Hierarchical analysis in optimization of enterprise units

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Abstract. In the article the method of hierarchical analysis as applied to research of functioning of the technical services in industrial enterprise. Formed the hierarchy of objectives that realize the service of production’s technical preparation. The hierarchical model represents the main functions of the enterprise unit that implements the planning of production facilities. The significance of the main functions is determined by several important criteria. Analysis used the matrix of pairwise comparisons and hierarchical synthesis. In calculation we use expert assessments of the individual criteria credibility. Comparison the function’s values with the cost of their implementation allows to detect the mismatch and optimize the department work.

1. Introduction. To gain strategic advantages in the markets of engineering products is a permanent task for the industrial enterprise. This task related to the awareness of the priority of scientific and technical preparation services in the enterprise structure. It is their activity that determines the level of quality and competitiveness of the goods and services offered to the market for industrial purposes. In this regard, an important task is to optimize the organization and management of services of the enterprise on the basis of modern scientific methodologies.

A powerful tool for the implementation of tactical and strategic changes in the organization is the methodology of activity based cost (ABC). It can be used to optimize the various activities and levels of the organization. However, the use of this tool in the field of organization and management is not well developed at the moment. Expediency of this methodology is determined by the possibility of allocation in the management of elementary, repetitive functions, works and operations. It is also important the availability of relevant documentation and regulatory framework [1].

We research possibility of using the ABC instruments on the example of the technological preparation service of machine-building enterprises. This service may be called Department of the chief technologist, DCT; or Bureau of technological preparation of production, BTPP) [2, 3]. These units occupy an intermediate position between the design product development service and production units.

2. Discussion. The main function of this division is to ensure the technological readiness of the enterprise to produce products in a given quality, a given amount and at a certain cost. The consumer of this function is the subsystem of the main production; quality indicators of performance are the following:

- the volume and composition of the set of technological documentation;
- quality of documentation;
- terms of documentation;
- the cost of work on the TPP.

Another main function, which is external, is the organization and management of TPP processes. The use of a functional approach is aimed at optimizing the activities of the DCT to improve the
management efficiency of technological preparation of production [5]. Based on the essence of the subject area, and the requirements for this unit in the enterprise, you can build a tree of goals to improve the organization and management of TPP. This takes into account the statement of the chief technologist’s department of the machine-building plant.

Based on the study of normative documents that regulate the activities of the DCT, it is possible to build a hierarchy and interconnection of works. We based on the target orientation activities of specialists in organization and management of technological preparation. The most significant and deployed here are the following groups of functions:

- development of organizational and technical measures;
- calculation of production capacity;
- development of calendar schedules at the chamber of technological preparation of production [4].

As an example, to illustrate the capabilities of the functional approach to the analysis, let us consider the second functional group. Its hierarchical model is presented in the corresponding scheme (Fig. 1). According to it, the main function $F_1$ is implemented with the help of several basic functions; the output of process is the control information. Each of the main functions, for its part, implies the execution a number of more specific formalized works [5].

Further implementation of the functional-cost approach requires the construction of a combined functional-structural model of the object. This means the establishment of a correspondence between the functions performed and the structural elements that implement these functions. This will allow us to accurately determine the cost associated with the performance of each function. After that it is possible to determine the existing imbalances in the organization of processes (figure 1).

![Hierarchical model of object’s main function](image)

**Figure 1.** Hierarchical model of object’s main function

This feature is implemented by the corresponding function unit which is called Bureau of facilities; that is the part of DCT. The elements that implement those functions are the employees of this division, as well as their computer equipment.

For further calculations, we present the staffing of Bureau (table 1).

**Table 1.** The staffing of the Bureau of facilities.

| Heldpost                      | Number of people | Monthly salary, rub | Sum, rub   |
|-------------------------------|------------------|---------------------|------------|
| 1. Head of Bureau             | 1                | 38000.00            | 38000.00   |
| 2. Principal Engineer         | 1                | 32000.00            | 32000.00   |
| 3. Engineer of 1 category     | 2                | 25000.00            | 50000.00   |
| 4. Technician-technologist    | 2                | 22000.00            | 44000.00   |
Implementation of the considered functions is provided with the use of three automated workstations on the personal computers basis. Their total cost (account with the installed licensed software) is 70000.00 rubles.

The salary of specialists is the main component of the costs for the implementation of the considered functions. To accurately determine the cost of each function, we present a matrix with distribution of functional responsibilities between the employees of this unit. This distribution is characterized by the proportion of time (in percentage) spent by each specialist performing work within each function (table 2):

**Table 2.** Matrix of the functional distribution of work between specialists.

| No | Specialist                     | Prepare initial data | Converting data | Define unbalance | Documented results |
|----|--------------------------------|----------------------|-----------------|------------------|--------------------|
| 1  | Head of Bureau                 | 10.00                | 20.00           | -                | 50.00              |
| 2  | Principal engineer             | 30.00                | 20.00           | 10.00            | 20.00              |
| 3  | Engineer of 1 category         | 20.00                | -               | 30.00            |                    |
| 4  | Engineer of 1 category         | -                    | 40.00           | -                | 30.00              |
| 5  | Technician-technologist        | 40.00                | -               | 30.00            | -                  |
| 6  | Technician-technologist        | -                    | 20.00           | 3000             | -                  |
|    | Subtotal                       | 100.00               | 100.00          | 100.00           | 100.00             |

The time norm for the j work of i object \( t_{ij} \) will be defined as the sum of constant part of it \( t_{cij} \) and the variable \( t_{vij} \), which is determined by the complexity of the managed object.

In order to establish a constant part \( t_{cij} \) of the time expenditure, determined by the specifics of the field of activity, it is necessary to classify the work into routine, formalized and creative. To do this, we apply a functional approach.

At the most General level, it can be selected the following functions implemented in the course of project activities:

- data entry;
- data conversion to the appropriate format;
- analysis of the original data array;
- search for previously saved solutions in the system;
- find acceptable analogues;
- develop / transform solution;
- build possible solutions;
- choose the optimal solution.

In practice, the implementation of these functions involves a different set of operations and tools, in particular software.

In the course of work, implementing the basic functions, repeated a number of basic thinking techniques. For project activities techniques form a set of identical in nature blocks: "input", "process", "output". They are repeated in the course of work, but differ in the volume and complexity of data processing. In this case the complexity depends on the frequency of repetition of elementary operations in the process.

A set of information about the importance of operations and the distribution of their specific weights in the work can be recorded in a special matrix. Then the complexity of the work, and accordingly the constant part of complexity \( t_{cij} \) will be determined by the ratio of combinations of conditions variants on the blocks "input", "process", "output".
Later we will return to the final distribution of the performing functions costs. Now let us turn to the essence of the main functions, and determine their significance relative to the main function [6].

For a more accurate solution of this problem we use a hierarchical approach. In this we determine the significance as a complex criterion, which is concretized through a number of subordinate criteria [7]. The formation of these particular criteria set is an unformalized creative procedure performed by an expert in this subject area, based on the characteristics of a specific task.

In this case, we propose to use three particular characteristics of the functions:
- \( K_1 \) – responsibility;
- \( K_2 \) – difficulty;
- \( K_3 \) – strategic value of results.

Display the appropriate hierarchy for a more visual representation of the task (figure 2):

![Figure 2. Hierarchy for determination of value function.](image)

According to the methodology for the analysis of hierarchical systems it is necessary to make a pairwise comparison of alternatives – in this case alternatives is the main functions – with respect to each of particular criteria. The comparison is carried out in matrices using a generally accepted nine-digit scale, according to which 1 means the equivalence of the compared alternatives, and 9 – the maximum degree of preference of one alternative over another. Fractional values, respectively less than one, are used to indicate the inverse relationship between the alternatives [8].

We present a matrix of paired comparisons (MPC) filled with expert estimates, with the calculated values of eigenvectors. This values determine the ranking of alternative functions for each of the particular criteria:

|     | \( F_{11} \) | \( F_{12} \) | \( F_{13} \) | \( F_{14} \) | \( W_1 \) |
|-----|-------------|-------------|-------------|-------------|---------|
| \( K_1 \) | 1           | 3           | 3           | 1           | 0.381   |
| \( F_{11} \) | -           | 3           | 3           | 1           | 0.381   |
| \( F_{12} \) | 1/3         | -           | 1/3         | 1/2         | 0.103   |
| \( F_{13} \) | 1/3         | 3           | -           | 1/2         | 0.230   |
| \( F_{14} \) | 1           | 2           | 2           | -           | 0.286   |

|     | \( F_{11} \) | \( F_{12} \) | \( F_{13} \) | \( F_{14} \) | \( W_2 \) |
|-----|-------------|-------------|-------------|-------------|---------|
| \( K_2 \) | 1           | 3           | 4           | 5           | 1       |
| \( F_{11} \) | -           | 1/7         | 1/5         | 1           | 0.075   |
| \( F_{12} \) | 7           | -           | 3           | 5           | 0.514   |
| \( F_{13} \) | 5           | 1/3         | -           | 1/4         | 0.211   |
| \( F_{14} \) | 1           | 1/5         | 4           | -           | 0.199   |

|     | \( F_{11} \) | \( F_{12} \) | \( F_{13} \) | \( F_{14} \) | \( W_3 \) |
|-----|-------------|-------------|-------------|-------------|---------|
| \( K_3 \) | 1           | 3           | 4           | 5           | 1/7     |
| \( F_{11} \) | -           | 1/3         | 1/5         | 1/7         | 0.054   |
| \( F_{12} \) | 3           | -           | 4           | 1/4         | 0.265   |
| \( F_{13} \) | 5           | 1/4         | -           | 1/5         | 0.207   |
| \( F_{14} \) | 7           | 4           | 5           | -           | 0.546   |
Next it is necessary to carry out a convolution, or hierarchical synthesis of calculated priority vectors of alternatives, taking into account the different weight of the selected particular criteria as part of the general criterion "the significance of the function". To do this we multiply the matrix composed of the MPC eigenvectors by the vector of particular criteria weights.

In general it can be represented as follows (equation (1)) [9]:

$$\begin{pmatrix}
h_1 \\
h_2 \\
.. \\
h_m
\end{pmatrix} =
\begin{pmatrix}
w_{11} & w_{12} & .. & w_{1n} \\
w_{21} & w_{22} & .. & w_{2n} \\
.. \\
w_{m1} & w_{m2} & .. & w_{mn}
\end{pmatrix}
\times
\begin{pmatrix}
a_1 \\
a_2 \\
.. \\
a_n
\end{pmatrix}
$$

(1)

where $h_i$ – the integral estimate of the i-th alternative, $i = 1...m$;

$w_{ij}$ – evaluation of the i-th alternative by the j-th criterion, $j = 1...n$;

$a_j$ – the weight of the j-th partial criterion in relation to the general evaluation criterion (the vector of weights is normalized, i.e. $\sum a_j=1$).

Expert rate the weights of individual criteria importance of the functions in the following way: A1 = 0.3; A2 = 0.4; A3 = 0.3.

We calculate the ranked vector of integral estimates of the importance of alternatives in MS Excel, using the built-in matrix multiplication function (see figure 3):

![Figure 3. On-screen calculation form in MS Excel.](image)

We get the ranked vector of integral estimation of alternatives:

$$H = (0.16; 0.32; 0.22; 0.33)$$

These values reveal the predominant importance of the second and fourth main functions as part of the main function for the analyzed object.

Next, we must return to the costs of implementing the functions under consideration. Comparison of values of these costs and the significance of the functions will reveal the existing imbalances in the organization of the capacity Bureau work. In the future we will be able formulate measures to optimize it.

In the process of determining labor costs, it is possible to calculate the share of employees in the performance of functions, and the corresponding costs of functions (equation (2)):

$$C_{f_j} = \sum_i C_{f_j}^i, \quad C_{f_j}^i = a_{ij} \cdot L_i$$

(2)

where $C_{f_j}^i$ – cost of the j-th function of the i-th employee;

$a_{ij}$ – share of the i-th employee in the performance of the j-th function;

$L_i$ – average monthly salary of the i-th employee.

Submit the average monthly cost of functions in the following table (table 3) [10]:

| Costs elements | Salary | Social | Amortization of | Total costs |
|----------------|--------|--------|-----------------|-------------|
|                |        |        |                 |             |

[10]
Functions & contributions

| Function                  | AWP  |
|---------------------------|------|
| Prepare initial data      | 10800.00 |
| Converting data           | 14200.00 |
| Define unbalance          | 14100.00 |
| Documented results        | 1280.00  |
| Subtotal                  | 48300.00 |

Should now calculate the values of specific relative functional costs and build the chart "importance – costs", which graphically displays the results obtained (equation (3)):

\[
Z_i = \frac{z_i}{h_i}
\]  

(3)

where \( z_i \) – specific relative costs to 1 point of the importance of the \( i \)-th function;  
\( Z_i \) – relative total cost of the \( i \)-th function, as a proportion of the total cost.

Substituting the previously obtained values, we have the following values:  
\( z1 = 1.46; \quad z2 = 0.96; \quad z3 = 0.98; \quad z4 = 0.78. \)

3. Conclusion. Results are graphically submitted for drawing (see figure 4):

![Figure 4. Diagram «Importance – Costs»](image)

Obviously mismatch in the ratio of cost and importance for the first and fourth functions. To solve this problem, it is necessary to optimize the processes of the relevant work, to redistribute responsibilities between employees, to unify the documentation used.

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