Using the hierarchical analysis method for decision making in a business activity

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Abstract. Information technology is widely used in all spheres of human activity. The choice of supplier for small businesses is one of the main tasks of the entrepreneur and has an impact on the success of his activities. For a solution of the problem of the choice of the supplier, this research proposes the use of an automated information system to implement and evaluate the characteristics of suppliers, as well as ranking them. As the mechanism of the choice of the best supplier use of a method of the analysis of hierarchies intended for a solution of problems of the choice of alternatives by means of their multicriteria rating is offered. The developed software system allows to keep records on the receipt, sale and characteristics of the goods, to carry out settlement operations and reporting documentation, as well as to select suppliers who meet all requirements of the entrepreneur, and as a result to conduct business at a higher quality level.

1. Introduction
Now considerable attention is paid to automated systems of support of decision-making in technical [1-3], commercial, organizational and other fields of activity [4-6]. Their application increases labor productivity, automates manual operations of collection of information and execution of documentation [7-9].

The process of supporting decision-making and optimal selection in commercial activity is carried out using economic and mathematical methods [10], fuzzy logic algorithm and software-information support [11]. In the activity, a businessman should make independently the decisions of the choice of the supplier not always leading to a successful outcome because of complexity of coverage of the available set of requirements to importers (suppliers) [3].

Program implementation of a mathematical model of the choice of the supplier for the commercial organization, will allow to use different criteria, to consider their importance and as a result to give full-fledged and comprehensive assessment. The mathematical model is based on use of a method of the analysis of hierarchies for comparison of suppliers by certain criteria. The Method of the Analysis of Hierarchies (MAH) is the systematic procedure for hierarchical representation of the elements defining a key part of the problem. The method consists in decomposition of a problem on more and more simple components and further processing of the sequence of judgments of the person making decision on paired comparisons.

The aim of the article is to show how the developed software system allows not only to keep records of the receipt, sale of marketable products and documentation, but also to rank partners according to their business and commercial qualities.
2. Methodology

Often economic, political, medical, social, administrative problems have several options of solutions. Selecting one solution from a set of possible options, the person making the decision, is guided only by intuitive representations. As selection processes are in many respects similar in different fields of activity, it is necessary to use the universal method of support of decision-making corresponding to the natural course of a human thought [12].

The problem of search of the necessary candidate solution is relevant also when choosing the supplier in a business activity. This is caused by the fact that each supplier sells goods at the determined price specified in the consignment note of delivery (in the order). Information on goods and its characteristics, volume of purchase, cost contains in the order from the supplier. This information, as well as data on sales of goods, are entered in the database of the developed automated information system (AIS) [12, 13].

Due to the limitation of financial means, the businessman needs to carry out periodically contrastive analysis of suppliers by several criteria to be convinced of expediency of continuation of further trade relations. MAH does not order to the person making a decision of any "correct" solution", and allows it to find such alternative which will in the best way be coordinated with his understanding of a key part of the problem and requirements to its solution in an interactive mode.

When using a method of the analysis of hierarchies, as criteria for suppliers the following characteristics were used: delivery cost; terms of execution of the order; minimum size of the order and also criteria of sales: the profit made by the delivered goods; percent of the sold goods in relation to the ordered quantity. On the basis of the analysis of these data the rating of suppliers is formed and the best is selected (figure 1) [13].

![Figure 1. Decomposition of a task.](image)

Implementation of a MAH assumes passing of the following stages.

1. Preliminary ranking of criteria, as a result of which they are arranged in descending order of importance.

2. Pairwise comparing of criteria by importance on a nine-point scale and compilation of a joint matrix of size (n x n).

   The system of pair data brings to the result which can be presented in the form of back symmetric matrix. If in the course of filling of a matrix element $i$ is more important than element $j$, then a cage $(i, j)$, corresponding to line $i$ and column $j$, is filled with an integer number, and a cage $(j, i)$, corresponding to line $j$ and column $i$, is filled with an inverse number (fraction).

3. Filling of the table. This is done line by line with the most important criterion. Integer estimates are applied first. The corresponding fractional estimates are then calculated automatically.

   The more important the ranked criterion, the more integer estimates will be in the corresponding row of the matrix.

   Since each criterion is equal in importance, the main diagonal of the matrix will always consist of units. The sum of the components will be one.
Each component of the normal vector of priorities (NVP) represents the assessment of importance of the corresponding criterion (for example, the first component represents the assessment of the first criterion importance).

3.1 Calculation of an average geometrical matrix in every line

\[
a_i = \sqrt{n} pr_1, \quad a_2 = \sqrt{n} pr_2, \ldots \quad a_n = \sqrt{n} pr_n,
\]

where, \( pr_1 \) – work of elements of the first line; \( pr_2 \) – work of elements of the second line; \( pr_n \) – work of elements of the \( n \) line.

3.2 Calculation of mean geometric sum

\[
\sum a_i = a_1 + a_2 + \ldots + a_n.
\]

3.3 Calculating components of a Normalized Priority Vector (NPV):

the first component \( NPV_1 = \frac{a_1}{\sum a_i} \), the second one \( NPV_2 = \frac{a_2}{\sum a_i} \), \( n \) - component \( NPV_n = \frac{a_n}{\sum a_i} \).

4. Checking the consistency of local priorities by calculating three characteristics.

4.1 Own value of a matrix

\[
\lambda_{max} = \text{sum}_1 \times NPV_1 + \text{sum}_2 \times NPV_2 + \ldots + \text{sum}_n \times NPV_n.
\]

4.2 Index of coordination (IC)

\[
IC = \frac{\lambda_{max} - n}{n - 1},
\]

where, \( n \) – number of lines.

4.3 Coherence relations (CR)

\[
CR = \frac{IC}{IAC},
\]

where, IAC – indicator of accidental coherence, determined theoretically for the case where the estimates in the matrix are represented randomly, and dependent only on the size of the matrix [9].

Matrix scores will be considered consistent if the CR condition \( \leq 10\%-15\% \) is met. If the condition is not met, then they must be recounted.

5. Pairwise comparing of options for each criterion. It is similar to the way it was done for criteria. Consistency of local priorities is checked for each table by calculating three characteristics (fourth step).

6. Defining of the general criterion (priority) for each variant:

\[
C(B_i) = AC_1 \times NPV_1 + AC_2 \times NPV_2 + \ldots + AC_n \times NPV_n,
\]

where, \( AC_1 \) – assessment of \( B_1 \) by the first criterion, \( AC_2 \) – assessment of \( B_2 \) according to the second criterion, \( AC_n \) – assessment of \( B_n \) by unlimited criterion.

In the manner described above, the criteria \( C(B_2), C(B_3), \ldots \) at the same time in expression of \( B_1 \) it is replaced with \( B_2, B_3, \ldots \) respectively. The table is filled out.

7. Determining the best solution for which the value of \( K \) is maximum.

8. Checking of reliability of the decision.

8.1 Calculation of the generalized index of approval (GIA):

\[
GIA = IC_1 \times NPV_1 + IC_2 \times NPV_2 + \ldots + IC_n \times NPV_n.
\]

8.2 Calculation of the generalized coherence relation (GCR):

\[
GCR = GIA / GIAC,
\]
where, GIAC is determined by the table at the level of IAC (indicator of accidental coherence) for matrixes of comparison of options by criteria. The solution is considered reliable if $\text{GIAC} \leq 10-15\%$, otherwise it is necessary to adjust matrixes of comparison of options by criteria.

In figure 2 the scheme of an algorithm of calculation of rating of suppliers is submitted by method of the analysis of hierarchies. Apparently in figure 2, as a result of work of a method of the analysis of hierarchies the choice of the best supplier taking into account the imposed requirements to applicants is implemented. Therefore, use of this method will allow giving to the businessman intellectual support, selecting from a set possible, the best supplier.

![Figure 2. Scheme of an algorithm of a method of the analysis of hierarchies.](chart)

3. Results and discussion

For the implementation of the described algorithm the automated information system was developed for the choice of suppliers which includes assessment of characteristics of suppliers and also the choice of the best method of the analysis of hierarchies with use. During the work with this system use of two access levels is supposed, each of which has the rights:
- the role of the operator is carried out by the seller-cashier;
- the role of the person making a decision is carried out by the individual entrepreneur.

Control object is process of the analysis of sales of goods and drawing up rating of suppliers of these goods. For visualization of work of AIS the chart of options of use of the UML language submitted in figure 3 was used.
The individual entrepreneur is the person making a decision and can implement the following functions: data entry, login, maintaining data on suppliers, data reading from a DB, editing data, maintaining data on orders, the analysis of sales, drawing up rating of suppliers. The seller-cashier can implement login, maintaining data on sales, forming of the sales report. Application of a method of the analysis of hierarchies when choosing the supplier in the conducted research was implemented for automation of a business activity of shops selling footwear. The primary window of an automated information system "Shoe shop" is given in figure 4.

![Figure 3. Chart of options of use.](image)

The main menu of the program consists of the following items: rating of suppliers, sales report, sales registration, receipts of shoe, information of suppliers, and exit (figure 4).

At menu selection of "Receipts of shoe" of the subparagraph "New delivery" the new window with a possibility of creation of laid on delivery and adding of information on goods opens. For viewing and updating available information on suppliers it is necessary to select item of the "Information on Suppliers" main menu (figure 4).
In addition, it is possible to carry out a multi-criteria analysis of shoe suppliers (figure 5). By filter you can choose men’s or women’s shoes, season and suppliers with whom the businessman works. As a result, the rating of firms is displayed depending on the criteria: minimum batch, order completion date, delivery cost, demand for products (ratio sold to delivered), and profit. To improve the visual picture of the results on the left, histograms of the rating of selected supplier firms are shown (figure 5).

![Figure 5. Rating of suppliers.](image)

Figure 6 shows the information maintenance and storage in the database according to the above criteria.

![Figure 6. Calculations.](image)

To view the sales report, one need to select the appropriate menu item, set the product categories from the drop-down list, select the time period and click on the “Show” button (figure 7). The figure 7 demonstrates the results by item name, sales, profit on sale for all firms for the selected period of time and by type of shoe (female, male).

For maintaining reference books, it is necessary to select the corresponding menu item also. Information on shoes category, product characteristics, units of measurements, etc. is kept (figure 8).

The distinctive feature of the article is not only the theoretical description of the used mathematical method, but also its practical implementation in comparison with the works [4, 11-13]. In [11] the method of hierarchy analysis is applied to the algorithm of the system of support of decision-making on selection of a supplier in wholesale trade. The problem is solved in general form with conditional
suppliers and weighting factors. Authors of [4] used the hierarchy analysis method to select a supplier when upgrading the enterprise. Conditional suppliers and selection criteria are considered. The paper [12] describes the mathematical model of method of the analysis of hierarchies for finding weight coefficients without specific reference to practical implementation.

![Sales report](image1)

**Figure 7.** The sales report for the period.

![Reference books](image2)

**Figure 8.** Reference books of the database.

The theoretical approach of solving the problem of finding the best supplier in commercial activity was described in [13]. The calculation was made on conditional data, where the selection criteria were price, quality, payment terms, quantity, and distance to supplier. This article described the mathematical model and its implementation using the developed software system, which allowed one to automate the process of doing business and choosing the best supplier. A distinctive feature was the ergonomic and intuitive user interface, which improves the visual picture of maintaining information and obtaining results. It also had a database that stores all the necessary information for successful business.
The presented software system allows automating the process of doing business and deciding on businessman with suppliers. A distinctive feature is the ergonomic and intuitive user interface, which improves the visual picture of maintaining information and obtaining results, as well as the database, which stores all the necessary information for successful business.

4. Conclusion

The developed software system keeps records and stores information on goods receipt, suppliers, and sales registration. Performs cost and profit settlement, article search, purchase orders, and reporting documents for different time intervals. The database edits and stores information on the category and characteristics of the goods, units of measurement and firms with which the entrepreneur is slave. The software system analyzes suppliers by calculating the rating. It allows you to implement supplier selection according to certain criteria: lot size, delivery time, delivery cost, percentage sale of goods from a specific supplier, profit from sales.

Thus, the developed software system will facilitate the work of a businessman in making decisions on businessman with firms carrying out delivery of commodity products.

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