CHAPTER 12

# The Use of Artificial Intelligence in Automation of Planning and Operational Management of Organizational and Technical Systems in the COVID-19 Pandemic

*Oleg V. Balashov, Dmitriy S. Bukachev, and Julia V. Gnezdova*

## Introduction

Organizational and technical systems (OTS) include systems, at the objects of which decisions are made on the implementation of measures, coordinated with the actions of other objects (systems) or aimed at coordinating these activities. Technical-engineering systems have a hierarchical structure. Functioning of OTS (production, banking, medical, construction, military systems, and a number of others) occurs in conditions of uncertainty of the information processed in decision-making. Uncertainty

O. V. Balashov
Smolensk Branch of the Joint Stock Company "Radio Factory", Smolensk, Russia
e-mail: smradio@mail.ru

D. S. Bukachev · J. V. Gnezdova (✉)
Smolensk State University, Smolensk, Russia



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of information can be caused by its incompleteness, redundancy, unreliability, vagueness, and inaccuracy (Fertier et al., 2020). There are two types of information uncertainty conditions: statistical and non-statistical uncertainty conditions (Matorin & Zhikharev, 2019). As conditions of statistical uncertainty of processed information, such conditions of OTS functioning are considered, under which it is possible to implement the same decisions repeatedly (under fixed conditions of situation), as well as to collect and process statistical information about the course of implementation of these decisions. To assess the decisions made under these conditions, the methodological tools of probability theory and utility theory are used (Lee et al., 2019, 2020).

The conditions of the OTS functioning, in which there is a continuous change of the situation, leading to the uniqueness of the decisions made, correspond to the conditions of non-statistical uncertainty of the processed information. To assess the decisions made under these conditions, it is proposed to use the methodological tools of the theory of possibilities (Dyubua & Pred, 1990).

The conducted research allowed us to develop such an approach and prove that it can form the basis of creating a technology of automated OTS management, which involves solving the problems of developing a plan of upcoming actions, assessing the progress of its implementation and correction (re-planning in a short time) if necessary. The approach to the development of models for assessing the feasibility of decisions is based on the situational synthesis of models for assessing the capabilities of the system to implement management decisions that correspond to the considered situation of its functioning.

It is worth noting that solving the problems of automated planning and correction of previously formed plans for complex OTS is especially relevant in conditions of increasing risks and non-statistical uncertainty in the COVID and post-COVID period.

The proposed idea is to equip the control systems of the OTS facilities with intelligent decision support systems (IDSS). The core of the IDSS should include the means to perform the following functions:

- representation of the objective of object functioning and situations in a formalized form;
- identification of the current situation of object functioning;
- situational synthesis of the models for evaluating the decisions about the tasks to be made;

- formation of a rational strategy for management of the object;
- development of the plan of forthcoming actions;
- assessment of the implementation progress and automated correction of the forthcoming action plan (if necessary, re-planning).

To solve the tasks of modeling of the OTS, it is proposed to use expert systems combined in decision support systems (DSS) (Fertier et al., 2020; Zhang et al., 2020). However, there are no theoretical developments to ensure the creation of a system that controls the operation of DSS, and there is no approach to assessing the feasibility of human decisions under the conditions of non-statistical uncertainty of the processed information. The lack of these developments is the main reason that the existing approaches to the automation of management processes in the OTS are not focused on the implementation of such IS functions as the automated development of plans for upcoming actions, assessment of the progress of their implementation and correction. Theoretical tools of existing approaches provide the construction of AI and IS, providing the solution of primary information processing and only partially its secondary and tertiary processing.

## Methodology

In existing approaches to the design and functioning of IS, a large place is given to the tasks of data access and primary processing. Modern information technologies allow solving the problem of information and technical compatibility and portability of software, and also allow solving the problems of data replicability and inoperability. The analysis of modern information technologies shows that the capacity to solve the problems of primary data processing clearly exceeds the needs determined by the existing approaches to automated OTS management.

First of all, we are talking about the fact that modern information technology is not focused on solving the main problems of the OTS. Such problems include the solution of problems of automated development of plans of forthcoming actions, assessment of the progress of their implementation and correction. The practical output of all existing information technologies is the organization of rapid access to data and their primary processing. The high value of these technologies for users in various OTSs is undoubted, but this value would be even higher if these technologies were able to solve the problems of secondary and tertiary information processing. There are two main reasons holding back the development of information technology in this direction.

Secondly, it is the previously mentioned topical problem of developing models for evaluating the feasibility of decisions made under conditions of non-statistical uncertainty of processed information.

The plan of forthcoming actions developed in an automated way on some object of OTS management should be coordinated with the plans developed in the same way on its subordinate objects. The plan of forthcoming actions worked out at some OTS object is connected to a set of data in various databases which are created in the process of the plan development. The number and structure of databases are not known in advance, which is determined by the non-statistical nature of decisions made during development of plans of forthcoming actions.

The process of coordinated development of plans of forthcoming actions at all objects of the system involves the transfer from one object to another of substantial amounts of data, representing a version of the plan of forthcoming actions of this object or its fragments. Receiving this data object in advance does not “know” quantity and structures of databases in which it will be necessary to place the data from the transmitting object.

Thus, there is a problem of openness OTS on the logic of data processing. The solution to this problem is the transfer of the databases themselves. However, the data itself is of little value to the decision maker. For automated processing of the received plan, software is needed to reproduce this plan (formalized representation and processing of the plan in the computer memory, as well as visualization of the plan). Moreover, software code is needed, which contains a scenario of this reproduction (logic of the plan). Data transfer in the process of implementation of the previously formed plan requires the transfer of the same data, but with a shorter processing time. Hence, the problem of software portability arises when solving the problems of automated development of plans and their implementation. The solution to this problem goes beyond data transfer and database management technologies and requires a single software at each OTS facility, which may include:

1. tools for developing plans for upcoming actions, assessing the progress of their implementation, and correcting them;
2. tools to ensure the portability of software, including from one hardware platform to another.

This software should provide openness in data and logic of their processing not only between the objects of one OTS, but also between the objects of different OTSs.

## Results

The proposed technology of automated control requires the availability of IDSS with a typical core consisting of secondary and tertiary data processing tools, which operate under unified rules, at the facilities of different OTSs. At the same time, it is possible to implement the IS on different hardware platforms.

*Development of plans of forthcoming actions, evaluation of their implementation, and correction* are made according to algorithms, common for objects of various OTSs. These algorithms include algorithms for developing a plan of forthcoming actions, evaluating the progress of its implementation and correction, and algorithms for modifying the subject area. The last algorithm is intended for the continuous analysis of available resources of the system and correction, in case of their change, of lists of situational features and control decisions, matrices of conformity, and other data forming the subject area of IDSS.

*Integration with other OTSs* is performed by means of coordination by the considered system of the plan of forthcoming actions with similar plans of other systems. The distinctive feature of this process from the process of development of the plan of forthcoming actions is the use of algorithm of modification of a subject area in the process of coordination of plans of forthcoming actions of integrating OTS. Subject domain modification in this case consists in increasing the number and volume of databases, as well as in expanding the lists of situational features and control decisions. Practical implementation of the algorithm of subject area modification is carried out by logical mechanisms of the IDSS kernel.

*The intellectual system of the OTS object* within the framework of the proposed technology is understood as a software shell, providing interaction between a computer and a person, and providing him with opportunities to control the functional equipment of the object when solving problems of developing a plan of forthcoming actions, assessing the progress of its implementation and correction. The basis of this shell is formed by a typical IDSS kernel.

## Discussions

Let's consider the modular structure of the typical IDSS kernel and describe the tasks solved by each module.

*The main task of the current situation identification module* is to control the modules of identification of current values of situational features (MICVSF), which are elements of the application software. An improved method of situational management is proposed for the module operation. Conducted by authors of researches have allowed to draw a conclusion about possibility of setting correspondence of type "value of situational feature - set of control decisions." The validity of this approach is explained by the fact that each situational feature (SP) corresponds to a certain subject area, in which decisions are made that depend on the state of the object. Each SP corresponds to a finite set of its possible values, and each value corresponds to a finite set of decisions about the performance of actions (tasks).

Another disadvantage of the situational management method is the lack of means of evaluating the expediency of transition of OTS from one situation to another. To eliminate this disadvantage, it is proposed to evaluate the decisions aimed at transition of the system for each OTS from its current value to the required value. This evaluation is based on the analysis of the possibility, usefulness, and necessity of performing each control decision from the set of decisions corresponding to the current value of the SP.

A situational feature is considered to be a factor of the environment for identification of its current value, which requires analysis of the subject area corresponding to this factor. At present, the rules of selecting situational features and their values are being developed. Conducted researches allowed to distinguish three groups of situational signs: corresponding to external and internal factors of situation, as well as functional capabilities of the system.

Each MICVSF is an intellectual system, the task of which is to collect and evaluate the uncertainty of information necessary to identify the current value of the situational feature, identification of the current value and generation of control decisions, and corresponding to this value. Assessment of uncertainty of information consists in checking its consistency, reliability, and completeness.

The set of identified values of situational attributes at a fixed point in time forms the current situation. In other words, the current situation is understood as a formalized representation of the state of the considered TS, processes, and conditions of its functioning at a fixed point in time.

The number of controlled MICVSF can vary, and one of the tasks of the module under consideration is to provide the decision maker (a person) with the ability to compose the structure of the situation (to determine the number of considered situational attributes). In order to process in the computer memory situational features, the values of which have different physical meaning and dimensionality situations are represented in the form of fuzzy sets of the second level (Melihov et al., 1990).

The MICVSF control is understood as the activation of each of the set of data modules according to the current value of its update period. It should be noted that the values of the update period for each MICVSF can change depending on the emerging situation. Changing of the update period is performed with the help of the timer of the Current Situation Identification Module.

The main task of the *plan development module* is development of a rational plan of forthcoming actions and its formalized representation in computer memory. A necessary condition for developing a plan is the presence of current and target situations. Identification of the current situation is continuously performed by an appropriate mechanism of the IDSS kernel. Formation of a target situation is also performed by an appropriate mechanism of the IDSS kernel.

The target situation is a set of required values of situational attributes, corresponding to the state of the system, to which it must be transferred. The presence of the current and target situations makes it possible to form the structure of the plan of forthcoming actions, which is carried out by the control strategy formation module. A management strategy is understood as a set of basic (intermediate) situations separating the current situation from the target one.

Thus, management strategy is considered as a structure of the plan of forthcoming actions. When forming a management strategy, several variants of the strategy can be obtained.

Developing a plan of forthcoming actions consists in working out successive plans of transition of the system from a situation to a situation on the "path" from the current situation to the target one. To work out such plans, modules for developing a plan for transition of the system from one situation to another are activated. Each such plan is a virtual model of predicted actions of the system during its transition from one situation to another. Virtual model consists in the fact that it represents all possible combinations of various kinds of real models used in modeling the predicted actions of the system and the conditions of its functioning during transition from one situation to another. The list of real models is determined by the purpose of the system.

The description of synthesis of virtual models will be given when considering the work of the module of development of the plan of transition of the system from situation to situation. Logical links between real models are determined by the content of the situation under consideration, as well as by the content of the situation to which it is necessary to transition. Since the functioning of organizational and technical systems takes place in conditions of non-statistical uncertainty of processed information about the state of the system and conditions of its functioning, these links are unknown in advance and are formed directly in the process of developing the plan. On this basis, before the development of the plan of upcoming actions, the models of implementation of control decisions, forming the content of this plan, as well as the number, structure and volume of databases corresponding to these models, are unknown.

To each of set of plans of transition of system from one situation to another, forming the contents of the plan of forthcoming actions, there correspond values of the indicators characterizing opportunities and necessity of this transition. Consequently, as a result of development of the plan the distributions of values of possibilities and necessity of transition of the system from the current situation to the target one are formed. The processing of these distributions allows to obtain the values of indicators, which characterize the possibility and necessity of achieving the target situation. The offered approach to development of plans of forthcoming actions assumes realization of procedure of "return" by situations, situational attributes and control decisions with the purpose of achievement of required values of possibility and necessity of achievement of a target situation.

Integration of the system under consideration with other organizational and technical systems is performed at the level of plans for their upcoming actions and consists in the coordination of these plans. Two variants of coordination of plans are possible.

The first variant takes place when the structure of the plan of forthcoming actions is based on the structure of a similar plan of another system. In this case, the system in question acts for the benefit of the other system. An example is a team of electricians acting in the interests of a complex team of builders. For systems that integrate in such a way, the target situation will be accompanied by the marks of situations (via data transmission channels) that reveal the structure (idea) of the plan of forthcoming actions of the system the system in whose interest the system in question will act.

The second option takes place when integrating systems agree their plans in order to eliminate conflict situations. In this case, restrictions caused by the functioning of other systems are imposed on the implementation of some or other control decisions that form the content of the plan of forthcoming actions of the system under consideration.

*The task of the module of formation of a target situation* is a formalized representation in computer memory of a goal of functioning of the system by transformation of a text, a speech message, and/or multimedia data into a set of values of situational attributes corresponding to their content. At the heart of the solution of the task is the processing of role situations, consisting of role frames and frames of concepts (Kuzior et al., 2019; Trunk et al., 2020).

*The module of development of the plan of transition of the system from one situation to another* is designed to develop a plan of this transition and provides the decision maker (human) with the ability to solve the following tasks:

a. matching control decisions corresponding to the current values of various situational attributes;
b. situational synthesis of virtual models for implementation of control decisions;
c. development and formalized representation of virtual plan of system transition from one situation to another;
d. evaluation of priorities of control decisions.

Coordination of control decisions consists in their evaluation for consistency, continuity, non-duplicity, and isolation in time. This evaluation is made in the process of structurization of the plan of transition of the system from one situation to another. The structurization is based on the process of "unfolding" the technological chains of executing the control decisions generated as a result of identifying the current values of situational attributes. In turn, the process of "deployment" is based on the approach proposed by the authors of the article to the classification of control decisions on the execution of actions (tasks) (Eber, 2020).

According to the classification developed by the authors, all solutions are divided into three types: actions, tasks, and generalized tasks.

Generalized tasks are a set of tasks performed by heterogeneous objects of a system. For example, for construction: simultaneous work of several teams—painters, plumbers, electricians, etc.

The main idea of the proposed classification is the correspondence of each action, the model of its implementation by some OTS object in the considered conditions of the environment, taking into account the design and technical features of this object. This model describes the process of action performance and allows to estimate its feasibility. From action implementation models (the number of which for each object is small), synthesis of virtual models of feasibility of control decisions on execution of tasks and general tasks is performed. In this case, technology (structure of models) of implementation of control decisions on execution of tasks and general tasks is determined in the process of identification of current situations not only for the object in question, but also for objects subordinate to it. To transfer a system or object from one situation to another, it is necessary to develop models of implementation of generalized tasks, as well as to determine the predicted result of the implementation of control decisions on the execution of actions.

The procedure of structurization of a control decision consists in constructing a process chain for implementing this decision (it determines the list of control decisions to execute actions and lower-order tasks and the sequence of their execution). Formation of data objects consists in defining the initial, intermediate data, and the required result of the control solution execution.

Estimation of feasibility of a control decision is formed of a set of estimations, characterizing the capabilities of control decisions about the execution of lower-order tasks, included into the technology of the decision in question. The logic of the human-formed technology of the control decision under consideration is represented in a formalized form (coded). The coding process consists in activating an appropriate procedure, which is a part of the control logic processing system of the IDSS core.

Formation of an alternative variant of realization of the control decision on performance of an action (task) is performed at the level of setting the identifiers of databases, data objects, and the code of logic of realization of the decision in this variant corresponding to the considered variant. Each variant is assigned one or more evaluations characterizing its quality (solution feasibility).

Selection of a rational variant is carried out by an appropriate procedure based on the processing of quality evaluation of all alternatives. It should be noted that this procedure is universal for various managerial decisions.

Assessment of the feasibility of control decisions under conditions of non-statistical uncertainty is carried out with the help of such a measure of uncertainty as a measure of possibility, which characterizes the feasibility of a decision under the conditions of the environment in question (Bogachov et al., 2020; Eber, 2020).

The availability of assessments characterizing the possibilities and the necessity of control decisions providing the transition of the system from one situation to another allow their convolution to determine the possibilities and the necessity of this transition. The presence of these evaluations for each of the set of control decisions under consideration allows to determine their priority, which is subsequently used by the control system of the IDSS kernel when prioritizing the processes it controls.

The proposed approach to development of a virtual model of the plan of transition of the system from one situation to another involves implementation of the procedure of "return" by situational attributes and control decisions in order to obtain the required values of assessments of the system's capability to perform this transition.

*The module of realization of the plan of forthcoming actions (operative management)* is intended for solving the following main tasks:

a. comparison of the current situation with its corresponding situation in the previously formed plan;
b. activation of the model of the previously formed plan of transition of the system from one situation to another;
c. situational synthesis of a virtual model of the system transition plan from the current situation to the required situation;
d. Evaluation of the expediency of maintaining the management strategy and the target situation;
e. integration of the system with other systems and its self-organization in critical situations.

The purpose of comparing the current situation with the corresponding situation in the previously formed plan of upcoming actions is to determine the degree of correspondence of the situations under consideration and to determine those control decisions and situational attributes that cause this discrepancy. If a mismatch is detected, the transition plan from the current situation to the next one is corrected. If necessary, the entire plan of upcoming actions or its separate fragments can be corrected, and the management strategy and the target situation can be adjusted. If correction is not necessary, the model of the previously formed transition plan is activated.

The assessment of the expediency of preserving the management strategy is carried out by activating the mechanism of forming the management strategy. The essence of the evaluation process consists in revealing a possible change in the management strategy as a set of basic situations, caused by a discrepancy between the current situation and the corresponding situation in the previously formed plan. It is necessary to identify two extreme cases, leading to the need to change the management strategy.

The first case can be caused by low values of possibilities of system on its transition from current situation to required situation under condition of coincidence of values of situational attributes in current situation with values of the same attributes in corresponding situation of previously formed plan.

The second case takes place when the current situation differs from the corresponding situation in the previously formed plan by values of situational attributes. As a result of evaluating the expediency of preserving the management strategy, a management strategy corresponding to the current situation is formed. Formation of this management strategy is also performed using the module of formation of the management strategy.

Changing the management strategy causes the need to develop a new plan of forthcoming actions directly in the process of the system operation. The need to change the target situation may occur when the current management strategy does not ensure the achievement of the target situation due to the absence or low capacity of the system to transition from the current situation to the target situation.

One of the most important problems arising in the operation of the IDSS is the assessment of compliance of data on the subject area with the conditions of the environment under consideration. To solve this problem, it is proposed to introduce subject domain modification procedures into the upcoming action plan implementation module. Three cases of using these procedures are distinguished.

The first case occurs when there is a sharp change in the structure and resources of the system, leading to a change in the content of the lists of situational attributes and control decisions. For example, the illness of workers of certain specialties, which will cause a decrease in the ability to perform all tasks, the technology of execution of which includes this action.

The second case takes place when integrating the system in question with some other system. In this case the lists of situational characteristics and control decisions of a given system are supplemented by corresponding data about situational characteristics and control decisions of another system.

The third case takes place at self-organization of the system in the case when objects belonging to different systems are integrated into one system.

Thus, a virtual plan of forthcoming actions of a system consists of some set of real models and a set of objects-data of the first type necessary for creation of virtual models of implementation of control decisions that form contents of the plan, and also a control code defining the sequence and conditions of implementation of control decisions. In other words, into the external memory of the computer is written not the program code of virtual model of the plan (although in principle it is possible), but relatively small control code and data necessary for formation of the virtual model of the plan in the working memory of the computer.

*The control system* is intended for controlling the operation of the IDSS. Its main tasks are to manage processes, assess their priority, control and manage computational resources.

## Conclusions

An artificial intelligent system supports interaction between the computer and a human in the process of planning and operational management. The result of this interaction is the synthesis and execution of programs that simulate human decisions. Automatic synthesis of these programs is performed on the basis of a description of decisions made by a human. The basis of an intellectual control system should be the core of the IDSS kernel. An IDSS kernel, “tuned” to a certain set of subject areas, forms the basis of a control system of an OTS object. A subject area is described by lists of control decisions on performing actions (tasks) and situational attributes. These lists, as well as the software corresponding to them, can be modified in the process of functioning of the OTS object.

The development of a theoretical approach to the automation of planning and operational management processes, as well as the construction of a kernel of the IDSS, allowing the automation of these processes, leads to the close integration of artificial intelligence technologies and decision-making theory. Further development of this approach will make it possible to develop a methodology for the construction of IDSS, providing automation of the processes of planning and operational management of OTS objects.

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