Development of Consumer Decision Support System Based on Modified Kepner-Tregoy Method

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***Abstract*—Applying multiple attribute decision making methods for implementation of consumer decision support systems demonstrated essential effectiveness. A large set of quantitative and qualitative attributes, need in detailed account of individual preferences and at the same time importance of providing simplicity for user, makes it necessary to improve methods of obtaining weighted coefficients and attribute values. This paper introduces modification of Kepner-Tregoy method. Modification includes grouping attributes according several major aspects of product characteristics and dividing process of obtaining weighted coefficients into several steps. To provide greater flexibility of consumer decision support process it is proposed to extend fixed set of possible attributes by allowing users to set desirable values for some additional product characteristics. Functionality of consumer decision support tool developed on base of this method is expanded by adding administrator mode.**

Keywords—decision support systems, Kepner-Tregoy method, multiple attribute decision making, weighted coefficients.

I. INTRODUCTION

Decision support technology is a relatively new in software development, but it has very promising perspectives. Using decision support systems (DSS) can result in significant time savings as well as improving decision making.

Problem solvers are not only managers working in corporation. Consumers in their turn are also problem solvers. Practical experience shows that very often peoples' behavior is not rational, and their decision making process is influenced by various factors [1, 2, 3]. Considering consumer decision making process it is necessary to differentiate level of involvement. It defines how personally, socially and economically a customer is involved with a product in order to buy it.

When talking about purchasing household appliance, like kitchen electrical devices, for families with low and medium income it can be considered as high involvement purchase. For example, price of such product as fridge may be an essential part of monthly income of average consumer. Under those circumstances potential buyer will spend more time for exploring and comparing available products before making a purchase decision. Nowadays market suggests large variety of products which differ by their functionality, price, quality and other attributes. Even rigorous research may not result into optimal choice. In such situations decision support tools for consumers might be useful. Consumer decision support tools are mostly represented by web-based product recommendation services such as DooYoo.co.uk, eOpinions.com, or Ask.com. Those recommendation services perform sorting of available products according to parameters, defined by the user. They provide information about products and other users' opinions in form of reviews and scores. Consumer DSS are represented by in-store mobile DSS and on-line desktop DSS. DSS in the form of online terminals and smart displays are not widespread but also available in some shops and restaurants. Those tools help to reduce search complexity.

Usually a weighted adding strategy is used in this king of software. In order to consider user requirements in details it is necessary to take into account a large number of attributes [4]. There are several ways to perform this task. Requesting user for weighted coefficient for each of attributes can take some time and be difficult for consumer, because he can get confused with large list of parameters. Another solution is to assign weights automatically, using average statistical values about consumers' priorities. In this case there is a very high risk of disobeying individual preferences of each specific customer.

Furthermore, it is necessary to provide user with possibility to set specific values to additional characteristics of products. This option should allow prioritizing products according to specific settings without eliminating options which don't correspond to the settings.

Most of consumer DSS suggest only consumer mode. Adding an administrator mode to DSS allows managers using it to work with store database, collect and review statistical information about consumer preferences.

For solving problems described above in this paper it is represented modification of Kepner-Tregoy method. Modifications include improving method of obtaining weighted coefficients and attribute scores. It is allowed setting limitations for some additional characteristics of product (price range, size brand etc.). Suggested stepwise obtaining of weighted coefficients provides precise consideration and ranking user preferences, and obtaining more accurate result. On base of modified Kepner-Tregoy method it was developed database-driven consumer decision support tool.

II. MULTIPLE-CRITERIA DECISION MAKING

Complexity of real-world decision making problems does not allow obtaining optimal decision by analyzing a single attribute. Decisions based on mono-dimensional approach are

not applicable for solving real problems. Hence, it is expedient to use simultaneous analysis of all criteria of problem. In this case an issue of uniqueness of evaluation model and consideration conflicting factors inside same evaluation model arises inevitably.

Multiple criteria decision making (MCDM) allows development and implementation of decision support methodologies to manage multiple criteria and multiple goal decision making problems. For example, MCDM has methods which allow explicit modeling of relationships between goals [5]. Such methodologies allow aggregating goals. They oriented on decision support which means the role of decision maker is active. Decision maker sets his/her own preferences which will be represented as consistent decision model [6].

Choosing fridge can serve as example of multiple-attribute decision making problem. List of criteria is represented by following factors:

- price;
- size;
- functionality;
- reliability… etc.

Solution methodologies of multiple attribute decision making problems are suggested by such schools of thinking as Multiple objective mathematical programming school, Goal programming school, Fuzzy-set theorists, Multi-attribute utility theorists, Analytic hierarchy process (AHP). Basic concepts of some of them are given below.

Definition 1 (weighted score method)

Let S_{ij} be a score of option i using criterion j, w_j weight for criterion j, S_i score of option i is given as (1).

$$S_i = \sum w_j S_{ij} \tag{1}$$

The option with the best weighted sum S_i is selected.

The method can be modified by using $U(S_{ij})$ and then calculating the weighted utility score. To use utility the condition of separability (2) and (3) must hold.

$$U(S_i) = \sum w_j U(S_{ij}) \tag{2}$$

$$U(S_i) \neq U \sum w_j S_{ij} \tag{3}$$

Fuzzy set theory considers such aspect of human thinking as uncertainty in decision making. Mathematically fuzzy set is defined as collection of elements where values represent attributes' grade of membership in the fuzzy set. Fuzzy sets allow groping data without specific definition of their boundaries. Following definitions demonstrate some basic aspects of fuzzy sets:

Definition 2

Let X be a universe of discourse, then a fuzzy set is defined as (4) and characterized by a membership function (5).

$$A = \{(x, \mu_A(x)) | x \in X\}, \tag{4}$$

$$\mu_A : X \rightarrow [0, 1] \tag{5}$$

$\mu_A(x)$ denotes the degree of membership of the element x to the set of A [7].

Definition 3

For each fuzzy set A in X if (6) is fulfilled.

$$\pi_A(x) = 1 - \mu_A, \forall x \in X \tag{6}$$

Then $\pi_A(x)$ is called the degree of indeterminacy of x to A[8, 9].

This model can manage both qualitative and quantitative data; however, considering the number of parameters and the complexity of the framework, formulation of the membership functions for prequalification criteria and has difficulties.

III. Modification of Kepner-Tregoy method

A. *Obtaining weighted coefficients*

While purchasing electrical kitchen appliance consumers are usually aware of several basic aspects of product: financial, comfort and functionality, quality and lifetime, prestige. Those aspects may include various sub-aspects. In developed consumer decision support application quality aspect's sub-attributes include:

- reliability of material;
- reliability of appliance and long lifetime;
- manufacturer's post-warranty service.

Financial aspect consists of:

- reasonable price;
- economical power consumption;
- free post-purchase service.

Prestige aspect is represented by such factors as:

- high popularity among other buyers;
- brand's popularity.

Comfort and functionality aspect's sub-aspects differ depending on the type of product, because certain set of technical characteristics should be considered. For example, for fridge such sub-aspects include:

- low noise level;
- manual temperature control for refrigerator;
- additional comfort functions.

To provide detailed and easy ranking of numerous attributes is suggested to perform assigning of weighted coefficients in few steps:

- Assigning weights to four basic aspects;

- Ordering their sub-aspects in decreasing order according to their importance;
- Calculate weighted coefficients of sub-aspects on base of their order;
- Calculate final weights of attributes considering sub-aspects weights and corresponding group weight.

$K1_i$ - coefficient values, obtained from user directly (altogether 4 coefficients, where: $K1_1$ - common weight for financial aspect's sub-aspects, $K1_2$ - common weight for comfort and functionality aspect's sub-aspects, $K1_3$ - common weight for Quality and lifetime warranty aspect's sub-aspects, $K1_4$ - common weight for Prestige aspect's sub-aspects).

After evaluating major aspects, user is required to place sub-aspects of those groups in order of decreasing importance. $K2_{n_i}$ coefficients' values are automatically calculated in accordance with this order.

In standard Kepner-Tregoy method weights of different aspects may be equal. According to suggested method weights' values are different and they may not be only integers but also a floating point values, which allows more detailed ranking of attributes.

Kepner-Tregoy method implies that weighted coefficient variables are integers, which belongs to interval from 0 to 10. Hence, it was important to assign weights to aspects and sub-aspects so that final weight value would be proportional to this interval.

$K2_{n_i}$ belongs to range [0; 1]. It is obtained using (7), where

i – basic aspects of product [1; 4]

n_i - sub-aspects of product n_1 [1; 3], n_2 [4; 6], n_3 [7; 9], n_4 [10; 11]

p_{n_i} – is place of sub-aspect in sequence made by consumer,

U_i - number of sub-aspects, which allows sorting

K1 – weights of the basic aspects

K2 – weight of sub-aspect

$$K2_{n_i} = \frac{1}{U_i} * (U_i + 1 - p_{n_i}) \quad (7)$$

Final weight of attribute may be represented as (8).

$$W_{n_i} = K1_i * K2_{n_i} \quad (8)$$

B. Obtaining scores of attributes

S_V – score of current product's current attribute is calculated on base of data in database. Its value is assigned proportionally to interval [0; 10]. When attribute value corresponds to only one value from database obtaining of attribute score depends on type of database value:

1) database value is Boolean. Attribute is assigned 0 in case Boolean value is false and 10 when it's true;

2) database value is integer. For example, brands repute coefficient in database represented by value in range from 0 to 10 so it is directly assigned to attribute);

3) floating point number. For example, to convert price value into score of corresponding attribute, maximum and minimum price values products should be find. Interval between maximum and minimum product price is divided into 10 equal intervals. Attribute value is assigned in accordance with interval price belongs to. If price belongs to first interval attribute value is assigned 1, if to second – 2, etc. Size of step is calculated according to (9).

$$Step = \frac{MAX\ PriceV - MIN\ PriceV}{10} \quad (9)$$

$[MIN\ Price_V; MIN\ Price_V + Step)$ – interval 1;

$[MIN\ Price_V + Step; MIN\ Price_V + Step * 2)$ – interval 2, etc.

4) integer numbers such as coefficient of popularity among other buyers. Interval between maximum and minimum number of sold product items is divided into 10 equal intervals. Attribute values are obtained in the same manner as for floating point value.

When attribute value depends on several fields of database, for example, an Additional functionality attribute equally depends on *x* Boolean fields *F* (Function 1, Function 2, Function .., Function x values), then attribute's value is obtained in following way. Maximum possible value for attribute is 10. Hence, when corresponding value in database equals to true, value of each of additional functions is $\frac{10}{numberOfFunctions}$. When database corresponding value is false function's value is 0. Score of such an attribute is calculated according to (10).

$$S = \sum_{j=0}^{x} F_j \quad (10)$$

C. Obtaining additional coefficients

A_v (sum of additional coefficients) is calculated as (11), A_k is an additional coefficient for current options. Set of additional options for each type of product was formed considering most wide used queries of users of on-line electrical kitchen appliance shops. This set includes brand, price range, size (for big appliance, such as fridges, microwaves and ovens). Some settings depend on type of product (for example, for fridge camera type may be specified).

$$A_V = \sum_{k=1}^{n} A_k \quad (11)$$

If product fulfills condition, specified by user, then A_k is assigned 1 (true), otherwise – 0 (false). If user does not use additional settings A_k is also assigned 0.

D. Weighted sum and best options

To consumer result is represented by two best options among products available in database.

Weighted sum for set of alternatives is obtained using (12) or (13):

$$T_V = \sum_{i=1}^{4} \sum_{n_{i=1}}^{Ui} W_{n_i} * S_{V_{(i-1)*3+n}} \quad (12)$$

$$T_V = \sum_{i=1}^{4} \sum_{n_{i=1}}^{Ui} K1_i * K2_{n_i} * S_{V_{(i-1)*3+n}} \quad (13)$$

Where *i* – basic aspects of product [1; 4]

n_i - sub-aspects of product n_1 [1; 3], n_2 [4; 6], n_3 [7; 9], n_4 [10; 11]. U_i – number of sub-aspects, *K1* – weights of the basic aspects, *K2* – weights of sub-aspects, *V* – current product (fridge, microwave, oven etc.);

When we have got several best alternatives, those alternatives should be compared considering additional requirements, if they were set by user. Fulfillment of those requirements are reflected by additional coefficients A_{Vk}, where *k* is current requirement, and *m* is the total number of additional requirements. Then weighted sum for product items, considering additional requirements, should be calculated according to (14).

$$T_V = \sum_{i=1}^{4} \sum_{n_{i=1}}^{Ui} K1_i * K2_{n_i} * S_{V_{(i-1)*3+n}} + \sum_{k=1}^{m} A_{Vk} \quad (14)$$

If *T* is a sequence of products' weighted sum, then two best results belong to this sequence (15).

$$R_1,\ R_2 \in T \quad (15)$$

Selection of best options is performed by finding products with maximum value of weighted sum (16).

$$R_1 = MAX(T_V) \quad (16)$$

Second best result obtained from initial sequence of weighted sums eliminating firs best result (17).

$$R_2 = MAX(T_V \backslash R_1) \quad (17)$$

IV. Developed Consumer Decision Support Application (CDSA)

Main purpose of CDSA is to help customers of electrical kitchen appliance shops to choose product, which will be optimal individually for each customer.

Additional purpose is to collect statistical information about consumers' preferences, in order to help store administrators in improvement of management effectiveness.

CDSA provides administrator with limited access to store database. CSDA administrator is allowed to add new products and product characteristics.

Consumer interaction with CDSA may be represented as "black-box" model. Fig. 1 reflects such a view.

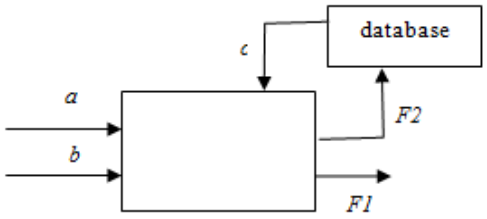

Fig. 1. "Black-box" model of consumer interaction with CDSA

Where *a* and *b* – input parameters. *a* is user input, which includes his/her basic preferences in product, specifically, evaluation of quality, economical, prestige and functionality aspects and their sub-aspects. *b* stands for additional options, which user may set for product. *c* – database product characteristics values. *F1* – output, represented by couple of most suitable alternatives, *F2* – statistics about consumer preferences, represented by coefficients calculated on base of user input.

Administrator interaction with CDSA model may have two scenarios. First – reviewing statistics, second - altering data in database. Corresponding model showed on Fig. 2.

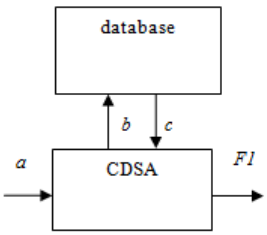

Fig. 2. "Black-box" model of administrator interaction with CDSA

Where *a* – an administrator's input, *b* – CDSA query to database for reviewing statistics or changing data, *b* - database return. *F1* – output. Depending on administrator's input, it may be represented by statistical information, message about successful changing data or error message.

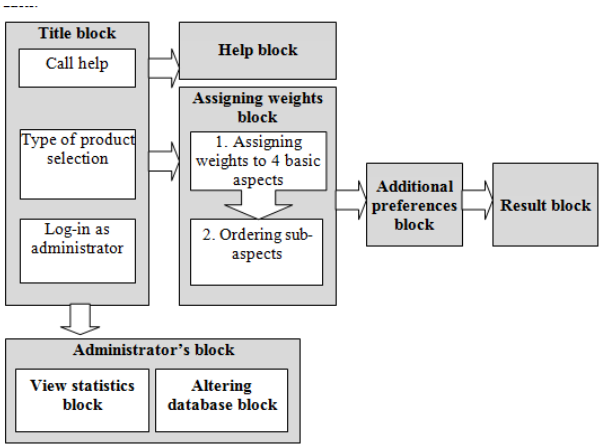

Fig. 3. CDSA model

Simplified scheme of CDSA is reflected of Fig. 3. It includes several blocks:

- Title block. In case system used by consumer he may choose one of suggested products and then proceed to the next stage; consumer also may choose to go to Help block. If system is used my administrator or shop manager he should log-in to get access to administrator's block.
- Help block. On this block user may review CDSA manual.
- Assigning weights block includes 5 stages. On first stage consumer assigns weights to four major aspects of product characteristics. On 2, 3, 4 and 5 stages he works with each of aspects in detail.
- Additional preferences block is step, where consumer may set additional requirements for product if he wants.
- In Result block consumer may review CDSA suggestions about optimal product items, then exit or return to title page.
- Administrator's block allows user to review statistics about consumer preferences. Also user may add some characteristics to database and add new products.

V. EXPERIMENT AND CONCLUSION

In order to test validness of work of CDSA, experiment, described below, was performed. After selection of a group of bachelor and master's degree students of TUTE, uniformity of this group was researched by interviewing its members. The task was to form group, which consists of members who may represent any average consumer. Hence, members of definitively formed group were not necessary familiar with scientific decision making methods and did not have knowledge about technical characteristics and their influence on quality, reliability and lifetime of device. Most of group members consider buying electrical kitchen appliance as high involvement purchase. That means that they do not pick product randomly, before buying they usually do information search about devices' price, functionality, lifetime etc.

Experiment included three parts. During Part 1 of experiment members were given information about characteristics of each fridge item which is available in database. (Initially for ease of experiment number of fridge items in database was limited to 10). Group members made their choice without using additional decision support tools.

Part 2 consisted in "blind" using consumer decision making system. Members of group were given task to assume that they need to buy fridge. Then they used CDSA to obtain two best options.

Comparison between result which was obtained by using CDSA and without CDSA shows that number of result coincidences, including first and second best options, was 71%.

During Part 3 of experiment group members were suggested to compare product, they choose in Part 1 of experiment, with options, suggested by CDSA, and pick option which is, on their opinion, is better.

Result showed that 82% of group members, whose initial choice did not coincide with CDSA suggested options, after comparison choose one of options suggested by CDSA.

Further test with increasing number of product items in database showed that gap between coincidence of initial choice and options suggested by CDSA is also increasing. Number of people who on Stage 3 of experiment opted for result suggested by CDSA strives for 93%. Results obtained during experiment are showed on Fig. 4

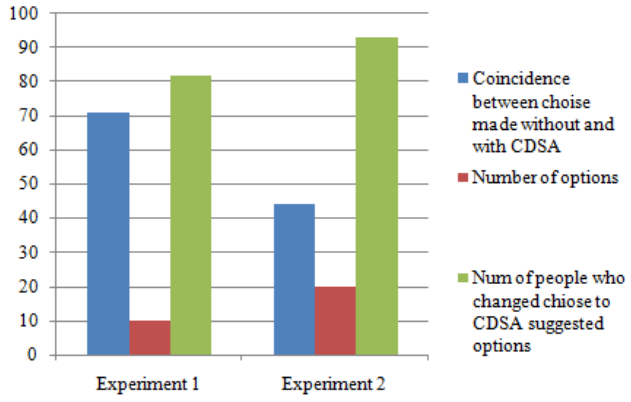

Fig. 4. Results of research of CDSA adequacy

It was defined that derivations from expected result were mostly related to additional options coefficients. After correcting corresponding CDSA part, result of further experiments confirmed an adequacy of CDSA. Results also showed that CDSA is more effective on big amount of options, which corresponds real situation at big shops and supermarkets, where assortment of products varies widely.

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