Modelling of information systems with increased efficiency with application of optimization-expert evaluation

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Abstract. The paper is associated with the management of information systems to improve the efficiency of their activities. The approach takes into account the modern capabilities of information monitoring of the performance of management objects, rating information systems. It is proposed to develop a set of problem-oriented modeling and optimization procedures. They are based on the results of monitoring and rating assessments, which ensure the adoption of managerial decisions to improve the efficiency of information system objects. The structure of the system for managing the effectiveness of the objects of information systems has been formed. To develop models and algorithms for making managerial decisions on planning the increase in efficiency based on optimization and expert evaluation.

1. Introduction

In order to create a promising option when planning information systems, it is first necessary to set the function of changing the effectiveness for the planning period [1, 2]. The way this function is specified affects the structure of the optimization model and the algorithmic procedure for solving the optimization problem. When searching for a multi-step solution for the entire planning period, there is ambiguity in fulfilling extreme and boundary requirements, which leads to many options for managerial decisions.

Multivariance requires the use of expert judgment to make the final decision [3]. Evaluation by an expert group allows you to rank options by importance to increase efficiency. For the effective functioning of the subsystem of intellectual decision-making support, it is necessary to optimize the distribution of additional costs to achieve conditions for increasing the efficiency of the information system and form the final expert assessment [4]. In this case, verification of the optimal nature of management decisions is carried out by comparing the rating of the information system with rating estimates of the activities of a number of information systems and positioning on rating scales.

This paper presents an investigation of increased efficiency of information systems with application of optimization-expert evaluation.

2. Formation of an optimization model when planning to increase the efficiency of information systems

We will consider the creation of optimization models with two methods for setting the function of
changing the efficiency, when the planning boundary $T + t_1$ is set, here $t_1 = \overline{T}, \overline{T}$ are the numbers of time periods with the upper boundary $T_1$. There may be two options:

Carrying out calculations of how the efficiency changes with the growth of costs during the time period $t_1 = 1, T_1$ and sequentially set performance values that are planned for each of the time periods [5, 6].

We proceed from the fact that, based on model (1), it is possible to make a forecast based on the estimated effectiveness

$$Z = \varphi_x(z, t), \tag{1}$$

where $z$ are costs. For a given planning boundary $T + t_1$, with the corresponding costs $z_{t_1}, t_1 = \overline{T}$, located in the interval $0 \leq z_{t_1} \leq z^0, t_1 = \overline{T}$. In this case, the function values are calculated

$$\varphi_E(z_{t_1}, t_1), \forall t_1 = 1, T_1. \tag{2}$$

Based on what the form of the resulting function will be, we can draw conclusions about the characteristics of the change in efficiency during the period $t_1 = 1, T_1$.

Based on this information, using an expert approach, you can define functions that show an accelerated change in efficiency. On their basis, volumes are optimized that lead to an increase in income, so that there is no excess of the amount of expenses indicated under such conditions $z^0$

$$\sum_{t_1} z_{t_1} \leq z_0. \tag{3}$$

Let the accelerated change functions be denoted as follows

$$\varphi_{t_1}^{E}(z_{t_1}), \tag{4}$$

here the index $t_1$ illustrates that the function has values that relate to the values $z_{t_1}$ over the range $0 \leq z_{t_1} \leq z^0$.

Let us define the relative values of the variables $\hat{z}_{t_1}$ and function (5):

$$\hat{z}_{t_1} = \frac{z^0 - z_{t_1}}{z^0} \cdot 100\%, \tag{5}$$

$$\varphi_{t_1}^{E} = \frac{\varphi_{t_1}^{E} - \varphi_E(T)}{\varphi_E(T)} \cdot 100\%, \tag{6}$$

here $\varphi_E(T)$ is the value of the performance indicator that the information system reached when the $T$-th time period ends.

Variables (4) are characterized by integer values lying inside the interval

$$0 \leq \hat{z}_{t_1} \leq \hat{z}^0, \tag{7}$$

here $\hat{z}^0 = \frac{z^0 - z(T)}{z(T)}$,

$z(T)$ — the amount of costs leading to the fact that revenues are growing by the end of the $T$-th period.

How the function (5) changes will be predicted as a managerial decision over the interval

$$0 \leq \hat{\varphi}_{t_1}^{E} \leq \hat{\varphi}^0_{t_1}, \tag{8}$$

this gives an S-shaped function [7].

The rate of change of function (6) will be different for different intervals (5). At the same time, revenue growth can be partially or fully offset by rising costs.

Based on the indicated administrative management decision, at which intervals (6), (7) and characteristics of the dependence of efficiency at such intervals for each of the time periods are set, there is the possibility that the optimal process for changing the volume of costs that lead to growth income, due to the fact that the maximum is ensured for the overall increase in efficiency [8] over the entire time
Such an optimization model still needs to be supplemented by restriction (3) and the requirement that \( \hat{z}_{t_1} \) is not negative:

\[
\sum_{t_1}^{T_1} \hat{z}_{t_1} = z^0, \quad z_{t_1} \geq 0, \quad t_1 = 1, T_1.
\] (10)

Then (9) and (10) together lead to the problem of separable programming.

3. The results of modelling

Let’s look at an example of how such a task will be solved in the case of planning for 3 time periods.

When solving the optimization problem, it is necessary to calculate the values \( \hat{z}_1, \hat{z}_2, \hat{z}_3 \), when given \( \hat{z}_0 = 6\%, \hat{\phi}^0 = 7\% \) and there are some values of S-shaped functions \( \hat{\phi}^1(x_1), \hat{\phi}^2(x_2), \hat{\phi}^3(x_3) \), while \( \hat{\phi}^0 = 7\% \), for partially compensated costs, and \( \hat{\phi}^0 = 5\% \) for fully compensated costs. Then such an optimization model is formed:

\[
\hat{\phi}^1(\hat{z}_1) + \hat{\phi}^2(\hat{z}_2) + \hat{\phi}^3(\hat{z}_3) \to \max_{\hat{z}_1,\hat{z}_2,\hat{z}_3}, \quad \hat{z}_1 + \hat{z}_2 + \hat{z}_3 = 6, \quad z_1,z_2,z_3 = 0,1,2,3,4,5,6.
\] (11)

We give the results that result from a multi-step process of making optimal decisions. It is determined based on the state vector at the \( k \) -th step

\[
v_k = (v_{k1}, v_{k2}, ..., v_{kt_1}, ..., v_{kt_1}),
\]

here \( 0 \leq v_{k1} \leq \hat{z}_0 \), and there is a function \( f_k(v_{k+1}) \).

- For \( k = 1 \) it turns out \( f_1(p_2) = \max_{0 \leq \hat{z}_1 \leq \hat{z}_0} \hat{\phi}^1(\hat{z}_1) \).

If we consider certain values \( v_2 = 0,1,2,...,6 \) of the function \( \hat{\phi}^1 \) and the variables \( \hat{z}_1 \), then they are given in table 1.

Table 1. Results of the first step in a multi-step adoption process optimal solutions.

| \( v_2 \) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|----------|---|---|---|---|---|---|---|
| \( f_1(v_2) \) | 0 | 0.5 | 1 | 3 | 6 | 6.5 | 7 |
| \( \hat{z}_1(v_2) \) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

- When \( k = 2 \), optimal solutions of the set of one-dimensional problems are determined

\[
f_2(v_3) = \max_{0 \leq \hat{z}_2 \leq v_3} [\hat{\phi}^2(\hat{z}_2) + f_1(v_3 - \hat{z}_2)].
\]

The results are given in table 2.

Table 2. Results of the second step in the multi-step adoption process optimal solutions.

| \( v_3 \) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|----------|---|---|---|---|---|---|---|
| \( f_2(v_3) \) | 0 | 0,5 | 1 | 3 | 6 | 6.5 | 7 |
| \( \hat{z}_2(v_3) \) | 0 | 0,1 | 0,1 | 0 | 0 | 0,1 | 0,1 |

Then, with \( v_3 = 1,2,5,6 \), the optimal value \( \hat{z}_2(v_3) \) will have more than one value:

\[ \hat{z}_{2,1}(v_3) = 0, \hat{z}_{2,2}(v_3) = 1. \]

- When \( k = 3 \), a solution to the one-dimensional optimization problem is found for a fixed value \( v_4 = z^0 = 6 \):
\[ f_3(v_4) = \max_{0 \leq z_3 \leq v_4} [\phi^3(\hat{z}_3) + f_2(v_4 - \hat{z}_3)]. \]

Function \( f_3(v_4) \) will be a multi-extreme function. It has the largest value of 7, when the following values are \( \hat{z}_3(v_4) \):
\[
\hat{z}_{3,1}(6) = 0; \hat{z}_{3,2}(6) = 1; \hat{z}_{3,3}(6) = 2; \hat{z}_{3,4}(6) = 4; \hat{z}_{3,5}(6) = 5; \hat{z}_{3,6}(6) = 6.
\]

Let us consider the first value as optimal

\[ \hat{z}_3^* = \hat{z}_{3,1}(6) = 0. \]

In this case, the state variable will equal

\[ v_3 = v_4 - \hat{z}_3^* = 6 - 0 = 6. \]

From the table 2 it turns out that for \( v_3 = 6 \) the value of the function \( f_2(v_3) = 7 \) and \( \hat{z}_2^* = \hat{z}_{2,1}(v_3) = 0 \) or \( \hat{z}_2^* = \hat{z}_{2,2}(v_3) = 1 \). Due to the ambiguity, it is necessary to build a tree of optimal solutions (table 3, figure 1).

**Table 3.** Many solutions for optimizing the effectiveness of information systems for a given planning interval.

| A bunch of decisions | \( \hat{z}_1^* \) | \( \hat{z}_2^* \) | \( \hat{z}_3^* \) | \( \phi^3(\hat{z}_1^*) \) | \( \phi^2(\hat{z}_2^*) \) | \( \phi^3(\hat{z}_3^*) \) |
|---------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1                   | 6               | 0               | 0               | 7               | 0               | 0               |
| 2                   | 5               | 1               | 0               | 6,5             | 0,5             | 0               |
| 3                   | 5               | 0               | 1               | 6,5             | 0               | 0,5             |
| 4                   | 4               | 1               | 1               | 6               | 0,5             | 0               |
| 5                   | 4               | 0               | 2               | 6               | 0               | 0               |
| 6                   | 2               | 0               | 4               | 1               | 0               | 6               |
| 7                   | 1               | 1               | 4               | 0,15            | 0,5             | 6               |
| 8                   | 1               | 0               | 5               | 0,5             | 0               | 6,5             |
| 9                   | 0               | 1               | 5               | 0               | 0,5             | 6,5             |
| 10                  | 0               | 0               | 6               | 0               | 0               | 7               |

The scheme for creating a variety of management decisions to optimize the effectiveness of the information system for given planning time intervals is shown in figure 2.

**Figure 1.** Tree of optimal solutions for \( \hat{z}_3^* = 0 \).
Thus, we have $n_1 = \overline{1, N}$ options for management decisions to increase the cost to increase the level of efficiency for each planning interval $t_1 = \overline{1, T_1}$

$$z_{t_1n} = z(T)(\dot{z}_{t_1n} - 1) \quad (12)$$

4. Optimization results based on rating

The optimization results were analyzed using rating assessment of the information system and other information systems [9, 10]. For this, a primary information base was formed.

The primary information indicators matrix is supplemented by the fact that the system indicators [11-13] are ranked, they are calculated based on the formula

$$\Pi_i = \sum \Pi_{ij} \quad (13)$$

here $\Pi_{i_0}$ is an indicator of the $i$-th rating indicator of the rating system ($s$); $\Pi_{ij}$ is an indicator in the $i$-th rating indicator of the $j$-th ranking subject $z$.

Performance indicators of information systems are given in table 4.

![Diagram](image)

**Figure 2.** The scheme for creating many decisions related to optimizing the effectiveness of information systems.
Table 4. The structure of the primary information base by indicators activities of ranking entities and systems

| Subjects of ranking | Performance indicators |
|---------------------|------------------------|
| Information system_1 | П_1 П_2 П_3 П_4 П_5 П_6 П_7 П_8 П_9 |
| ...                 |                        |
| Information system_j | П_j П_j П_j П_j П_j П_j П_j П_j П_j |
| System              | ΣП_j ΣП_j ΣП_j ΣП_j ΣП_j ΣП_j ΣП_j ΣП_j |
|                     | 10.7 11.68 11.73 11.98 12.15 12.67 13.57 14.86 15.96 |

The following are the values of rating indicators:

\[ P_{nj} = \frac{\bar{y}_j}{\bar{y}_j} \]

The calculation results of rating indicators for each thematic area can be presented in Table 5.

Table 5. Rating indicators

| Subjects of ranking | Rating indicators |
|---------------------|-------------------|
| Information system_1 | P_1 P_2 P_3 P_4 P_5 P_6 P_7 P_8 P_9 |
| ...                 |                   |
| Information system_j | P_j P_j P_j P_j P_j P_j P_j P_j P_j |
| System              | ΣP_j ΣP_j ΣP_j ΣP_j ΣP_j ΣP_j ΣP_j ΣP_j |
|                     | 5.7 5.88 6.75 7.41 7.17 7.69 7.77 7.96 7.98 |

Next, the ranking coefficients of ranking subjects and the system are calculated. This parameter is considered as the ratio of rating indicators of ranking subjects to the corresponding rating indicators of the system according to the formula:

\[ K_{nj} = \frac{P_{nj}}{P_n} \]

where \( K_{nj} \) is the significance coefficient of the j-th rating indicator of the j-th ranking subject.

Based on the results, an analysis is made of the positioning of information systems on rating scales. Positioning of ranking subjects on rating scales makes it possible to verify the results of optimization of information systems management processes and assess the expected risks in the forecasted period.

5. Conclusion

The analysis of ways to optimize the management of the effectiveness of information systems based on monitoring and rating assessment and decision making is given. Proposals are given for a system for managing the effectiveness of information systems, some examples are shown.

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