



## RECOMMENDER SYSTEM FOR REAL ESTATE MANAGEMENT

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**Abstract.** The analysis of information, the expert and decision support systems used in real estate management that were developed by researchers from various countries assisted the authors in creating their own Recommender System for Real Estate Management (RSREM). The database of real estate management was developed providing a comprehensive assessment of alternative versions from the economic, technical, technological, infrastructure, qualitative, technological, legislative and other perspectives. Based on the above complex databases, the developed Recommender System for Real Estate Management enables the user to analyse alternatives quantitatively (i.e. a system and subsystems of criteria, units of measure, values and weights) and conceptually (i.e. the text, formula, schemes, graphs, diagrams and videotapes) and provides recommendations.

**Keywords:** Real Estate Management, Multiple Criteria Analysis, Recommender System.

**JEL Classification:** D81.

## REKOMENDACINĖ NEKILNOJAMOJO TURTO VALDYMO SISTEMA

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**Santrauka.** Informacijos analizė, įvairių šalių tyrėjų pasiūlytos ekspertinės ir sprendimų paramos sistemos, skirtos nekilnojamajam turtui valdyti, paskatino autorius sukurti savo rekomendacinę nekilnojamajo turto valdymo sistemą (RNTVS). Nekilnojamajo turto valdymo duomenų bazė sudaryta atliekant visapusišką alternatyvų vertinimą ekonominiu, techniniu, technologiniu, infrastruktūros, kiekybiniu, teisiniu ir kitais aspektais. Remiantis sudaryta duomenų baze sukurta rekomendacinė nekilnojamajo turto valdymo sistema leidžia vartotojui alternatyvas analizuoti kiekybiškai (t. y. kriterijų sistema ir posistemiai, matavimo vienetai, vertės ir svoriai) ir konceptualiai (t. y. tekstas, formulės, schemas, grafikai, diagramos ir vaizdo įrašai) bei pateikti rekomendacijas.

**Reikšminiai žodžiai:** nekilnojamajo turto valdymas, daugiakriterinė analizė, rekomendacinė sistema.

## 1. Recommender systems and recommendation methods

Definitions of recommender systems can be found in different literature sources as follows:

- Any system that produces individualized recommendations as output or has the effect of guiding the user in a personalized way to interesting or useful objects in a large space of possible options (Burke 2002).
- Recommender system provides users with a ranked list of the recommended items (Herlocker *et al.* 2004).
- [...] people provide recommendations as inputs, which the system then aggregates and directs to appropriate recipients (Resnick, Varian 1997).
- Recommender systems form a specific type of information filtering (IF) technique that attempts to present information items that are likely of interest to the user. Typically, a recommender system compares the user's profile to some reference characteristics, and seeks to predict the 'rating' that a user would give to an item they had not yet considered. These characteristics may be from the information item (the content-based approach) or the user's social environment (Recommender systems 2011).

Adomavicius and Tuzhilin (2005) present an overview of the field of recommender systems and describe the current generation of recommendation methods that are usually classified into the following three main categories: content-based, collaborative, and hybrid recommendation approaches. Adomavicius and Tuzhilin (2005) also describe various limitations of current recommendation methods and discuss possible extensions that can improve recommendation capabilities and make recommender systems applicable to an even broader range of applications. These extensions include, among others, an improvement of understanding of users and items, incorporation of the contextual information into the recommendation process, support for multi-criteria ratings, and a provision of more flexible and less intrusive types of recommendations.

Recommender systems have been evaluated in many, often incomparable, ways. Herlocker *et al.* (2004) review the key decisions in evaluating collaborative filtering recommender systems: the user tasks being evaluated, the types of analysis and datasets being used, the ways in which prediction quality is measured, the evaluation of prediction attributes other than quality, and the user-based evaluation of the system as a whole. In addition to reviewing the evaluation strategies used by prior researchers, Herlocker *et al.* (2004) present empirical results from the analysis of various accuracy metrics on one content domain where all the tested metrics collapsed roughly into three equivalence classes. Metrics within each equivalency class were strongly correlated, while metrics from different equivalency classes were uncorrelated.

Recommender systems represent user preferences for the purpose of suggesting items to purchase or examine. They have become fundamental applications in electronic commerce and information access, providing suggestions that effectively prune large information spaces so that users are directed toward those items that best meet their needs and preferences. A variety of techniques have been proposed for performing recommendation, including content-based, collaborative, knowledge-based and other techniques. To improve performance, these methods have sometimes been combined in hybrid recommenders (Burke 2002). Burke (2002) surveys the landscape of actual and possible hybrid recommenders, and introduces a novel hybrid, EntreeC, a system that combines knowledge-based recommendation and collaborative filtering to recommend restaurants. Burke (2002) shows that semantic ratings obtained from the knowledge-based part of the system enhance the effectiveness of collaborative filtering.

Sarwar *et al.* (2000) investigate the use of dimensionality reduction to improve performance for a new class of data analysis software called "recommender systems". Recommender systems apply knowledge discovery techniques to the problem of making product recommendations during a live customer interaction. These systems are achieving widespread success in E-commerce nowadays, especially with the advent of the Internet. The tremendous growth of customers and products poses three key challenges for recommender systems in the E-commerce domain. These are: producing high quality recommendations, performing many recommendations per second for millions of customers and products, and achieving high coverage in the face of data sparseness. One successful recommender system technology is collaborative filtering, which works by matching customer preferences to other customers in making recommendations. Collaborative filtering has been shown to produce high quality recommendations, but the performance degrades with the number of customers and products. New recommender system technologies are needed that can quickly produce high quality recommendations, even for very large-scale problems (Sarwar *et al.* 2000).

When building the user's profile a distinction is made between explicit and implicit forms of data collection. Examples of explicit data collection include the following: asking a user to rate an item on a sliding scale; asking a user to rank a collection of items from favorite to least favorite; presenting two items to a user and asking him/her to choose the best one; asking a user to create a list of items that he/she likes. Examples of implicit data collection include the following: observing the items that a user views in an online store; analyzing item/user viewing times; keeping a record of the items that a user purchases online; obtaining a list of items that a user has listened to or watched on his/her computer; analyzing the user's social network and discovering similar likes and dislikes. The recommender system compares

the collected data to similar data collected from others and calculates a list of recommended items for the user. Several commercial and non-commercial examples are listed in the article on collaborative filtering systems. Recommender systems are a useful alternative to search algorithms since those help users discover items they might not have found by themselves. Interestingly enough, recommender systems are often implemented using search engines indexing non-traditional data. (Recommender systems 2011). Adomavicius and Tuzhilin (2005) provide an overview of recommender systems. Herlocker *et al.* (2004) provide an overview of evaluation techniques for recommender systems.

One of the most commonly used algorithms in recommender systems is Nearest Neighborhood approach (Sarwar *et al.* 2000). In a social network, a particular user's neighborhood with similar taste or interest can be found by calculating Pearson Correlation, by collecting the preference data of top-N nearest neighbors of the particular user (weighted by similarity), the user's preference can be predicted by calculating the data using certain techniques. Another family of algorithms that is widely used in recommender systems is Collaborative Filtering. One of the most common types of Collaborative Filtering is item-to-item collaborative filtering (people who buy x also buy y), an algorithm popularized by Amazon.com's recommender system (Recommender systems 2011). The Netflix Prize, a contest with a dataset of over 100 million movie ratings and a grand prize of \$1,000,000, has energized the search for new and more accurate algorithms. The most accurate algorithm in 2007 used 107 different algorithmic approaches, blended into a single prediction. Predictive accuracy is substantially improved when blending multiple predictors. Our experience is that most efforts should be concentrated in deriving substantially different approaches, rather than refining a single technique. Consequently, our solution is an ensemble of many methods (Bell *et al.* 2007).

## 2. Determination of rational real estate management processes

A real estate management process consists of closely interrelated stages: i.e. consultation, planning, procurement, implementation and monitoring. A real estate management process may have many alternative versions. These variants are based on alternative consultation, planning, procurement, implementation and controlling stages and their constituent parts. The above solutions and processes will be considered in more detail later. For instance, alternative space management variants can be developed by varying their space organization, removals, inventory compilation/updating and main services solutions (building security, reception, telephone switchboard, cleaning, snow-clearing service, upkeep of outdoor real estate, garden care, plant care in the building, post room, travel office, office service, central secretariat, canteen man-

agement, removals service, central archive, courier services, office supplies and safety specialist). Therefore, thousands of real estate management process alternative versions can be obtained. The diversity of available solutions contributes to a more accurate evaluation of climatic conditions, risk exposure, maintenance services, as well as making the project cheaper and results in a better way of satisfying a client's aesthetic, comfort, technological and other requirements. This also leads to a better satisfaction of the needs of all the involved parties in the real estate management process.

Various interested parties (e.g. users, owners, and real estate managers, etc.) are involved in the real estate management process, and trying to satisfy their needs and affecting its efficiency.

The above needs or objectives include the expected cost of real estate management services, occupier, owner and building support, building inspection, budgeting, cost optimization, coordination of services, accounting. It also includes contract management; leasing management; technical operations management; maintenance, inspection and, repair of equipment and systems (gas, water, wastewater, heating, ventilation, cooling, electrical systems, lifts, warehousing systems, automatic door and gate, communication, cable and network, security, laundry and dry-cleaning systems, general building equipment, other equipment and systems), etc. Real estate management companies should be able to offer a range of services that can be flexibly extended or reduced.

The problem is how to define an efficient real estate management process when many various parties are involved because the alternative versions come to thousands and the efficiency changes with the alterations in the business environment conditions and the constituent parts of the process. Moreover, the realization of some objectives seems more rational from the economic perspective though from other perspectives (i.e. technological, comfort, space, administrative, technical, etc.) they have various significances. Therefore, it is considered that the efficiency of a real estate management process depends on the rationality of its stages as well as on the ability to satisfy the needs of the interested parties and the rational character of micro and macro-level environment conditions.

A formalized presentation of the research shows how changes in the business environment and the extent to which the goals pursued by various interested parties are satisfied, cause corresponding changes in the value and utility degree of the real estate management process. With this in mind, it is possible to solve the problem of optimization concerning the satisfaction of the needs with reasonable expenditures. This requires an analysis of the real estate management process versions allowing one to find an optimal combination of pursued goals and available finances.

The determination of the utility degree and value of the real estate management alternatives under investigation and the establishment of the priority order for their implementa-

tion do not present much difficulty if the criteria numerical values and weights have been obtained and the multiple criteria decision making methods are used.

By way of an illustration, we provide a short analysis of a criteria system of some real estate management constituent parts. They include computer-aided real estate management systems, service of a real estate, and equipment.

Cormier (2000) described the process and elements for comparison and the selection when considering various computer-aided real estate management systems. Cormier (2000) considered the following criteria system: modules and tools (lease management, move management, strategic space planning, maintenance management, accounting/charge-back, communication/cable management, personnel management, etc.) and also considered cost information (cost of software, cost of training, cost and ease of software integration, cost of software maintenance, and after-sale support), technical information (platform, network access, native database support, database connectivity, user interface, security, reports, file formats, and interoperability) and key features.

The service of a real estate can be evaluated as: operational productivity, aesthetic value or public image, comfort (noise, colour, air quality, thermal comfort, and working conditions) flexibility, and cost (design, construction, indirect expenses, operating and maintenance expenses, renovation costs, the interest paid on loan).

Effectiveness of equipment can be evaluated by the following criteria system:

- Price;
- Expenses for use;
- Expenses for repair (maintenance, capital);
- Capacity;
- Number of operations performed;
- Reliability;
- Comfort;
- Physical and technical durability;
- Weight.

One of the main tasks of the efficient implementation of real estate management is multiple criteria optimization of its life cycle process with the aim of maximum purpose satisfaction of all interested parties in the process. The interested parties and their aspired goals make up one entity. However, there are some potential conflicts among interested parties: e.g. speed versus waste, cost versus quality, capital cost now versus after-operational efficiency, aesthetics and comfort versus cost, environment versus user needs, etc. The greater the scope of the realization of pursued goals (taking into account their significance) the greater (in the opinion of interested parties) the total efficiency of the project. In other words, the total efficiency of a project is directly proportional to the entity of its realized goals.

### 3. Multiple criteria analysis of real estate management alternatives

Most of all calculators, analysers, software, neural networks, decision support and expert systems seek to find out how to make the most economic real estate management decisions and most of all these decisions are intended only for economic objectives. Real estate management alternatives under evaluation have to be evaluated not only from an economic position, but take into consideration qualitative, technical, technological and other characteristics as well. For example, an analysis of the service of real estate is usually performed by taking into account operational productivity, aesthetic value or public image, comfort (noise, colour, air quality, thermal comfort, working conditions), flexibility, and cost (design, construction, indirect expenses, operating and maintenance expenses, renovation costs, the interest paid on loan). Real estate management alternative solutions allow for a more rational and realistic assessment of economic, technical, technological, space conditions and traditions and for greater satisfaction of different customer requirements. Therefore, by applying multiple criteria analysis methods and decision support systems the efficiency of real estate management calculators, analysers, software, neural networks, decision support and expert systems may be increased.

Bauer *et al.* (2000) discussed six major real estate phases which include the following: definition of need, planning and programming, design, construction, operate/maintenance and decision for use the next time. According to Bauer *et al.* (2000) each of these phases has five process groups called: initiating, planning, execution, controlling and closing. On that score, a real estate management's life cycle has many alternative versions. Variants are based on the project's alternatives of the definition of need, planning and programming, design, construction, operate/maintenance and other processes. The above solutions and processes may be further considered in more detail. For example, there are several ways that companies can provide necessary cleaning services (Smith *et al.* 2000): in a traditional department, all personnel are company employees; in support of a traditional department, some companies are adding their services to a competent consultant; the company can use a management service to support its own production team; in a full-service program, a service company provides all the management and production personnel, tools, equipment and supplies; in combination programs, the company uses its employees to perform part of the cleaning responsibilities and the contracts with a service company for the remainder.

Thousands of real estate management's life cycle alternative versions can be obtained in this way.

The determination of the utility degree and market value of the real estate management alternatives under investigation and the establishment of the priority order for their implementation do not present much difficulty if the cri-

teria numerical values and weights have been obtained and the multiple criteria decision-making methods are used.

#### **4. A method of multiple criteria complex proportional evaluation and defining the utility degree of real estate**

This method is directly related with utilitarianism moral philosophy. For example, for Bentham (1948), conduct is to be judged by its consequences to the community. Actions are moral to the extent that they promote the community's utility, and immoral to the extent that these lessen it. Utility is understood in subjective terms as the net balance of whatever a person finds to be pleasurable and painful, with the former obviously increasing that balance and the latter decreasing it. Rather than being conceived holistically as an entity in its own right, the community is nothing more than the name we give to a collection of individuals. Accordingly, Bentham holds that the community's utility is the sum of individual utilities. It can be calculated by placing the number of those positively impacted by an action, weighted by the intensity and duration of their net pleasure, in the positive column and then doing the same in the negative column for those negatively affected by net pain. If the positive side of the ledger exceeds the negative, communal utility rises and the action passes the moral bar, and vice versa, if the negative column outweighs the positive column (Bentham 1948).

The determination of the utility degree and value of the alternative under investigation and establishment of the priority order for their implementation do not present much difficulty if the criteria numerical values and weights have been obtained and the multiple criteria decision making methods are used.

All criteria are calculated for the whole alternative. The process of determining the system of criteria, their initial weights and qualitative criteria numerical values of the alternative under investigation is based on the use of various expert methods. The determination of quantitative criteria numerical values is based on the use of various statistical methods, analysed alternatives, recommendations and other documents.

The results of the comparative analysis of the alternatives are presented as a grouped decision making matrix where columns contain  $n$  alternatives being considered, while all quantitative and conceptual information pertaining to them is found in lines.

Quantitative and conceptual description of the research object provides the information about various aspects of a real estate life cycle (i.e. economic, legal/regulatory, institutional, political, social, traditions, cultural, philosophical, ethical, confidence, happiness, religion, emotional, psychological, etc.). Quantitative information is based on the criteria sys-

tems and subsystems, units of measure, values and initial weights as well as the data on the alternatives development.

Conceptual description of a real estate life cycle presents textual, graphical (schemes, graphs, diagrams, drawings), visual (videotapes) information about the alternatives and the criteria used for their definition, as well as giving the reason for the choice of this particular system of criteria, their values and weights. This part also includes information about the possible ways of multi-variant design. Conceptual information is needed to make more complete and accurate evaluation of the alternatives considered. It also helps to get more useful information as well as developing a system and subsystems of criteria and defining their values and weights.

In order to perform a complete study of the research object, a complex evaluation of its economic, legal/regulatory, institutional, social, traditions, cultural, philosophical, ethical, confidence, happiness, religion, emotional, psychological and other aspects is needed. The diversity of aspects being assessed should follow the diversity of ways of presenting data needed for decision making. Therefore, the necessary data may be presented in numerical, textual, graphical (schemes, graphs, charts), formula, videotape and other forms.

The grouping of the information in the matrix should be performed so as to facilitate the calculation process and to express their physical meaning. In our case the criteria system is formed from the criteria describing the life cycle of real estate which can be expressed in a quantitative form (quantitative criteria) and the criteria describing the life cycle of real estate which cannot be expressed in a quantitative form (qualitative criteria).

The researchers from various countries engaged in the analysis of real estate life cycle and its stages did not consider the research object being project by the authors of the present investigation. However, they did not consider the research object that the research project presented here (see section "Conceptual Model of Real estate in Lithuania"). This research object may be described as a life cycle of the real estate that includes the stakeholders involved and the environment which impact a life cycle in some particular manner, thus forming an integral, whole entity. This formulated research object underwent complex analysis performed with the help of the multiple criteria analysis, a new method specially developed for this purpose: a method of multiple criteria complex proportional evaluation and defining the utility degree of real estate.

This method assumes direct and proportional dependence of significance and priority of investigated versions on a system of criteria adequately describing the alternatives and on values and weights of the criteria. The system of criteria is determined and the values and initial weights of criteria are calculated by experts. All this information can be corrected by interested parties taking into consideration their pursued goals and existing capabilities. Hence, the

**Table 1.** Grouped decision making matrix of real estate life cycle multiple criteria analysis

| Quantitative information pertinent to alternatives  |                  |                  |                  |                       |                    |     |                    |     |                    |
|---|------------------|------------------|------------------|-----------------------|--------------------|-----|--------------------|-----|--------------------|
| Criteria describing the life cycle of a real estate   | *                | Weight           | Measuring units  | Compared alternatives |                    |     |                    |     |                    |
|   |                  |                  |                  | a <sub>1</sub>        | a <sub>2</sub>     | ... | a <sub>j</sub>     | ... | a <sub>n</sub>     |
|   | Z <sub>1</sub>   | q <sub>1</sub>   | m <sub>1</sub>   | x <sub>11</sub>       | x <sub>12</sub>    | ... | x <sub>1j</sub>    | ... | x <sub>1n</sub>    |
| Quantitative criteria   | Z <sub>2</sub>   | q <sub>2</sub>   | m <sub>2</sub>   | x <sub>21</sub>       | x <sub>22</sub>    | ... | x <sub>2j</sub>    | ... | x <sub>2n</sub>    |
|   | ...              | ...              | ...              | ...                   | ...                | ... | ...                | ... | ...                |
|   | Z <sub>i</sub>   | q <sub>i</sub>   | m <sub>i</sub>   | x <sub>i1</sub>       | x <sub>i2</sub>    | ... | x <sub>ij</sub>    | ... | x <sub>in</sub>    |
|   | ...              | ...              | ...              | ...                   | ...                | ... | ...                | ... | ...                |
|   | Z <sub>t</sub>   | q <sub>t</sub>   | m <sub>t</sub>   | x <sub>t1</sub>       | x <sub>t2</sub>    | ... | x <sub>tj</sub>    | ... | x <sub>tn</sub>    |
|   | Z <sub>t+1</sub> | q <sub>t+1</sub> | m <sub>t+1</sub> | x <sub>t+1 1</sub>    | x <sub>t+1 2</sub> | ... | x <sub>t+1 j</sub> | ... | x <sub>t+1 n</sub> |
| Qualitative criteria  | Z <sub>t+2</sub> | q <sub>t+2</sub> | m <sub>t+2</sub> | x <sub>t+2 1</sub>    | x <sub>t+2 2</sub> | ... | x <sub>t+2 j</sub> | ... | x <sub>t+2 n</sub> |
|   | ...              | ...              | ...              | ...                   | ...                | ... | ...                | ... | ...                |
|   | Z <sub>i</sub>   | q <sub>i</sub>   | m <sub>i</sub>   | x <sub>i1</sub>       | x <sub>i2</sub>    | ... | x <sub>ij</sub>    | ... | x <sub>in</sub>    |
|   | ...              | ...              | ...              | ...                   | ...                | ... | ...                | ... | ...                |
|   | Z <sub>m</sub>   | q <sub>m</sub>   | m <sub>m</sub>   | x <sub>m1</sub>       | x <sub>m2</sub>    | ... | x <sub>mj</sub>    | ... | x <sub>mn</sub>    |
| Conceptual information pertinent to alternatives (i.e. text, drawings, graphics, video tapes) |                  |                  |                  |                       |                    |     |                    |     |                    |
| C <sub>f</sub>  | C <sub>z</sub>   | C <sub>q</sub>   | C <sub>m</sub>   | C <sub>1</sub>        | C <sub>2</sub>     | ... | C <sub>j</sub>     | ... | C <sub>n</sub>     |

\* The sign z<sub>i</sub> (+ (-)) indicates that a greater (less) criterion value corresponds to a higher significance for stakeholders

assessment results of alternatives fully reflect the initial data jointly submitted by experts and interested parties.

The determination of significance and priority of alternatives is carried out in four stages.

**Stage 1.** The weighted normalized decision making matrix D is formed. The purpose of this stage is to receive dimensionless weighted values from the comparative indexes. When the dimensionless values of the indexes are known, all criteria, originally having different dimensions, can be compared. The following formula is used for this purpose:

$$d_{ij} = \frac{x_{ij} \times q_i}{\sum_{j=1}^n x_{ij}}, \quad i = \overline{1, m}; \quad j = \overline{1, n}, \quad (1)$$

where x<sub>ij</sub> – the value of the i-th criterion in the j-th alternative of a solution; m – the number of criteria; n – the number of the alternatives compared; q<sub>i</sub> – significance of i -th criterion.

The sum of dimensionless weighted index values d<sub>ij</sub> of each criterion x<sub>i</sub> is always equal to the significance q<sub>i</sub> of this criterion:

$$q_i = \sum_{j=1}^n d_{ij}, \quad i = \overline{1, m}; \quad j = \overline{1, n}. \quad (2)$$

In other words, the value of significance q<sub>i</sub> of the investigated criterion is proportionally distributed among all alternative versions a<sub>j</sub> according to their values x<sub>ij</sub>.

**Stage 2.** The sums of weighted normalized indexes describing the j-th version are calculated. The versions are described by minimizing indexes S<sub>-j</sub> and maximizing indexes S<sub>+j</sub>. The lower value of minimizing indexes is better (price of the plot and real estate, etc.). The greater value of maximizing indexes is better (comfortability and aesthetics of the real estate, etc.). The sums are calculated according to the formula:

$$S_{+j} = \sum_{i=1}^m d_{+ij}; \quad S_{-j} = \sum_{i=1}^m d_{-ij}, \quad i = \overline{1, m}; \quad j = \overline{1, n}. \quad (3)$$

In this case, the values S<sub>+j</sub> (the greater is this value (alternative ‘pluses’), the more satisfied are the interested parties) and S<sub>-j</sub> (the lower is this value (alternative ‘minuses’), the better is goal attainment by the interested parties) express the degree of goals attained by the interested parties in each alternative. In any case the sums of ‘pluses’ S<sub>+j</sub> and ‘minuses’ S<sub>-j</sub> of all alternatives are always respectively equal to all sums of significances of maximizing and minimizing criteria:

$$S_+ = \sum_{j=1}^n S_{+j} = \sum_{i=1}^m \sum_{j=1}^n d_{+ij},$$

$$S_- = \sum_{j=1}^n S_{-j} = \sum_{i=1}^m \sum_{j=1}^n d_{-ij}, \quad i = \overline{1, m}; \quad j = \overline{1, n}. \quad (4)$$

In this way, the calculations made may be additionally checked.

**Stage 3.** The significance (efficiency) of comparative versions is determined on the basis of describing positive alternatives ('pluses') and negative alternatives ('minuses') characteristics. Relative significance  $Q_j$  of each alternative  $a_j$  is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-min} \cdot \sum_{j=1}^n S_{-j}}{S_{-j} \cdot \sum_{j=1}^n \frac{S_{-min}}{S_{-j}}}, \quad j = \overline{1, n} \quad (5)$$

**Stage 4.** Priority determination of alternatives. The greater is the  $Q_j$ , the higher is the efficiency (priority) of the alternative.

The analysis of the method presented makes it possible to state that it may be easily applied to evaluating the alternatives and selecting most efficient of them, being fully aware of a physical meaning of the process. Moreover, it allowed to formulate a reduced criterion  $Q_j$  which is directly proportional to the relative effect of the compared criteria values  $x_{ij}$  and significances  $q_i$  on the end result.

Significance  $Q_j$  of real estate  $a_j$  indicates satisfaction degree of demands and goals pursued by the interested parties - the greater is the  $Q_j$ , the higher is the efficiency of the real estate. In this case, the significance  $Q_{max}$  of the most rational real estate will always be the highest. The significances of all remaining real estate are lower as compared with the most rational one. This means that total demands and goals of interested parties will be satisfied to a smaller extent than it would be in case of the best real estate.

The degree of real estate utility is directly associated with quantitative and conceptual information related to it. If one real estate is characterized by the best economic and political aspects, while the other shows better social, philosophical and ethical characteristics, both having obtained the same significance values as a result of multiple criteria evaluation, this means that their utility degree is also the same. With the increase (decrease) of the significance of real estate analyzed, its degree of utility also increases (decreases). The degree of real estate utility is determined by comparing the real estate analysed with the most efficient real estate. In this case, all the utility degree values related to the real estate analysed will be ranged from 0% to 100%. This will facilitate visual assessment of real estate efficiency.

The degrees of utility of the real estate considered as well as the market value of the real estate being valued are determined in seven stages.

**Stage 1.** The formula used for the calculation of real estate  $a_j$  utility degree  $N_j$  is given below:

$$N_j = (Q_j : Q_{max}) \cdot 100\%, \quad (6)$$

here  $Q_j$  and  $Q_{max}$  are the significances of the real estate obtained from the equation 5.

The degree of utility  $N_j$  of real estate  $a_j$  indicates the level of satisfying the needs of the parties interested in the real estate. The more goals are achieved and the more important they are, the higher is the degree of the real estate utility. Since stakeholders are mostly interested in how much more efficient particular real estate are than the others (which

**Table 2.** Real estate life cycle multiple criteria analysis results

| Quantitative information pertinent to alternatives   |       |        |                 |                       |          |     |          |     |          |
|--|-------|--------|-----------------|-----------------------|----------|-----|----------|-----|----------|
| Criteria describing the life cycle of a real estate  | *     | Weight | Measuring units | Compared alternatives |          |     |          |     |          |
|  |       |        |                 | $a_1$                 | $a_2$    | ... | $a_j$    | ... | $a_n$    |
| $X_1$  | $z_1$ | $q_1$  | $m_1$           | $d_{11}$              | $d_{12}$ | ... | $d_{1j}$ | ... | $d_{1n}$ |
| $X_2$  | $z_2$ | $q_2$  | $m_2$           | $d_{21}$              | $d_{22}$ | ... | $d_{2j}$ | ... | $d_{2n}$ |
| $X_3$  | $z_3$ | $q_3$  | $m_3$           | $d_{31}$              | $d_{32}$ | ... | $d_{3j}$ | ... | $d_{3n}$ |
| ...  | ...   | ...    | ...             | ...                   | ...      | ... | ...      | ... | ...      |
| $X_i$  | $z_i$ | $q_i$  | $m_i$           | $d_{i1}$              | $d_{i2}$ | ... | $d_{ij}$ | ... | $d_{in}$ |
| ...  | ...   | ...    | ...             | ...                   | ...      | ... | ...      | ... | ...      |
| $X_m$  | $z_m$ | $q_m$  | $m_m$           | $d_{m1}$              | $d_{m2}$ | ... | $d_{mj}$ | ... | $d_{mn}$ |
| The sums of weighted normalized maximizing (alternatives 'pluses') indices of the alternative  |       |        |                 | $S_{+1}$              | $S_{+2}$ | ... | $S_{+j}$ | ... | $S_{+n}$ |
| The sums of weighted normalized minimizing (alternatives 'minuses') indices of the alternative |       |        |                 | $S_{-1}$              | $S_{-2}$ | ... | $S_{-j}$ | ... | $S_{-n}$ |
| Significance of the alternative  |       |        |                 | $Q_1$                 | $Q_2$    | ... | $Q_j$    | ... | $Q_n$    |
| Priority of the alternative  |       |        |                 | $P_1$                 | $P_2$    | ... | $P_j$    | ... | $P_n$    |
| Utility degree of the alternative (%)  |       |        |                 | $N_1$                 | $N_2$    | ... | $N_j$    | ... | $N_n$    |

\* The sign  $z_i$  (+ (-)) indicates that a greater (less) criterion value corresponds to a greater significance for stakeholders

can better satisfy their needs), then it is more advisable to use the concept of real estate utility rather than significance when choosing the most efficient solution.

A degree of real estate utility reflects the extent to which the goals pursued by the interested parties are attained. The more objectives are attained and the more significant they are, the higher will be real estate degree of utility.

## 5. Recommender System for Real Estate Management

Based on the analysis of the existing information, expert and decision support systems and in order to determine the most efficient versions of real estate management a Recommender System for Real Estate Management (RSREM) consisting of a database, database management system, model-base, model-base management system and user interface was developed.

### 5.1. Database

Real estate management involves a number of interested parties who pursue various goals and have different potentialities, educational levels and experiences. This leads to various approaches of the above parties to decision-making in this field. In order to do a full analysis of the available alternatives and to obtain an efficient compromise solution, it is often necessary to analyse economic, qualitative, legal, social, technical, technological and other types of information. This information should be provided in a user-oriented way.

The presentation of information needed for decision-making in the RSREM may be in a conceptual form (i.e. digital/numerical, textual, graphical, diagrams, graphs and drawing, etc.), photographic, sound, video and quantitative forms. The presentation of quantitative information involves criteria systems and subsystems, units of measurement, values and initial weights that fully define the provided variants. Conceptual information means a conceptual description of the alternative solutions, the criteria and ways of determining their values and the weights, etc.

In this way, the RSREM enables the decision-maker to receive various conceptual and quantitative information on real estate management from a database and a model-base allowing him/her to analyse the above factors and to form an efficient solution.

The analysis of database structures in decision support systems according to the type of problem solved reveals their various utilities. There are three basic types of database structures: hierarchical, network and relational. RSREM has a relational database structure where the information is stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and is saved in the computer's external memory as

a separate file. Logically linked parts of the table form a relational model.

The following tables form the RSREM's database:

- Initial data tables. These contain information about the real estate (i.e. building and complexes).
- Tables assessing real estate management solutions. These contain quantitative and conceptual information about alternative real estate management solutions: market, competitors, suppliers, contractors, renovation of walls, windows, roof, etc.

To design the structure of a database and perform its completion, storage, editing, navigation, searching and browsing, etc., a database management system was used in this research.

The user seeking for an efficient real estate management solution should provide, in the tables assessing real estate management solutions, the exact information about alternatives under consideration as to the client's financial situation. It should be noted that various users making a multiple criteria analysis of the same alternatives often get diverse results. This may be due to the diversity of the overall aims and financial positions of the users. Therefore, the initial data provided by various users for calculating the real estate management project differ and consequently lead to various final results.

The character of the objective's choice for the most efficient variant is largely dependent on all available information. It should also be noted that the quantitative information is objective. The actual real estate management services have real costs. The values of the qualitative criteria are usually rather subjective though the application of expert's methods contributes to their objectivity.

The interested parties have their specific needs and financial situation. Therefore, every time when the party uses the RSREM they may make corrections to the database according to their aims and their financial situation. For example, a certain client considers the sound insulation of the external walls to be more important than their appearance while another client is quite of the opposite opinion. The client striving to express his/her attitude towards these issues numerically may ascribe various weights values to them that eventually will affect the general estimation of a refurbishment project. Though this assessment may seem biased and even quite subjective, the solution finally made may exactly meet the client's requirements, aims and affordability.

The tables assessing real estate management solutions are used as a basis for working out the matrices of decision-making. These matrices, along with the use of a model-base and models, make it possible to perform a multiple criteria analysis of alternative real estate management projects, resulting in the selection of the most beneficial variants.



## 5.2. Model-base

The efficiency of a real estate management variant is often determined by taking into account many factors. These factors include an account of the economic, aesthetic, technical, technological, comfort, legal, social and other factors. The model-base of a decision support system should include models that enable a decision-maker to do a comprehensive analysis of the available variants and to make a proper choice. The following models of a model-base aim at performing the functions of:

- a model for the establishment of the criteria weights,
- a model for multiple criteria analysis and for setting the priorities,
- a model for the determination of a project's utility degree,
- a model for the determination of a project's market value,
- a model for the recommendations.

According to the user's needs, various models may be provided by a model management system. When a certain model (i.e. search for real estate management alternatives) is used the results obtained become the initial data for some other models (i.e. a model for multiple criteria analysis and setting the priorities). The results of the latter, in turn, may be taken as the initial data for some other models (i.e. determination of utility degree, market, suppliers, contractors, renovation of walls, windows, roof, etc.).

The management system of the model base allows a person to modify the available models, eliminate those that are no longer needed and add some new models that are linked to the existing ones.

Since the analysis of real estate management is usually performed by taking into account economic, quality, technical, technological, legal, social and other factors, a model-base should include models which will enable a decision-maker to carry out a comprehensive analysis of the available variants and make a proper choice. The following multiple criteria analysis methods and models as developed by the authors (Zavadskas *et al.* 1994) are used by the RSREM in the analysis of the real estate management alternatives:

1. A new method and model of complex determination of the weight of the criteria taking into account their quantitative and qualitative characteristics was developed. This method allows one to calculate and co-ordinate the weights of the quantitative and qualitative criteria according to the above characteristics.
2. A new method and model of multiple criteria complex proportional evaluation of projects enabling the user to obtain a reduced criterion determining the complex (overall) efficiency of the project was suggested. This generalized criterion is directly

proportional to the relative effect of the values and weights of the considered criteria on the efficiency of the project.

3. In order to find what price will make a valued project competitive on the market, a method and model for determining the utility degree and market value of projects based on the complex analysis of all their benefits and drawbacks was suggested. According to this method the project's utility degree and the market value of a project being estimated are directly proportional to the system of the criteria and adequately describe them, the values and weights of these criteria.
4. A new method and model of multiple criteria multi-variant design of a project's life cycle enabling the user to make computer-aided design of up to 100,000 alternative project versions was developed. Any project's life cycle variant obtained in this way is based on quantitative and conceptual information.

Application of Recommender System for Real Estate Management (RSREM) allows one to determine the strengths and weaknesses of each phase and its constituent parts. Calculations were made to find out by what degree one version is better than another and the reasons disclosed why it is namely so. Landmarks are set for an increase in the efficiency of real estate management versions. All this was done argumentatively, basing oneself on criteria under investigation and on their values and weights. This saved users' time considerably by allowing them to increase both the efficiency and quality of real estate management analysis.

There is a list of typical real estate management problems that were solved by users:

- Analysis of interested parties (competitors, suppliers, contractors, etc.);
- Determination of efficient loans;
- Analysis and selection of rational refurbishment versions (e.g. roof, walls, windows, etc.);
- Multiple criteria analysis and determination of the market value of real estate (e.g. residential houses, commercial, office, warehousing, manufacturing and agricultural buildings, etc.);
- Analysis and selection of a rational market;
- Determination of efficient investment versions, etc.;
- Providing recommendations.

## 6. Conclusions

Real estate management is an information business. Technological innovation mainly through changes in the availability of information and communication technology

include calculators, analysers, software, neural networks, decision support and expert systems that have been provided by a variety of new services developed by the real estate management sector. Most of all calculators, analysers, software, decision support and expert systems, neural networks seek to find out how to make the most economic real estate management decisions, and most of all these decisions are intended only for economic objectives. Real estate management alternatives under evaluation have to be evaluated not only from the economic position, but take into consideration qualitative, technical, technological and other characteristics as well. Therefore, applying multiple criteria analysis methods and recommender systems may increase the efficiency of real estate management calculators, analysers, software, neural networks, decision support and expert systems. Based on an analysis of existing information, expert and decision support systems and in order to determine the most efficient versions of real estate management, Recommender System for Real Estate Management was developed by authors of the paper. The related questions were also analysed in this paper.

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