Approach to evaluating the organizational effect of the intelligent technological control system

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Abstract. The article considers the issues of evaluating the organizational effect of the intelligent decision support system functioning for the control of complex technical systems. An approach to the indicator formation of the organizational effect of the intelligent system functioning at the level of a technological control system is proposed. A diagram illustrating the proposed approach is presented. It combines, an organizational goal and objectives of introducing an intelligent system, its main functional capabilities, a system of factors that significantly affect the magnitude of a positive effect, a system of sources used to implement certain factors, qualitative assessment criteria potential positive effects from the implementation of the system, the system of indicators of the organizational effect and mathematical models and methods of their calculation by cause-and-effect relationships. A comparative evaluation method was applied to determine the organizational effect of the intelligent system functioning. It is based on the values comparison (difference) of the generalized indicators of the effect of the technological control system functioning with and without the intelligent system. In comparison with the existed methods, the proposed approach to evaluating the effectiveness of an intelligent decision support system is based on a hierarchical system of indicators characterizing the organization of the technological control system for complex technical systems. The obtained theoretical results can be applied in the development and implementation of information systems to evaluate the preliminary, potential, planned and actual effect and organizational efficiency.

1. Introduction
The improvement of existed intelligent decision support systems (IDSS) and the emergence of new ones in science-intensive industries necessitate the development of scientific and methodological support for multi-aspect and multi-level analysis and efficiency evaluation, various types of effects and the efficiency of their functioning at all stages of the product life cycle (LC). The instrumental approaches to solving the problems of evaluating characteristics of IDSS are a constant subject of research [1-8]. Meanwhile, the scientific community does not have generally accepted universal mechanisms for such an evaluation in this field. At the same time, there exist significant methodological problems such as identification, analysis and evaluation of various nature effects distributed in time. Also, we have problems of the indicators system development for their evaluation that satisfies the requirements of compliance with the goal, understanding and application, as well as, the absence of redundancy. The main emphasis of research and practice is paid on the consideration of the economic and technical...
aspects of evaluation. The problems concerning the effects evaluation associated with improving the organization of activities (organization of management, work processes, advanced training of personnel) both of the enterprise as a whole and at the level of its structural divisions, long-term goals and the difficulty of expressing them in value form remain insufficiently studied. One of the urgent tasks of this work is to develop a model for evaluating the organizational effect (OE) of the IDSS functioning for the complex technical systems control (CTS) [9], which makes it possible to assess at the level of the technological control system (TCS). This goal is achieved by determining the main features of the IDSS implementation in terms of evaluating the organizational effect of its functioning, developing an approach to the formation of a generalized indicator of the organizational effect of the intelligent system functioning at the level of the technological control system.

2. Principle part
The organizational effect of the IDSS functioning is understood as an evaluative characteristic of the useful result obtained due to its implementation in the production process and leading to the improvement in indicators characterizing the enterprise’s organization at various structural levels. The development of the indicators system of the IDSS organizational effect is related to the specificity of the subject area, i.e., goals and objectives of implementation, the functionality and conditions for the intelligent system implementation, requirements of various stakeholders, the basic principles of evaluating the innovative projects’ efficiency and new methods. The main feature of evaluating the information technologies implementation is a problem of obtaining a cost estimation of the effects in the short term, since information processes have a direct impact not on a specific result, but on the intellectual and information processes associated with human activities, adding a factor of uncertainty to the cost relationship between the use of IDSS and the results of the activities.

The paper considers the issues of organizational evaluation on the example of IDSS for the control of CTS with a long-life cycle; their detailed description is given in [9]. The application of IDSS in TCS allows providing personnel with valuable (representative, objective, relevant, forehanded, accessible, useful, protected) information formed on the basis of information objects contained in the database (DB) [9], the knowledge base (KB) [9-11] and user’s requests. An information object means a description of a product, processes and resources in the form of text documents, drawings, pictures, graphs, photographs, formulas, tables, algorithms, numerical data, knowledge, etc., stored on digital media for performing certain actions on it in computer environments. However, the dynamics and terms of achieving the values of the basic indicators for different indicators are different and they are determined by the influence of both subjective and objective factors, for example, the filling speed, the database and knowledge base of IDSS updating. Thus, the speed of achieving the planned values of the effects associated with the database application to provide personnel with the reference information is significantly higher than the application of a knowledge base for analytical data processing, due to the peculiarities of training knowledge base models [10, 11]. Hence, it is necessary to take into account the temporal aspect of evaluating the indicators of effects concerning the short- and long-term prospects, the multistage evaluation with different depths of analysis throughout the entire life cycle of the product, taking into account the uncertainties and risks when determining and adjusting the values of the basic indicators for comparison. Four types of organizational effect and its indicators are identified depending on the stage the IDSS is located at; they are preliminary, potential, planned and actual. The preliminary effect from the implementation of IDSS is calculated at the pre-design stage of the life cycle at developing a feasibility study for the IDSS development intended for a potential customer. The initial data for calculating the predictive estimation of the preliminary effect are calculated by experts. The potential effect is calculated at the end of the technical documentation development for the product based on the results of the research tests of the models and predictive experts’ evaluations. After preliminary and acceptance tests of the prototype, the planned effect is determined. The initial data for calculations are planned indicators of the IDSS application. The actual effect of the IDSS functioning is regularly calculated at the stage of implementation and maintenance based on the results of application in operational conditions. The evaluation accuracy of the organizational effect increases with the
transition to the next stage of the life cycle due to a more detailed evaluation of the dynamics of the analysed indicators, factors affecting the change in the magnitude of the organizational effect, the results of corrective measures proposed as part of the plan for the transition from processes "as is" to processes "to be".

The authors propose to evaluate the organizational effect of IDSS \( E_{AO} \) on the basis of a comparative approach to the evaluation of solution variants that are alternative to ensure the production of specific products with certain characteristics in a given volume, according to the formula:

\[
E_{AO} = E_{AO}^1 - E_{AO}^2, \quad (1)
\]

where \( E_{AO}^1, E_{AO}^2 \) are the organizational effects of the functioning of the TCS with and without the IDSS application.

The selection of indicators for the complete, comprehensive and efficiency evaluation of the organizational effect of the IDSS functioning requires the analysis of the changes made to the control technology, represented a potential source of benefits. The implementation of the effective consideration of these changes is a diagram presented in figure 1. It illustrates the proposed approach to the formation of a generalized indicator of the organizational effect of the intelligent system functioning at the level of the technological control system. The purpose and tasks of introducing an intelligent system in the TSC are in direct connection with the industry specificity of the enterprise, the peculiarities of its state and functioning. In accordance with the purpose and objectives of implementation, the functionality of the IDSS is determined. The intelligent system implementation is accompanied by changes in the TCS related to its functionality expansion. The IDSS application in the control system leads to the factors that increase the organizational effects of the TCS functioning, creating conditions for obtaining a useful result. Table 1 shows the classification and systematization of factors in order to provide an integrated and systematic approach to the study their impact on the changes in organizational indicators. Table 2 classifies the sources of organizational effect. They are a set of resources available for application (the existed or generated ones) that can be implemented by the developed IDSS. The influence of the combination of the factors considered and the resources used is accompanied by the manifestation positive organizational effects. As efficiency criteria for evaluating potential positive effects from the implementation of the system, it is possible to single out:

- increase in labor productivity;
- reduction in labor, material and time costs;
- quality of the work improvement;
- optimization of personnel work;
- increase in a degree of control operations automation;
- optimization of access to effective information for all participants of the product’s life cycle.
On the basis of efficiency criteria for evaluating organizational effects, a four-level system of quantitative indicators presented in table 3 is formed.
Table 1. System of factors increasing the organizational effects of the TCS functioning.

| High-level factors                        | Factors of the 2\textsuperscript{nd} level                                                                 |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Improvement of management organization    | Automation of preparation for making management decisions                                               |
|                                           | Automation of the updating information process about a product, processes and resources within a lifecycle |
|                                           | Reduction in the level of uncertainty in decision making                                                 |
|                                           | Improvement of the quality of management decisions                                                      |
|                                           | Increase in the level of information security                                                            |
| Improvement of the work organization      | Increase in the level of information support                                                              |
|                                           | Increase in the level of communication support                                                            |
|                                           | Rational use of labor and material resources                                                              |
|                                           | Improvement of the labor division and cooperation through the organization of a unified information environment for cooperation |
|                                           | Increase in the degree of compliance of the qualification level of personnel with the work performed     |
| Professional development of personnel     | Formalization and replication of expert knowledge                                                        |
|                                           | Improvement of the qualifications and competence of personnel by providing quick access to valuable information about the product, processes and resources, integrated within the product life cycle |
|                                           | Increase in the level of perception, understanding and assimilation of information by providing visualization of analytical and reference information (decision processes, decisions, data, knowledge, documents, technical literature, etc.) |
|                                           | Improvement of the technical level of personnel through experience with the information system            |

Table 2. System of sources for increasing organizational effects of the TCS functioning.

| High-level sources                        | Sources of the 2\textsuperscript{nd} level                                                                 |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Decision making quality improvement      | Increase in the depth and efficiency of analytical calculations                                         |
|                                           | Increase in the composition, completeness, detail and types of information applied                      |
|                                           | Increase in the efficiency, urgency, relevance and reliability of the information received by comparing data from various sources |
|                                           | Reduction in the influence of the human factor on decision making through the use of mathematical methods and models |
|                                           | Improvement of the validity, completeness, clarity and clarity of decisions                             |
|                                           | Reduction in the risk of wrong decisions                                                                |
| Rational use of resources                | Reduction in lost working time by eliminating routine and automating complex operations                |
|                                           | Eliminate duplication of effort in obtaining effective information                                      |
|                                           | Reduction in the burden on staff and requirements for their qualifications                             |
|                                           | Reduction in material costs associated with the involvement of freelance specialists, production, copying, delivery and storage of documents |
|                                           | Reduction in the costs associated with recruiting, training and training personnel                      |
|                                           | Reduction in the duration of staff training                                                              |
| Reduction the complexity of operations   | Reduction in the cost of collecting, processing, storing and transferring the information             |
|                                           | Reduction in the cost of analysed problems and synthetised solutions                                     |
**Table 3.** Hierarchical system of the organizational effects indicators of the TCS functioning.

| Generalized high-level indicator | Complex indicators of the 2nd level | Complex indicators of the 3rd level | Single indicators of the 4th level |
|----------------------------------|-------------------------------------|-------------------------------------|-----------------------------------|
| Level of the TCS activities organization | Level of process control organization | Efficiency of updating information objects | Loss of documents prevention |
|                                   |                                     | Efficiency access to information resources | Prevent corruption of information |
| Labor organization level          |                                     | Efficiency of analytical information processing | Automation indicator for analytical information processing |
| Level of personnel recruitment, training and application | Security of information resources | Controllability of access to information resources without authority | Preventing Loss of Organizational Knowledge |
| Level of labor processes rationalization |                                     |                                      | Coefficient of provision TCS with the necessary technical tools |
| Labor organization level          |                                     |                                      | Personnel technical equipment level |
|                                    |                                     |                                      | External training cost ratio |

The consideration of the entire complex of mathematical models for evaluating the proposed indicators is beyond the scope of this study, due to the existing restrictions on the volume of the article. In this regard, table 4 shows, as an example, calculation formulas for evaluating some single indicators.
Table 4. A fragment of the mathematical models system for calculating single indicators of the organizational effect.

| Indicators (designations)                  | Calculation formulas                                                                 |
|-------------------------------------------|----------------------------------------------------------------------------------------|
| Efficiency of updating information objects \(\left(U_{OA}\right)\) | \(O_a = \frac{1}{n} \sum_{i=1}^{n} t_{2i} - t_{1i},\)                                     |
| Automation factor for analytical information processing \(\left(K_{A}\right)\) | \(K_a = \frac{1}{n} \sum_{i=1}^{n} \frac{t_{1i}}{t_{1i} + t_{2i}},\)                     |
| Level of automation coverage of inspection tasks \(\left(U_{OA}\right)\) | \(U_{OA} = \frac{n_1}{n_2},\)                                                      |

where \(t_{1i}\) is the creation time of the information object, \(t_{2i}\) is the time when the information object appears in the TCS, \(n\) is the number of changes made during the observation period.

where \(t_1\) is the complexity of performing automated operations, \(t_2\) is the complexity of performing non-automated operations, \(n\) is the number of measurements during the observation period.

where \(n_1\) is the number of control tasks solved automatically, \(n_2\) is the number of control tasks that can be principally automated.

It is proposed to use the organizational level of activities \(E_{AO}\) as an indicator characterizing the organizational effect of the IDSS functioning at the TCS level. The calculation of the indicator \(E_{AO}\) is proposed to be carried out on the basis of a comparative approach to evaluating solution variants. They are alternative to ensure the same final results of activities, according to the formula:

\[
E_{AO} = U_{AO}^1 - U_{AO}^2, \tag{2}
\]

where \(U_{AO}^1, U_{AO}^2\) are generalized indicators of the level of the TCS activities organization with and without the IDSS application.

The correspondence of the numerical value of the indicator \(E_{AO}\) to the required value determined in the terms of reference for each type of effect and the tendency of its change is evaluated in the process of the organizational effect analysis of the IDSS functioning.

Also, evaluations of complex and single indicators are carried out. It makes it possible to determine the reserves for changing the organizational effect, characterizing the unused opportunities to increase the value of a specific indicator, more accurately and urgently to find and take into account the impact on the result of specific organizational factors and sources. Recommendations and a system of measures aimed at improving the organizational, informational, legal, personnel and ergonomic support of the organizational subsystem of the TCS can be the result of the analysis.

3. Conclusion

The article considers an approach to evaluating the organizational effect of the IDSS functioning at the TCS level. It differs from the existed approaches by the presence of a procedure for the formation of a generalized indicator of organizational effect, consistently combining by cause-and-effect relationships the organizational goal and implementation objectives. It also differs by the main functional capabilities of the IDSS, a system of organizational factors and sources, qualitative criteria for evaluating potential positive effects from the implementation of the system, a system of indicators of organizational effect and mathematical models and methods for their calculation. It is proposed to apply a level of organization of activities as a criterion for evaluating the organizational effect determined by comparing the values (a difference) of generalized indicators of the level of organization of the activity of TCS with and without the IDSS application.
The obtained theoretical results can be applied in the development and implementation of information systems to evaluate the preliminary, potential, planned and actual effect and organizational efficiency, supplemented by other indicators depending on the goal, objectives, degree of detail and depth of analysis.

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