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METHODS OF DETERMINING THE PREFERENCE FOR PURPOSES OF THE CONSTRUCTION OF THE COMPUTERISED DECISION SUPPORT SYSTEM

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Abstract: The article presents the functionality of preference modelling for purposes of the multi-methodical, multi-criteria decision analysis implemented in the computerised decision support system. Research results can be considered through the prism of preference: authoritatively determined by the decision maker or democratically by the group of beneficiaries and from the perspective of scientific views of the council of experts. Preferences in the system can be determined using several different methods.

Keywords: analysis and preference determination methods, decision support system

INTRODUCTION

The term of preference is a concept found in economics (microeconomics) and is associated with the theory of consumer's choice. Consumer's preferences reflect his taste and depend on approval, satisfaction, habits. The buyer submits such combinations of goods, which maximise its utility, that is satisfaction derived from their consumption. The concept of preference is very often confused or equated with the concept of relation. Preference means the man's attitudes and is the feature of the real world, the feature of people. This term can be formally defined as a kind of relation [Ostasiewicz 2003]. In formal terms, preferences are understood as the pre-order (reverse and transitive binary relation) or the linear order (return, transitive and consistent binary relation) determined in the area of profiles of goods and services (basket of goods). The preference relation enables the assignment of the individual preferences scale to the consumer, on which the profiles of products can be valued and the choices can be optimised [Bąk 2004].

In the article, the term of preference is considered in the context of quantifying utility, which cannot be directly measured. Preferences specified in terms of the choice options allow the defining of the utility function, which in turn allows you to connect every option with the specified number characteristic [Bąk 2004]. The utility theories belong to the area of interest of microeconomics, while the preference testing methods are the research tool of micro-econometrics [Pełka, Rybicka 2012]. Preferences are the expression of the principles of the decision-maker's rationality. Their incidence means that in the set of all possible pairs made of the decision variants there was distinguished a subset, which constitutes the relation. While the utility is a concept, which allows to assign decisions with some contractual values, constituting their merged assessment due to preferences of the decision-maker. Assigning utility to decisions allows to bring the decision problem to the automatic choice of decisions of the highest value (utility) [Shapiro 1993].

The aim of the article is to present functionality of the computerised decision support system within the preference modelling for purposes of the multi-methodical, multi-criteria decision analysis. The research procedure in the system involves the selection (optimization of MLP – multi-criteria linear programming), ranking (AHP – Analytic Hierarchy Process) and grouping (Electre Tri) of decision variants (called the objects of analysis). Objects can be examined from the point of view of preference of the given person or group (coalition), that represents the specific side in the decision-making proceedings: decision-makers, beneficiaries, experts. Wherein it is assumed that preferences can be determined using several different methods.

ANALYSIS OF PREFERENCES AND METHODS OF THEIR MEASUREMENT

The preference analysis is the research approach, which involves the qualification of objects in the particular scale, what results in the hierarchy of objects' importance. The analysis provides the adequate measurement and objectification, and its aim is the multi-criterion evaluation focused primarily on comparative studies and on the selection of one from the set of alternative solutions.
The basic methods used within the preference analysis include the method of:

- *ranking,* which consists of determining the importance of a specific object in the given set, due to preferences and is used for their arrangement for purposes of the comparative and diagnostic studies;
- *scoring* consisting of the evaluation of objects using points (in any scale of real numbers); studies with this method include the evaluation:

- comparative, which means the qualification of importance of particular objects (systems, parameters, assessment criteria, etc.) based on relations between them;
- testing (diagnostic) which is the test of a degree of respecting the determined requirements by the given system;
- variation of direction towards the rational choice (optimal) solution [Stabryła 2002].

One should also mention the methods of the identification and diagnostic nature, which include, among others: surveys, interviews and checklists. These preferences of the preference analysis can be used in connection with other research methods.

The preference measurement is made on the basis of determined declarations expressed on the respective measurement scales or they are revealed through observations of the real market choices. One of the proposals of division of the preference measurement methods is their classification, resulting from the data theories, based on two criteria:

- *nature of relations between them* – data can be similar (closeness) or dominant (preference) in nature,
- *number of comparison of the object type* – comparisons are made in the area of one set or two sets.

As a result of different combinations of the presented division, one can obtain the following types of data:

- a single stimulus,
- preferential choice,
- comparison of stimuli,
- similarities between stimuli [Sagan 2009].

In practical studies, especially the marketing ones, the preference analysis used the historical observations and data describing intensions of consumers. We can distinguish the methods of preference measurement:

- disclosed, these are the analysis methods of historical data, which reflect the real market decisions of consumers – the source of data are the information about the past market choices of consumers from the direct or indirect polls,
- expressed regarding the suspected market behaviours of consumers – data reflect the intentions of consumers during measurement and are collected using the direct or indirect polls; there are used the methods representing the approach: composite (assessment methods of levels and attributes), decomposed (traditional methods of the conjoint analysis, methods based on choices) or mixed (hybrid methods of the conjoint analysis, the adaptive method of the conjoint analysis) [Bąk 2004].

The selection of a method is influenced by the researcher's decisions concerning the aim, subject and scope of the study, costs and technical capabilities.

For many years, the relation of the individual preference is the subject of interest of social sciences. Especially the issues for a better understanding of the decision-making problem. That is, the decision support, in which an important role is played by the analyst supporting the decision-maker in formulating decision variants, constructing criteria for variant assessment and the form selection of the assessment aggregation performed towards individual criteria. There is emphasised the multi-criteria nature of the decision process, and decisions usually lead to meeting the whole set of the decision-maker's needs [Nowak 2004].

In methods of multi-criteria analysis, information reflecting preferences of particular participants found in the decision support process are provided prior to the start of the calculation procedure. This is done by an analyst, who is a bystander, responsible for the whole decision-making process and communication with the decision-maker or the decision-maker himself, who can be an individual or a collective body (a group of people), and sometimes create a group of interests. Such a structure has an impact on the way of determining the preference. In case the decision-maker participates directly (or via the analyst) in the decision support process, he determines his preferences directly. While the group approach requires conducting of, for example, the direct questionnaire during the specially organised meetings [Thiel 2009]. According to the theory of making group decisions, such a choice takes place when it is performed by more than one person. While in the group thinking, striving to maintain the integrity of the group is more important than the facts. A good method of the group choice should have the following properties: limitless field, rationality of the group preference, Pareto optimality, independence of the irrelevant alternatives, no dictator [Sosnowska 1999].

The decision-maker making decisions may have to deal with a large number of decision-making variants, assessed by many criteria. The intuitive approach in the choice situation may lead to false conclusions. Therefore, it is important to use the appropriate procedure, which will enable the avoidance of decision errors. Among the decision support methods one can distinguish the multi-attribute technique (multi-criteria) of the decision assessment (MADA – *multi-attribute decision analysis*, MCDA – *multi-criteria decision analysis*). In literature there are many methods, which could be used for solving the decision-making problems. However, the mere choice of the appropriate procedure is a multi-criteria issue, because there should be considered many aspects, which include both the nature of the decision-making issue under consideration, possibilities of the tool used, its perception, flexibility and ease of use. There are methods of proven, universal character [Dytczak et al. 2010]. Such procedures include the method of multi-criteria decision-making AHP (*Analytic Hierarchy Process*), which is used for ranking the decision-making variants and indirectly to support their choice. It was developed by the American mathematician Prof. T. L. Saaty, whose works on the algorithm construction were started in the 70s [Saaty 1977, 1980]. The approach proposed by Saaty combines the elements of mathematics and psychology. It is used to solve decision-making problems, especially in situations, when criteria have the qualitative nature, and assessments are subjective and result from knowledge and experience o the analyst.

From the theoretical side, the problem of merging individual preferences is also contemplated on the basis of the utility theory. Inside it are formed some conditions, which should be met by the utility function describing the preferences of the whole group. Depending on the arrangement of these conditions, one can obtain a specific form of utility for the group. This function allows to obtain the problem solution and allows to formulate the analytical way of finding the final decision, just like the selection of the voting method allows to achieve the final decision based on the results of the vote [Shapiro 1993].

The approach towards assessment aggregation of the considered attributes, provided by experts, depends mainly in the way of allocating their assessments. We can distinguish two grasps of the work organisation of the team of experts:

- cooperation in assessing relations between the attributes of the group in question; assessments provided by individual experts are averaged, usually by the geometric mean;
- approach based on the autonomy of the individual experts in making of the assessments; in this grasp the rankings are aggregated, obtained from the separately operating experts [Dytczak et al. 2010].

Among the methods used to determine the preferences there can be observed, among others, the following suggestions:

- methods using the optimisation tools, based on the mathematical programming technique (linear programming),
- procedure for combining the opinions of the group of experts into focus, using the cosinus distance measure between the preference vectors, obtained by individual experts,
- aggregation of individual preference structures, (AIPS),
- the use of the Bayesian estimation procedure, which becomes particularly useful in case of issues with a great number of experts,
- using the theory of games by applying the criteria of minimal regret in searching for the agreement between experts [Dytczak et al. 2010].

MODELLING PREFERENCES IN THE COMPUTERISED DECISION SUPPORT SYSTEM

The topic of the discussion is the functionality of preference modelling in the computerised decision support system – DSS (version DSS 2.0 – authors Budziński R., Becker J., 2008-2014). It is a hybrid solution, which with the help of engineering techniques of the computerised data processing combines and provides the algorithms of different decision support methods in a simple and usable form. Integration of methods in the computer system is not accidental. The multi-criteria decision analysis covers the issues of choice, arrangement and grouping of objects (decision variants) from the point of view of the determined set of criteria and preferences and with the possibility of taking into account the set of restrictive conditions.

The information and decision process was divided into:

- *decision optimisation* based on the multi-criteria linear programming (MLP) with the utility function and including the choice of the strongest preferred objects, which on one hand is considered from the point of view of the disposer of resources, and on the other, supports the beneficiaries competing for these resources (e.g. tasks of allocating the EU funds or reverse auctions),
- *analysis*, which uses two approaches connected with the achievements of schools: American (AHP) and European (ELECTRE); this is about the preference analysis, rankings and grouping of objects (e.g. formulating the clients' profiles for purposes of the marketing analysis),
- *identification* in terms of quantitative methods of the econometric analysis and methods based on linguistic data (RST – rough set theory).

Integration of methods in the decision support system comes down to using their functionality on a common set of input data determined within the considered decision problem. The foundation of the method integration in the computer system is the acceptance of the coherent and flexible structure based on the notation of the MLP information method [Becker 2010]. It allows to define any model information structure (the so-called mathematical model template) for the decision task. In the template construction into account are taken the decision-maker's requirements determining the substantive scope of the object analysis (decision variants: W_1, W_2, …, W_n). They are expressed by: decision variables, restrictive conditions, one- or two-level structure of the assessment and preference criteria.

Based on the mathematical model template, into the system there is introduced the set of homogenous objects. Every decision variant is a record (row) in the table of the relational database and at the same time an autonomous, partial mathematical model, otherwise formalised form of the linear programming task, which has the solution (is not a contrary system). Technical and economic parameters in the partial model of each variant can be expressed in the form of numerical values and linguistic assessments determined by one expert of their team.

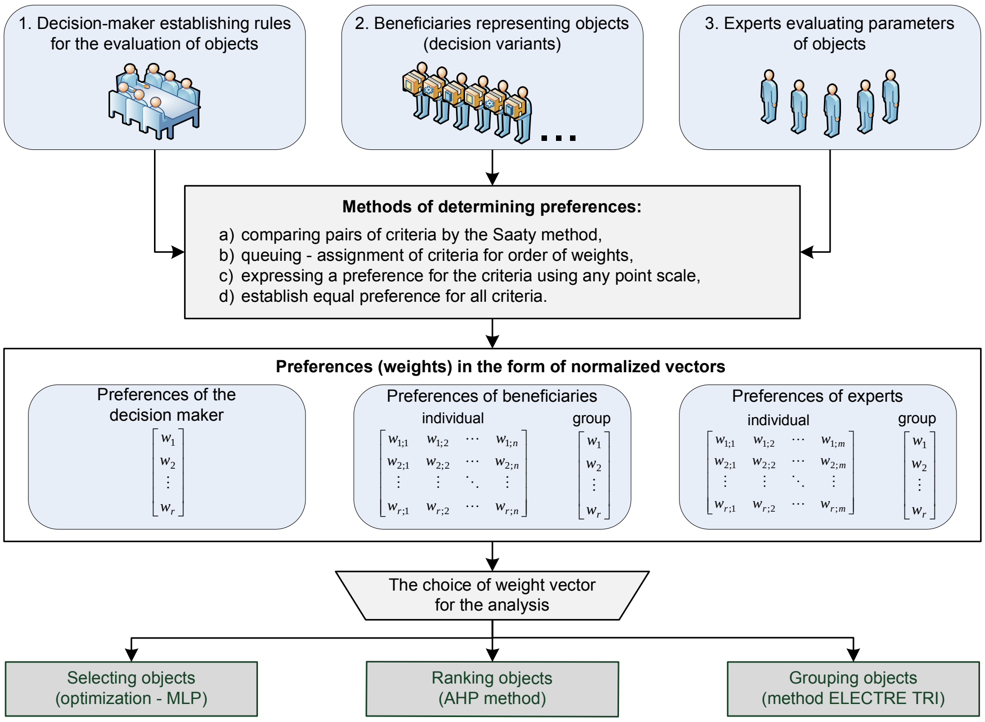
An essential part of the input data, common to the methods used in the system: MLP, AHP and ELECTRE TRI, includes:

- *value vectors of major criteria* $\mathbf{d}_t = \{d_{1;t}, d_{2;t}, \ldots, d_{r;t}\}$, which are declared with the partial models for the objects W_t ($t = 1, 2, \ldots, n$),
- *preference vector* (weight) $\mathbf{w} = \{w_1, w_2, \ldots, w_r\}$ mandatory for all analysed objects W_t , where $\sum_{k=1}^{r} w_k = 1$.

In the construction of the system there is predicted the possibility to generate results of the object analysis from the point of view of preferences of different participants, representing one of three parties in the decision process (fig. 1), we can distinguish here:

1) *decision-maker* fulfilling the superior function in the whole process, in most of the decision problems it appears in the role of the distributor of resources, for which the applicant beneficiaries apply for (then, the request is the object of analysis),
2) *objects of the analysis*, which are subordinated to the rules of the decision game and compete to obtain the highest score (subordinate function); the compared objects must constitute a category, which may include: people, organisations, proposals, service or product offers, plan variants, etc.,
3) *experts* (or respondents), who meet the measurement function (advisory, providing opinion), for an evaluation of parameters of each object.

Figure 1. Preferences in the decision support system



Source: own study

In the context of many users, an important issue is to provide them with ergonomic tool to express own preferences, which at the output generates weight factors in the form of a normalised eigenvector. In the DSS system, this function is performed by the special program (fig. 2), which enables the determination of preferences for main criteria and for non-obligatory level of sub-criteria.

The main and yet the substantively advanced function of determining preferences in the system is fulfilled by the popular Saaty method (used in the AHP method), which supports the articulation of decision-maker's preferences and validation of consistency of the expressed judgements, and their usage in the assessment aggregation process. The essence of this method is the presentation of results of comparison of assessment criteria in the form of square matrices, and calculations are based on the vector processing and non-linear algebra in terms of:

- *one user*, where by the pair comparison the relations between them are determined linguistically using the Saaty scale [Saaty 1980],
- *group of users*, who make the assessment as if they were the single users, and determination of the group preference takes place using the geometric mean.

The procedure of determining the normalised vector with the Saaty method takes place in four stages [Trzaskalik 2006]:

- summing up the assessment α_{ij} in each column of the comparison matrix $\mathbf{A} = [\propto_{ij}]_{i,j=1,\dots,r}$ according to the provision:
$$\sigma_j = \sum_{i=1}^{r} \alpha_{ij} \,, \tag{1}$$
where: α_{ij} − a number from the Saaty assessment scale, which is the result of pair comparison of r criteria (group notes are the values of the geometric mean from individual assessments),
- construction of the normalised matrix $\mathbf{B} = [\beta_{ij}]_{ij=1,\dots,r}$ − where:
$$\beta_{ij} = \frac{\alpha_{ij}}{\sigma_j} \,; \tag{2}$$
- calculation of the approximate scale vector $\mathbf{w}$ according to the formula:
$$w_i = \frac{1}{r} \sum_{j=1}^{r} \beta_{ij} \,; \tag{3}$$
- determination of the approximate eigenvalue of the matrix **A**:
$$\lambda_{\max} = \frac{1}{r} \sum_{i=1}^{r} \frac{(\mathbf{Aw})_i}{w_i} \,, \tag{4}$$
where $(\mathbf{Aw})_i$ means the i-th element of the vector formed as a result of multiplying the matrix **A** by vector **w**.

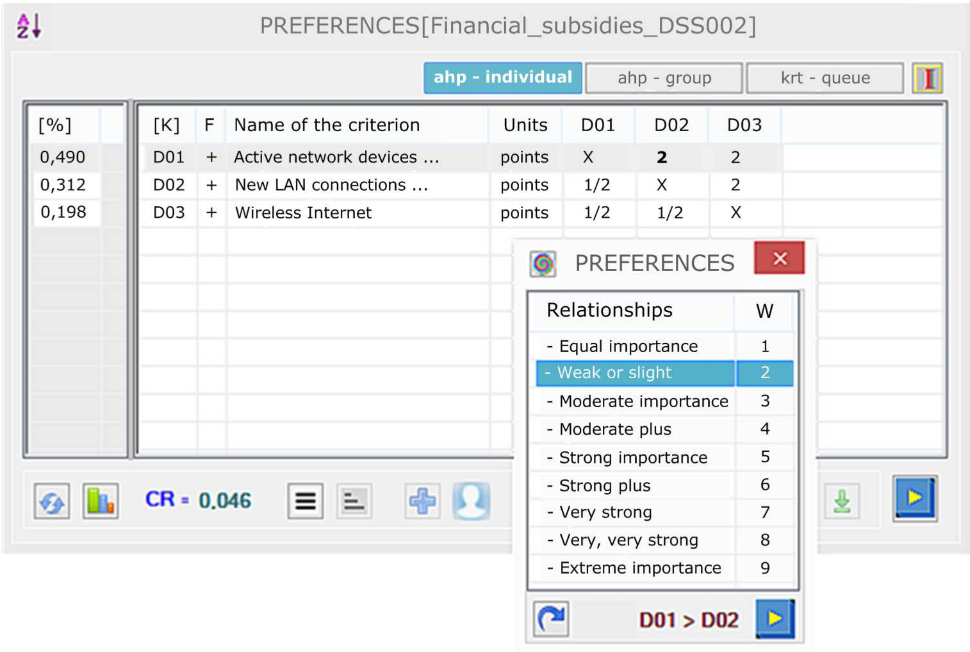
During the introduction of estimations, the special algorithm of the DSS system checks to what extent of the decision-maker's assessments written in the matrix $\mathbf{A} = [\propto_{ij}]_{i,j=1,\dots,r}$ are consistent. For this purpose, the compliance factor is calculated

$$C = \frac{\lambda_{\max} - r}{\varphi(r-1)} \,, \tag{5}$$

where: $\lambda_{\max}$ − the largest eigenvalue, r − comparison matrix size, φ – number read from the table of compliance rates for the r size [Saaty 1990]. If the ratio $C \leq 0{,}1$

the occurrence of the assessment conformity is considered. Otherwise, the pair comparisons should be performed once again.

Figure 2. Preference determination functions using the Saaty method in the DSS 2.0 system



Source: own study based on the DSS 2.0. system

A simpler solution, compared to the Saaty method, is the use of the so-called view recorder, thanks to which each of the assessing participants presents his judgment in the form of the aim order (queue of criteria) perceived by him. To increase the scope of perceiving the goal line, there was introduced the straight and curved parameterisation. Then, there is a possibility to map the situation, in which, e.g., higher goals are harder to achieve than the lower ones (or vice versa). The relevant mathematical effect was achieved by introducing conversion factors for the line quantification: proportional $w_l = l / \sum_{l=1}^{r} l$, increasing $w_l = l^2 / \sum_{l=1}^{r} l^2$ and decreasing $w_l = (1/l) / \sum_{l=1}^{r} 1/l$, calculated for l = 1, 2,…, r (where r is the number of criteria). For the selected conversion factor, there is created the initial assignment of D_k criteria to the values of generated weights w_l on the principle of $k = l$ = 1, 2,…, r. Each shift (change of order) D_k in the order changes the assignment of the w_l value. In case of line groups, for each k-th criterion there is calculated the arithmetic mean of the assigned values.

The supplementation of the option of determining the partial preferences in the system includes two use cases, in which all weights are introduced in the direct way. The first case is an arbitrary determination of positive weight values of particular criteria using any scoring scale. The provided values are automatically normalised into a vector, which sum of elements is equal to unity. The second case concerns the situation, in which preferences should be identical, e.g., for three criteria (r = 3) there will be the sizes of $w_k = 1/r$, i.e. 0,33 for each k = 1, 2,…, r. It should be added that the most popular are exactly these two cases of expressing preferences for criteria.

SUMMARY

Depending on the specifics of the decision problem, type of objects assessed in the DSS system and laws applicable to his process, as well as guidelines, procedures and rules, the decision-maker's task is to determine clear rules of conduct of this analysis. The most important of them can be determined by answering the following questions. What or who is the object of analysis? What assessment criteria of objects should be taken into account? Whose preferences for criteria should be included in the decision analysis: decision-maker's, expert's, group of experts or beneficiaries' representing the objects?

If the decision analysis has the character of cognitive research, the look at the results of optimisation, ranking and grouping of objects from the perspective of every side of the decision proceedings becomes interesting. Preferences may express the view:

a) authoritative – of a decision-maker being in the role of, e.g., manager or the board,
b) democratic – a group of beneficiaries, who are assessed (e.g. employees, students) or represent the analysis objects (e.g. proposals, offers, companies and others),
c) scientific – expert or group of experts (in case of a team of experts the resultant preference may also have the interdisciplinary character).

In the decision-making process with a group of experts, what is interesting is the study of relations between their individual beliefs (preferences) and assessments of objects (criteria values) and the analysis of the influence of the beliefs on the results of ranking and grouping.

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