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Formation of an Adaptive Decision-Making Support Means Components in Engineering Infrastructure Reconstruction Programs Management

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Abstract
The article is devoted to a decision-making support tool aimed at improving the efficiency of engineering infrastructure reconstruction program management in the context of developing the architecture and hierarchical structure of program work and program architecture management. As part of the study, the main components of the model are defined, which include a set of decision-maker preferences, decision-making tasks, sets of input data, and applied software components of the model. To support decision-making, the adaptive model applies the method of system modeling and forecasting the value of the objective function at a given system configuration. Forecasting is done using machine learning methods based on a dataset consisting of historical data related to existing engineering systems. The work describes the components of the redistribution of varied model parameters, which modify the model dataset based on the selected object type, which allows adapting the decision-making process to the existing program implementation goals. A description of the data post-processing process is provided, which allows the decision-maker to obtain information about the influence of the main parameters of the system on the target indicator. The main differences between the described adaptive decision support model and the currently existing tools have been determined. The application of the developed adaptive model is possible in the management of programs for the reconstruction of such engineering systems as systems of heat, gas, electricity supply, water supply and drainage, etc.

INTRODUCTION

The implementation of engineering infrastructure reconstruction programs (EIRP) in cities is of crucial importance both for ensuring the effective functioning of the communal economy and for the reconstruction of Ukraine as a result of the full-scale invasion of the russian federation.

In the context of EIRP management, the processes of developing the program architecture and hierarchical structure of works in the planning phase and architecture management in the implementation phase are of particular importance. At the same time, the development and management of the EIRP architecture is directly related to the adoption of management decisions regarding the selection of equipment for installation at the objects being reconstructed. During this, it is necessary to take into account the existing energy demand from consumers, state regulations and characteristics of the equipment installed at the system facilities, which are not subject to replacement within the framework of the implementation of the program.

The limitations of infrastructure programs and the effects of a turbulent external environment determine the expediency of using adaptive management methods in the management processes of private investment projects, including in the processes of making management decisions when developing and managing the architecture of programs, developing the hierarchical structure of works.

The issue of adaptive management in general and adaptive management of programs and projects in particular has been studied by many scientists, including Argent [1], Blokdyk [2], Silber [3], Wysocki [4], Feldbaum [5–7], Sukhonos [8] and others. Researchers have also developed means of adaptive management of programs [9], which can be used in different phases of their implementation. Adaptive decision support systems are considered in works [10–12].

Adaptive decision support tools have not yet been widely considered when applied to project and

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program management processes. Works related to such tools include [13], where an adaptive project management model was proposed for the creation of a professional doctorate in business management. However, currently there are no studies on the use of such tools in engineering infrastructure reconstruction programs.

Paper [14] analyzes internal and external variables in the management of large programs to improve the effectiveness of program risk management. The authors have developed a system dynamic model of the program that takes into account these variables, which can be used in the management of large programs. For engineering infrastructure reconstruction programs, a quantitative probabilistic modeling methodology of individual steps of the infrastructure restoration process, their dependence on environmental factors and human factors has been developed [15].

When managing engineering infrastructure reconstruction programs, it is possible to use engineering systems modeling and optimization tools to support management decision-making. However, currently there are no such tools that could be effectively used to support decision-making in the development and management of program architecture, development of a hierarchical structure of program work. Systems simulation tools [16–20] are among those that can be used in a limited way, but their analysis revealed a number of shortcomings:

- lack of consideration of the complexity of systems in the context of displaying system parameters and the interrelationship of their elements;
- impossibility of their application in the processes of program management due to the lack of elements of hints for the decision-maker that can be used to support management decision-making;
- impossibility of scaling of the tools for further application for systems of other levels;
- inconvenience in use for the decision-maker.

Accordingly, in order to ensure the effective implementation of engineering infrastructure reconstruction programs, it is necessary to have an adaptive tool for developing and managing the program architecture, developing a hierarchical structure of the program's work, taking into account existing limitations and the method of its application in program management processes.

ADAPTIVE DECISION SUPPORT MODEL

An adaptive decision support model is a model, which is characterized by the use of an adaptive approach, which consists in the possibility of changing system parameters in accordance with given conditions. Thus, if there is a model of the management object, for which there is a set of elements *El*, each of which is characterized by a certain set of parameters *Par*, when the value of the parameters changes, the value of the objective function are automatically determined and the possibility of corresponding modification of other parameters of the system elements depending on the existing restrictions.

In general, decision support when using the adaptive model considered in this paper is based on modelling. Engineering infrastructure systems are complex organizational and technical systems, for which formalization using standard methods, such as mathematical modeling, is difficult to implement. Accordingly, it is appropriate to depict it as an array of elements with specified parameters. Machine learning methods are used to create such a model. At the same time, it is not necessary to carry out mathematical calculations of the value of the objective function at the given values of the input data, since its forecasting takes place without the participation of the user on the basis of available historical data.

The model includes a dataset, which contains sets of parameter values of existing engineering systems, on the basis of which the primary training of the model takes place.

The structure of the adaptive decision-making support model in the engineering infrastructure reconstruction program management can be described by tuple 1.

$$DSM = \langle B, I, T, P_A \rangle, \tag{1}$$

where B is the set of preferences of the decision maker; I is the set of inputs; T is the set of tasks to implement decision support; P_A is the set of application software components.

At the same time, a set of tasks can be defined as follows:

$$T = T_I \bigcup T_F, \tag{2}$$

where T_I is the set of input data processing tasks; T_F is the set of tasks of predicting the values of the objective function.

The general scheme of the process of processing input data of the model is shown in the Fig. 1. The set of input data includes the following:

$$I = \left\{ I_{obj}, I_{\lim} \right\} \tag{3}$$

where I_{obj} is the object type; $I_{\lim}$ is the set of limitations of the model.

The limitations of the model are the values of the parameters of the elements of the object to be reconstructed, on the basis of which the value of the objective function is predicted.

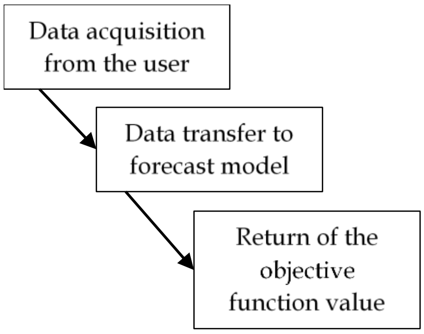

Figure 1. Scheme of the process of processing input data of the model

The type of object as an element of input data allows redistribution of parameters for forecasting depending on the purpose of implementing managerial impact. Thus, when managing an engineering infrastructure reconstruction program, it is possible to make decisions within the framework of the development and management of the program architecture by selecting such projects for the reconstruction of subsystems or individual objects of subsystems that would satisfy the general limitations of the program.

Forecasting the value of the objective function is carried out on the basis of input data of the model and is the main criterion for making a management decision when using the model. Also, the decision-maker has the ability to modify the values of the system parameters when re-predicting the values of the objective function for different system configurations.

The model for predicting system parameter values is represented by the Eq. 4.

$$F = \{MLM, DS, I, VPRC, PPM\}, \tag{4}$$

where *MLM* is the machine learning methods; *DS* is the dataset; *VPRC* is the variable parameters redistribution components; *PPM* is the post-processing mechanism.

Variable parameters redistribution components are model elements that provide its adaptation to modelling goals.

The goal of the engineering infrastructure reconstruction program is to reconstruct the system as a whole, one or several subsystems. As part of the management of such programs, there is a need to make decisions regarding the selection of projects for the reconstruction of objects that are part of the subsystems. Such objects, being part of the same subsystem, may have technical and technological differences, which requires an individual approach to supporting decision-making on their reconstruction. An example of such objects can be boiler houses and CHP plants in heat supply systems, condensing, nuclear, hydroelectric power plants in power supply systems, etc. Accordingly, it is necessary to ensure the possibility of adapting the decision-making process to the presence of such objects in the system to be reconstructed within the framework of the program.

The above-mentioned model components redistribute model parameters for different types of subsystem objects. The primary composition of model parameters is represented by set (5).

$$Par_T = \{Par_g, Par_{El_1}, Par_{El_2}, ..., Par_{El_n}\}, \tag{5}$$

where Par_T is the full composition of the parameters of the adaptive model; Par_g is the parameters common to objects of different types; Par_{El} is the parameters that are unique to a particular object type; n is the number of unique types of system objects.

At the same time, the *DS* dataset is a set of Par_T parameter values for a certain number of objects of different types.

The redistribution is based on the value of the linguistic variable I_{obj}. Its essence consists in removing from the dataset those parameters that are unique to all types of objects except the selected one and are not common to all types of objects. The result of the operation is a dataset that is unique for the selected object type.

The data post-processing mechanism provides the decision-maker with additional opportunities to take into account the interrelationship of system elements when optimizing its parameters by providing information on the influence of the main parameters on the target indicator in the form of graphs of indicator dependencies. The process of data post-processing is shown in Fig. 2.

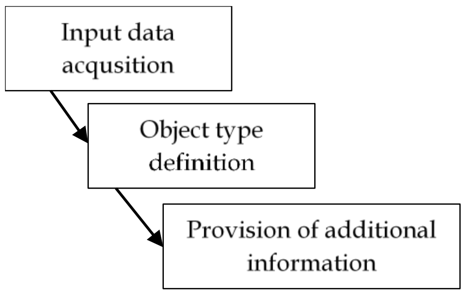

Figure 2. Process of post-processing of model data process

In the case considered in this paper, decision-making consists in choosing the optimal composition and configuration of the system from among the available alternatives through the prediction of the values of the objective function at different values of the parameters of the system elements with the possibility of their further modification to minimize the costs of implementing the program. Managerial impact is expressed in the selection of projects for the architecture of the program related to the replacement or installation of equipment at the facilities of the infrastructure system.

The essential differences of this model from other models considered in this paper and which can be used in the management of engineering infrastructure reconstruction programs are as follows:

- *adaptability*: the model is based on machine learning methods and applies data on existing engineering systems, accordingly, for each value of the objective function and set of constraints, system parameters are predicted based on available experience;
- *the possibility of scaling*: the composition of parameters in the model can be expanded to cover a larger number of subsystems, objects in the subsystems, etc.;
- *availability of post-processing tools*: the functionality of the model may include graphing parameter dependencies, calculation of additional system parameters;
- *presence of varied parameters redistribution components*: the components of the model provide the decision-maker with the opportunity to select the modeled object type, which allows adapting the decision-making process in the management of private investment to the goals of such programs.

The above makes the adaptive model an effective means of managing engineering infrastructure reconstruction programs.

CONCLUSIONS

This paper proposes an adaptive decision-making support instrument which can be used in engineering infrastructure reconstruction programs management. Its efficiency in program architecture development and management and WBS development is ensured by its adaptability, possibility of scaling, availability of post-processing tools and variable parameters redistribution components. The latter allow the decision-maker to use the model for different kinds of objects within the system to be reconstructed within the program.

The approach used in development of the model allows it to be used in reconstruction of different kinds of engineering infrastructure systems, including heat, gas supply, electricity supply, drainage etc.

Further approach will be related to developing a method of decision-making in engineering infrastructure reconstruction programs using the adaptive model described in this paper.

DISCLOSURE STATEMENT

No potential conflict of interests was reported by the author(s).

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Формування компонентів адаптивного засобу підтримки прийняття рішень при управлінні програмами з реконструкції інженерної інфраструктури

Ілля Худяков

Анотація. Стаття присвячена інструменту підтримки прийняття рішень, спрямованого на підвищення ефективності управління програмами з реконструкції інженерної інфраструктури у контексті розробки архітектури та ієрархічної структури робіт програми та управління архітектурою програми. В рамках дослідження визначено основні компоненти моделі, до складу яких входять множина переваг децидента, завдання прийняття рішень, множини вхідних даних та прикладних програмних компонентів моделі. Для підтримки прийняття рішень адаптивна модель застосовує метод моделювання системи та прогнозування значення цільової функції при визначеній конфігурації системи. Прогнозування відбувається за допомогою методів машинного навчання на основі датасету, що складається з історичних даних стосовно існуючих інженерних систем. У роботі описані компоненти перерозподілу варійованих параметрів моделі, що здійснюють модифікацію датасету моделі на основі обраного типу об'єкту, що дозволяє адаптувати процес прийняття рішень під наявні цілі реалізації програми. Наведено опис процесу пост-обробки даних, що дозволяє децидентові отримати інформацію про вплив основних параметрів системи на цільовий показник. Визначено основні відмінності описаної адаптивної моделі підтримки прийняття рішень від засобів, що існують на даний момент. Застосування розробленої адаптивної моделі можливо при управлінні програмами з реконструкції таких інженерних систем, як системи тепло-, газо-, електропостачання, водопостачання та водовідведення тощо.

Ключові слова: підтримка прийняття рішень, адаптивне управління, управління програмами, інженерна інфраструктура.

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