gather relevant data for objective weight (priority) estimation. A combination of both types of approaches (subjective and objective) can be considered when dealing with an evaluation that is performed infrequently and when the top management is involved. Expert opinions based on experience can be a vital addition to the pure quantitative evaluation that is normally performed. The following examples of the Balanced scorecard (BSC), plant performance scorecard and benchmarking represent applications of combined MADM approaches to managerial performance evaluations.

Application of MADM in Balanced Scorecard

The balance scorecard (BSC) represents a set of measures that give the company owners, managers, shareholders and also the company's employees a fast, comprehensive and understandable view of the business. According to Kaplan and Norton (1992), BSC includes financial measures as well as non-financial measures such as operational measures, i.e. customer satisfaction, internal processes, and the organization's innovation and improvement activities. The BSC aims to represent the company's long-term strategy in meaningful and actionable performance measures. The BSC is divided into four perspectives including: the financial perspective (measurement can be e.g. cash flow, ROI); the customer perspective (measurement can be e.g. on-time delivery, sales etc.); the internal business perspective (measures can be e.g. lead time; yield etc.); and the innovation and learning perspective (measures can be e.g. succession planning, % of employee trained etc.).

Both the hierarchical AHP and the network ANP methods are combined when a firm's evaluation uses BSC or in the implementation of BSC measures within an organization (Reisinger et al., 2003). In this study, the authors use the AHP for allocation of weights when implementing the BSC. The whole structure follows BSC measures and has 4 levels. This application shows the advantages of such an approach. The AHP/ANP methodological fundamentals help to achieve more accurate allocation of priorities among large numbers of different measures. On the other hand, the time-consuming

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

nature of the design and execution of the whole process means that it could not be effectively applied on a regular basis. Another type of application which has been investigated is strategy selection based on the BSC model using the AHP/ANP decision making methodology. This is a straightforward process that utilizes BSC measures and dimensions as decision making criteria and business strategic alternatives. In Varma et al. (2008), the authors used the AHP for weight allocation and then evaluated the pre-developed strategic alternatives. The result was allocation of priorities among strategies as support information for the decision maker. In this case, the more thorough decision making process enabled by the AHP allows for a more objective picture of the decision maker's priorities.

In general the whole BSC-AHP/ANP model consists of up to 7 steps (Saaty, 2006):

- mission and goal setting;
- identification of major strategic alternatives;
- definition of score cards according to 4 dimensions (BSC perspectives);
- identification of relevant measures in tactical, operative and long-term perspective;
- design of AHP/ANP structure with weight estimation and allocation among measures;
- application of AHP/ANP on identification of priorities among strategic alternatives;
- development of strategy maps with regard to results.

Regular use of this method could be recommended, however, it will always take time to convince managers of the merits of the methodology. Altogether, the BSC and AHP/ANP share some characteristics that can be beneficial for further development of their combination in managerial use such as: a multidimensional approach, relatively small number of measures, optimization approach, network model, strategy selection and cohesion, objective decision making, group decision making, transparency.

Plant performance scorecard
To show that the AHP/ANP method can help determine the most important measures pertaining to the performance evaluation one particular manufacturing company was chosen for the illustration. The research was performed in a middle size, manufacturing company doing business in the automotive industry. A panel of selected experts (director, HR manager, financial manager, quality manager and production manager) was chosen to evaluate the current company's measures of production performance based on BSC. These measures are run on monthly targets. For our illustration we have used a list of measures, which were divided into five categories/groups as shown in Table 2.

Table 2
Criteria and sub-criteria of AHP/ANP Performance Scorecard

Criteria (groups of measures)	Safety	Quality	Delivery	Cost	HR
Sub-criteria (measures)	Recordable incidents	Parts per million (PPR)	Just-in-time	Productivity	Training

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

Non-recordable incidents	Complaints	Inventory	Lean manufacturing	Absenteeism
Audit	Cost of quality	Premium Freight	Kaizen	Employee Turnover
	First Time Yield (FTY)		Overtime	Employees innovation
	Rolled Throughput		Equipment availability	

Each group was then divided into several (3 to 5) sub criteria. A proposal of the Performance Scorecard decomposition model of the measures' groups for the utilization of AHP/ANP is shown in Figure 4. The model has three levels: the goal (performance score), criteria and sub criteria. For the ANP approach, the sub-criteria should be put together in clusters that will be subject to pair-wise comparisons with a feedback loop (oriented arrows). These feedback loops form a network of interdependent criteria. This network is important for the final allocation of priorities. In comparison to the simple hierarchical AHP, this method requires more thinking and logical explanation of particular feedback loops. The time that is needed to execute and evaluate creates a disadvantage for the use of this method. However, a decision about the performance scorecard and the importance of its measures should not be made without considering the network nature of the different criteria (measures). The manager/expert must think about all possible factors' relations, and thus it can be said that the decision making is more rigorous. Also, it has to be mentioned that this process could be and should be done in a group using consensus or average aggregation of preferences.

The evaluation of the criteria and sub-criteria was performed by a panel of experts. They were interviewed in a group and were asked to reach a consensus about which criteria (measure) they preferred, and to fill in pair-wise comparison tables using these criteria.

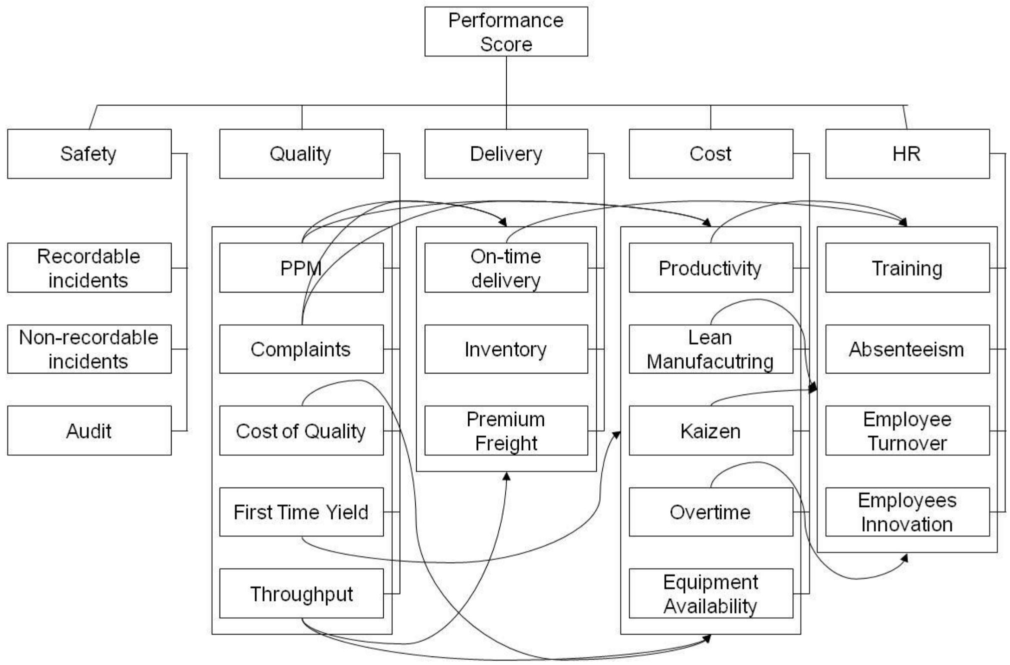

Figure 4. Performance Scoreboard AHP/ANP model

4. Conclusion

The strategic thinker or line manager needs information, and must also have the tools for evaluation of a particular situation or a decision making problem. Both external and internal factors must be considered, even though they exist in the form of qualitative or quantitative information. MADM methods can be used as tools which can cope with these factors. Furthermore, they can prioritize these factors and based on the decision making criteria and chosen MADM method also select a group of the most favorable alternatives. One of the most prominent features of MADM methodology is its ability to evaluate quantitative as well as qualitative criteria and alternatives on the same preference scale. These can be numerical, verbal or graphical. The use of verbal responses is intuitive, and it may also allow some ambiguity in non-trivial comparisons. Due to its pair-wise comparisons, AHP/ANP and DEMATEL need ratio scales. There are some disputes about scale as the best option of judgment expression, but most scholars still prefer this approach. Also, the concept of AHP/ANP pair-wise comparisons is inseparable from consistency checking. Often the evaluators are not familiar with AHP, and they will need to understand how the inconsistency translates into their decision making process. There might be some comparisons that are not just inconsistent, but actually contradictory. In most cases, these are errors that have to be fixed, but are very hard to find without a full understanding of the method. MADM methods can also serve as a basis for more transparent and traceable decision making. The fundamental advantages of multi-criteria decision making methods can be found in the decision maker's ability to evaluate each alternative using a large number of criteria. These methods compel the decision maker to express explicitly (not intuitively) their understanding of the importance of each criteria. Thus, the whole process of evaluation of alternatives becomes more transparent, and clear for other parties that are more or less engaged in the decision making process.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

REFERENCES

Behzadian, M., Otaghsara S.K., Morteza Y., Ignatius, J. (2012). A state-of the-art survey of TOPSIS applications. *Expert Systems with Applications*, *39(17),* 13051-13069.

Fontela, E., & Gabus, A. (1976). *The DEMATEL observer*. Battelle Institute, Geneva Research Center.

Gholami, M.H. & Seyyed-Esfahani, M. (2012). An integrated framework for competitive market strategy selection by using Fuzzy AHP. *Tehnicki vjesnik / Technical Gazette*, *19(4),* 769-780.

Görener, A. (2012). Comparing AHP and ANP: An application of strategic decisions making in a manufacturing company. *International Journal of Business & Social Science, 3(11),* 194-208.

Hashemkhani Z.S., Rezaeiniya, N., Aghdaie, M., & Zavadskas, E. (2012). Quality control manager selection based on AHP-COPRAS-G methods: A case in Iran. *Ekonomska Istrazivanja/Economic Research*, *25(1),* 88-104.

Henig, M. I., & Buchanan, J. T. (1996). Response to comments. *Journal Of Multi-Criteria Decision Analysis*, *5(1),* 19-21.

Hsiao-Chi, C., & Ya-Wen, Y. (2008). Using a strategic approach to analysis the location selection for high-tech firms in Taiwan. *Management Research News*, *31(4),* 228-244.

Hwang, C.L. & Yoon, K. (1981). Multiple attribute decision making. In: *Lecture Notes in Economics and Mathematical Systems,* 186. Berlin: Springer-Verlag.

Ishizaka, A. & Labib, A. (2011). Review of the main developments in the analytic hierarchy process. *Expert Systems with Applications*. *38(11)*, 14336-14345.

Jerry Ho, W., Tsai, C., Tzeng, G., & Fang, S. (2011). Combined DEMATEL technique with a novel MCDM model for exploring portfolio selection based on CAPM. *Expert Systems With Applications*, *38(1),* 16-25.

Keeney R.L. & Raiffa H. (1976). *Decisions with multiple objectives*. New York: John Wiley.

Lee, H., Tzeng, G., Yeih, W., Wang, Y., & Yang, S. (2013). Revised DEMATEL: resolving the infeasibility of DEMATEL. *Applied Mathematical Modelling*, *37(10/11),* 6746-6757.

Lotfi, F., & Fallahnejad, R. (2010). Imprecise Shannon's entropy and multi attribute decision making. *Entropy*, *12(1),* 53-62.

Mu, E. (2006). A unified framework for site selection and business forecasting using ANP. *Journal of Systems Science and Systems Engineering*, *15(2)*, 178–188.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

Opricovic, S. & Tzeng, G-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS, *European Journal of Operational Research*, *156(2),* 445-455.

Opricovic, S. & Tzeng, G-H. (2007). Extended VIKOR method in comparison with outranking methods, *European Journal of Operational Research, 178(2),* 514-529.

Opricovic, S. (1998). *Multicriteria optimization of civil engineering systems.* Belgrade: Faculty of Civil Engineering.

Pan, F.C. (2006). Escalate BSC power by AHP: Innovative approach for strategy implementation. *International Journal of Management and Decision Making*. *7(2-3),* 337-351.

Porter, M., E. (1980). *Competitive strategy: Techniques for analyzing industries and competitors*. New York: Free Press.

Porter, M., E. (1985). *Competitive sdvantage: Creating and sustaining superior performance.* New York: Free Press.

Poveda-Bautista, R., Babtista, D.C. & Garcia-Melon, M. (2011). ANP approach for competitiveness analysis in business sectors: The case of Venezuela. *Proceedings of the International Symposium on the Analytic Hierarchy Process*.

Saaty, T.L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, *15(3),* 234-281.

Saaty, T. L. (1986). Axiomatic foundation of the Analytic Hierarchy Process. *Management Science*, *32(7),* 841-855.

Saaty, T. L. (1994). Highlights and critical points in the theory and application of the Analytic Hierarchy Process. *European Journal Of Operational Research*, *74(3),* 426-447.

Saaty, T.L. (1996). *Decision making with dependence and feedback: The Analytic Network Process*. Pittsburgh, PA: RWS Publications.

Saaty, T.L. &Vargas, L.G. (2006). *Decision making with the Analytic Network Process economic, political, social And technological applications with benefits, opportunities, costs and risks*. Pittsburgh, PA: Springer.

Saaty, T.L., & Peniwati, K. (2007). *Group decision-making: Drawing out and reconciling differences*. Pittsburgh, PA: RWS Publications.

Saaty, T.L., & Shang, J.S. (2007). Group decision-making: Head-count versus intensity of preference. *Socio-Economic Planning Sciences*, *41*, 22–37.

Tsai, W., Yang, C., Leu, J., Lee, Y., & Yang, C. (2013). An integrated group decision making support model for corporate financing decisions. *Group Decision & Negotiation, 22(6),* 1103-1127.

Tzeng, G.H. & Huang, J.J. (2011). Multiple attribute decision making: methods and applications. Boca Raton, FL: CRC Press.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal Of Operational Research*, *169(1),* 1-29.

Varma, S., Wadhwa, S. and Deshmukh, S.G. (2008). Evaluating petroleum supply chain performance: Application of Analytical Hierarchy Process to Balanced Scorecard. *Asia Pacific Journal of Marketing and Logistics*, *20(3),* 343-356.

Wang, T., & Lee, H. (2009). Developing a fuzzy TOPSIS approach based on subjective weights and objective weights. *Expert Systems With Applications*, *36(5),* 8980-8985.

Yang, J. B., Dale, B. G., & Siow, C. R. (2001). Self-assessment of excellence: an application of the evidential reasoning approach. *International Journal Of Production Research*, *39(16),* 3789-3812.

Yuksel, I.Dagˇdeviren, M. (2007). Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile firm. *Information Sciences, 177*, 3364–3382.

Zmeskal, Z. & Franek, J. (2013). A model of strategic decision making using decomposition SWOT-ANP method. *Financial Management of Firms and Financial Institutions 9th International Scientific Conference Proceedings (Part I-III),* 172-180.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v6i2.254