Application of OLAP-technology in decision support system for enterprise management

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Abstract. The work is devoted to the study of methods for increasing the profitability of an enterprise based on management decisions that are close to optimal. It is shown that the enterprise, as an abstract control object, integrates at least four components: buildings, facilities and utilities, production facilities, financial and material stocks and personnel. Moreover, each of these components of the production system has its own management system, and enterprise management, therefore, is carried out at the second level of the hierarchy. Since the levers of direct control of the production system are managed by the first-level control systems, parametric, structural and organizational changes become the control actions at the second level and the main tasks of management are the competent redistribution of managerial resources between these influences. Relying on the presentation of information in the form of a hyper cube and taking advantage of the fact that all solutions lie on the plane of equal contributions, and then, taking it as the coordinate plane for counting the utility function, one can reasonably find points on this plane with a resource distribution close to optimal by maximizing this feature.

1. Introduction
In modern conditions, characterized by increasing fierce competition and the instability of economic conditions, increased demands are placed on production management with regard to the efficiency and quality decisions at all levels of the hierarchy. At the same time, the amount of information that needs to be taken into account for the formation of optimal informed decisions is steadily growing and it becomes impossible to effectively manage without the use of modern means of information support.

At high levels of the hierarchy, management is largely associated with the decision-making procedure and, in particular, with the process of redistributing control resources.

On the other hand, enterprise management refers to a special section of management theory - the management of abstract objects [1]. To optimize it, it is necessary to conduct a deep system analysis of the problems arising in this case.

2. Theory
Behind the concept of an enterprise is not hiding any one object. This concept is integrally displayed from at least four material carriers: buildings, structures and utilities, production facilities, financial and material stocks and personnel, which drives this entire production system. And, since the enterprise itself cannot be influenced as an abstract mapping, just as its state can be assessed, all these procedures must be mapped onto the indicated material media. Let us consider in more detail how the corresponding operators of actions and state estimates are formed.
Imagine the process of functioning of the enterprise in the form of a two-level system. The corresponding composition and the relationship of its elements are shown in Figure 1.

**Figure 1.** Diagram of a two-level enterprise management.
The classical notation is applied here: for vectors of controlled quantities - $\mathbf{Y}$, control and disturbing actions, respectively - $\mathbf{U}, \mathbf{F}$. The circuit depicted in Figure 1 can be described by operator equations

$$\mathbf{Y}_i = W^U_i \cdot \mathbf{U}_i + W^F_i \cdot \mathbf{F}_i, \quad i = 1,2. \quad (1)$$

Here $W^U_i$ and $W^F_i$ are the transfer functions of the control system with respect to control and disturbing actions, respectively.

If at the first level controlled quantities, controlling and disturbing influences are most often real, physically measurable, then at the second level of control special operators are necessary for their formation

$$A[\mathbf{Y}_1, \mathbf{V}] = W^U_2 \cdot \mathbf{B}[P, S, Org] + W^F_2 \cdot C[\mathbf{F}_1, \mathbf{X}], \quad (2)$$

Here, respectively, it is indicated: $A[\mathbf{Y}_1, \mathbf{V}]$ - operator of forming the level of profitability $\mathbf{Y}_2$ of the enterprise ($\mathbf{V}$ - additional indicators, characterizing the flow of the process, affecting profitability), $B[P, S, Org]$ - operator that integrates the changes and impacts in the production system, with the aim of increasing the profitability of the enterprise, $C[\mathbf{F}_1]$ - a second-level operator that generates disturbing effects on the corresponding control objects.

From the above formulas, the need for a systematic analysis of the formation of the action operators, both the control B and the disturbing C, as well as the level estimation operator of the controlled quantity A.

Since at the first level all control levers are managed by the corresponding system of the first level, at the second level of influence they are reduced to parametric, structural and organizational changes in the production system. The sizes allocated to each of the three listed types of changes (impacts) of resources are precisely the subject of the decision-making procedure and optimization [2] at the enterprise management level. These actions by the operator B are converted into control actions of the second control level. An integration scheme defining this operator can be proposed. Here we need some equivalent for heterogeneous changes, for example, expressed in unit costs of each type of change. Then the control action can be determined by the formula

$$U = \varepsilon_1 \cdot P + \varepsilon_2 \cdot S + \varepsilon_3 \cdot Org. \quad (3)$$

Here $\varepsilon_1, \varepsilon_2, \varepsilon_3$ are dimensional coefficients that reflect the corresponding share of resources allocated to a unit of parametric, structural and organizational impact on material carriers, which are combined by the concept of an enterprise.

The level of profitability of the enterprise $\mathbf{Y}_2$ is formed as the difference between income received in the market and expenses incurred in the production of sold products. It can be evaluated in many ways. Examples of such operators can be additive, multiplicative, or combined convolution. For example, the level of profitability can be determined by the sum

$$Y = \sum_{i=1}^{N} \alpha_i Z_i, \quad (4)$$

where $\alpha_i$ - weighting factors, $Z_i$ - values determining the level of profitability of the enterprise parameters.

However, this method of evaluation does not give zero, even if some constituent element of the production system, even the most important, is completely out of order and the output value in this case can have a zero value. In this case, the multiplicative method helps, in which the equality to zero of even one indicator resets the security level

$$Y = \beta \prod_{i=1}^{N} Z_i. \quad (5)$$

Here $\beta$ is the coefficient equalizing the dimension.

But in these two cases, the assessment of the level of profitability sometimes has an unacceptably large dynamic range. If the level of performance of each element of the entire system is important, you can mitigate the assessment using a method that can be called averaging

$$Y = \gamma_1 \sum_{i=1}^{N} \alpha_i Z_i + \gamma_2 \prod_{i=1}^{N} Z_i, \quad (6)$$

where $\gamma_1, \gamma_2$ are coefficients equalizing the dimension.
Thus, the decision-making procedure during enterprise management is reduced to identifying the shares of management resources associated as a limitation by formula (3), aimed at increasing the profitability of the enterprise, estimated by one of formulas (4) - (6).

The decision-making procedure itself can be carried out using one of the criteria convolution methods [3]. A sufficiently large number of methods is based on the construction of a utility function [4]. There are quite powerful interactive procedures in which the decision maker makes decisions in collaboration with computer algorithms [5,6]. Finally, many methods are based on the search for Pareto-optimal domains [7]

3. Model

From figure 1 it follows that even with a simple uniform distribution of control resources, they should be divided into at least 12 parts. In this case, it is more convenient to represent this procedure in a multidimensional space with the same number of coordinates, that is, use OLAP technologies and present the information in the form of a hypercube [8-15].

Moreover, each share is deposited on the corresponding coordinate axis and, since the amount of funds allocated for management is known in advance, the sum of all shares for any distribution should lie on the so-called plane of equal contributions.

Studying this statement of the problem, we notice that points with the same sum of coordinates are located on the hyperplane described by the equation

$$\sum_{i=1}^{n} x_i + D = 0$$

A distinctive property of this formula is the unit coefficients for all coordinates.

For two coordinates, this property has a straight line passing at an angle of 45 degrees to the coordinate axes. On such a straight line for each point, an increase in one coordinate leads to an equal decrease in the other, so that the sum will be saved.

Similar reasoning in three-dimensional space leads to a plane inclined at equal angles to all coordinate planes.

On the other hand, the geometrical place of the points having the same relationship between the coordinates will be a ray coming from the origin described by the equation

$$x_i = tx_{Ai}$$

where $x_{Ai}$ are the components of the radius of the vector defining the ray, $t$ is an arbitrary parameter that allows us to run along this ray.

If it is possible to determine the optimal distribution of control resources and, therefore, the ray of optimality, then decision-making will be reduced only to constructing a plane of equal contributions and finding the point of intersection of it with this ray. All these planes are parallel to each other and move away from the origin in proportion to the volume of allocated funds [16, 17].

As shown above, large-scale resources must be divided into three shares in accordance with their direction on parametric, structural and organizational changes in the system. Figure 2 shows the resources allocated for changes: 1 - parametric, 2 - structural and 3-organizational. The plane of equal contributions intersecting with the coordinate planes has the shape of an equilateral triangle.

We will allocate resources using the utility function, in this case it can be built on the plane of equal contributions as on the coordinate. The position of its maximum can be determined from the point of equal shares - A. Obviously, the least amount of resources is spent on parametric changes, so we go down on the plane of equal contributions below the BC line. Further we push from the center of the remaining area of the triangle - point D. Dividing this area in half, we find the centers of trapezoid E and F. Now the decision maker should choose from two alternatives: a radical change in the structure of the production system with a large effect (point F), or organizational changes with the previous structure and, accordingly, with less effect (point E).
4. Data and Method
Since the magnitude of the fractions is determined in relative units, we can designate the side of the equilateral triangle $a$ and calculate the whole geometry through it. The calculated data are summarized in Table 1.

| Section | PR  | PQ  | AD  | DE  | 0E  |
|---------|-----|-----|-----|-----|-----|
| Value   | $a$ | $a\sqrt{3}/2$ | $a\sqrt{3}/12$ | $5a/12$ | 0.465$a$ |

The final coordinates are presented as a histogram in Figure 3 for point E. For point F, the height of the columns remains the same, only resource numbers are changed.

5. Results and discussion
As follows from Figure 3, the difference in the shares between the resources on the parametric and structural effects was not so significant. The largest share of resources is allocated to organizational changes, that is, the decision-maker goes here along the path of creating the most favorable conditions, avoiding fundamental changes in the production system. For a real operating system, this path is most rational.
6. Conclusion
Thus, the use of OLAP technologies in the decision support system for enterprise management with the presentation of information in the form of a hypercube allowed us to offer a simple way to approach the maximum utility function. Thanks to the allocation of resources to parametric, structural and organizational changes in the production system close to optimal, it is possible to increase the profitability of the enterprise.

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