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Adaptive approach to engineering infrastructure reconstruction program and project management

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Abstract. Standard approaches to managing projects and programs for the reconstruction of engineering infrastructure in a turbulent environment are ineffective due to the lack of possibilities to adapt to external and internal influences. Therefore, the purpose of the article was to characterize the application of the conception of adaptivity in managing such projects and programs and to analyse the means for its application in management processes. The research presented in this article was conducted using scientific methods of critical analysis, systems analysis, mathematical modelling, formalization, analysis, synthesis, graphical and abstract-logical methods. The main constraints in the development of the program architecture were identified. The influence of the application of the standard approach to planning and managing programs and projects for the reconstruction of engineering infrastructure on the increase of the probability of risk emergence was investigated. The tasks of managing programs and projects in the implementation of management as the manifestation of control action were formulated. The concepts of active and passive methods of adaptive program management were considered, a combined method that involves preliminary modelling of managerial influences and learning from the experience of exerting such control actions was developed. The means of adaptive program management were analysed, the expediency of their use in the management of programs for the reconstruction of engineering infrastructure at different stages of their implementation was determined. The results of the study can be used by managers of programs and projects for the reconstruction or modernization of engineering infrastructure to determine approaches to management and selection of adaptive management tools for different phases of implementation, and also provide a methodological basis for further research

Keywords: organizational and technical systems, control action, risks, architecture planning, forecasting

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INTRODUCTION

The issue of reconstruction of the engineering infrastructure of cities is relevant both for Ukraine and for other countries of the world. Reconstruction measures can be implemented both at the micro level (modernization or repair of individual system facilities – boiler houses, substations, central heating plants, etc.) and at the macro level (reconstruction of large parts of systems or systems as a whole). Reasons for reconstruction may include physical or moral obsolescence of equipment, replacement of damaged equipment, adaptation of systems to current consumption conditions, optimization of resource consumption in energy production, etc.

The modernization and reconstruction of engineering infrastructures and their management are widely represented in the works of many scholars. For example, N. Yushchenko [1] offers methods for planning the reconstruction, modernization and replacement of technological equipment of heat substations, heat networks of thermal energy enterprises, developed on the basis of network planning methods. Adapted methods of graph theory, deterministic and probabilistic mesh models taking into account time, cost and resources are proposed. The author notes the possibility of using network methods for network planning and management systems (NPMSs), including the use of automated NPMSs. Although the proposed methods can be successfully applied in the implementation of programs and projects for the reconstruction and modernization of engineering infrastructure, they do not provide an integrated approach to the management of such programs.

The study by E. Ciapessoni [2] proposed a quantitative probabilistic methodology for modelling the process

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of restoring the infrastructure of power supply systems. This method enables the modelling of individual steps of restoring infrastructures and their dependencies on human and environmental factors. It allows to identify the most influential factors using an analytical model through what-if analysis, which avoids the use of the black box method in modelling when applying statistical data. This methodology allows for the consideration of external and internal factors that influence the processes of infrastructure restoration in their modelling, which enables better adaptation of reconstruction program management processes, which is also influenced by the use of statistical data on the processes under study. However, it involves only probabilistic process modelling and can be used as a tool for managing programs and projects, without implementing an integrated management approach.

The thesis of D. Nieviedrov [3] developed an integrated approach to managing the level of environmental and social safety of construction and reconstruction projects of critical infrastructure through the development and implementation of models and methods for assessing the impact of certain impacts in conditions of turbulent changes. Although the work considers the adaptation of certain processes to the impact of external factors, the presented results relate to managing individual processes of infrastructure reconstruction project management, not taking into consideration an integrated approach to their implementation. The article by N. Bespala [4] analyses the main directions of the strategic development of regional energy systems, gives a comparative description of some regional programs, and determines the steps for the implementation of Smart Grid in regional energy systems. The results of the study directly relate to the implementation of engineering systems development programs, but focus on the conceptual level of development of such programs and do not provide a specific methodology for their management.

The article by M. Çelik [5] provides an overview of the literature regarding the implementation of actions for the reconstruction of critical infrastructure in the implementation of humanitarian operations, the classification of research by the main problems that they address, models, problem-solving methods employed as well as the goals and main solutions formulated throughout the research process, the future directions of research in this field are identified. The work presents information on existing research regarding the reconstruction of critical infrastructure but does not provide a comprehensive methodology for managing relevant processes. In the context of adaptive management, there is a lot of attention paid to the management of natural resources [6], environmental protection [7], etc. Researchers K.E. Papke-Shields and K.M. Boyer-Wright [8] proposed a "rational adaptive" approach to project management, developed on the basis of strategic planning methods. According to the results of the empirical evaluation, this approach has a positive impact on the success of project implementation but only addresses project management planning and does not consider the specifics of projects and programs for the reconstruction of engineering infrastructure.

The existing studies relate mainly to the management of individual processes within the overall project management structure, whereas they do not provide at all or provide a limited application of adaptation mechanisms to external and internal influences. The issue of adaptivity in project and program management is poorly addressed. Therefore, this article aimed to analyse the structure of programs for the reconstruction of engineering infrastructure, identify the existing specifics of such programs, and describe the methodology for managing such programs using an adaptive approach.

MATERIALS AND METHODS

The research presented in this article is based on theoretical foundations regarding the adaptation of systems, concepts, and means of adaptive program management. In particular, a methodology regarding the separation of management types as the implementation of control action, depending on the application of the principles of adaptivity (the use of feedback, changes in the law of management, etc.) was applied [9-10]. To analyse the concept of adaptation, adaptivity, and adaptive management, the materials of thorough research in this field were used [11-13]. Consideration of the concept of adaptivity from the point of view of cybernetics is appropriate for analysing the possibilities of its implementation in the processes of managing complex organizational and technical systems and developing appropriate models. The study also used the definition of active and passive adaptive program management by K. Tervo-Kankare [14]. It enabled to synthesize a combined approach that considered elements of both studied approaches and is more effective for the implementation of program management processes. The methodology of adaptive program management is considered on the basis of the existing standard for program management by developed by the PMI (Project Management Institute) [15].

Methods of analysis and synthesis were used to study the process structure of program management and adaptive program management tools. The critical analysis method is used to evaluate existing research materials on adaptive program and project management. Methods of system analysis were employed to examine the program structure as well as the program management system. The method of mathematical modelling was used to develop program models and program management systems. The formalization method was used to describe the above systems, formulate restrictions for the program structure and tasks for managing programs for the reconstruction of engineering infrastructure. The graphical method was applied to illustrate the process structure of program management and processes of adaptive program management. The abstract-logical method was used to identify the specific features of managing programs for the reconstruction of engineering infrastructure as well as the typical risks associated with such programs.

RESULTS AND DISCUSSION

At the macro level, the reconstruction and modernization of engineering infrastructure are carried out through projects that are interconnected both in terms of resources and in their logic of technical interaction to achieve a global strategic goal. This allows to talk about an aggregate of such projects in the terminology of program management. The PMI Program Management Standard defines a program as a set of related projects, ancillary programs, and program activities managed in a coordinated manner to produce benefits not available under individual management [15]. Accordingly, the program model can be presented as follows:

$$P = \{Pr_1, Pr_2, \ldots, Pr_n\}), \quad (1)$$

with P being a program; Pr_n being a project. Constraints to the model are the availability of financial resources and the technical feasibility of implementing projects. The latter is related to the possibility of including in the program projects that perform the same functions in the process of achieving the strategic objectives of the program or do not contribute to the achievement of such objectives given the current environmental conditions. Constraints on finances and technical feasibility are reflected in the formulas (2; 4), respectively.

$$\sum_{i=1}^{n} Cf_i \leqslant Inv_p, \quad (2)$$

where Cf_n is the sum of the cash flows for the project i, which is part of the program architecture; Inv_p is the total investment in the program implementation; n is the total number of projects in the program architecture.

$$Ef_{P_{ri}} \neq Ef_{P_{ri+1}}; \quad (3)$$

$$\sum_{i=1}^{n} I^{s}_{P_{ri}} = 1, I^{s}_{P_{ri}} \geqslant 0, \quad (4)$$

where $Ef_{P_{ri}}$ is the effect of implementing the project i; $I^{s}_{P_{ri}}$ is the index of achieving the strategic objectives of the program for the project i. In this case, $Ef_{P_{ri}}$ can be displayed as a set (5).

$$Ef_{P_{ri}} = \{PA_1, PA_2, \ldots, PA_n\}, \quad (5)$$

where PA_n is the change in the parameter n of the object of management. The model of the program management system can be presented in the form of a formula (6).

$$PM = \{MD, MP, ID, K\}, \quad (6)$$

where PM is the program management system; MD is a set of managerial decisions; MP is a set of program management processes; ID is a set of program output data; K is a set of knowledge. The input set can be defined as:

$$ID = ID_{leg} \cup ID_{par} \cup ID_{req} \cup ID_{ei}, \quad (7)$$

where ID_{leg} is the regulatory framework in the field of program implementation; ID_{par} is the parameters of the system-object of management; ID_{req} is the requirements for the final product of the program; ID_{ei} is the data on the disturbances of the external environment of the program. The set of program management processes is shown in Figure 1.

Figure 1. Set of program management processes

Source: developed by the authors based on [16]

Sets of knowledge and solutions are responsible for the decomposition of program management processes. Sets of knowledge and managerial decisions include knowledge and managerial decisions on the management of program integration, program communication, etc. The application of a rigid standard approach to program management, which does not provide for adaptivity, is widespread in various types of programs. However, programs for the reconstruction of engineering infrastructure as programs, whose objects are complex organizational and technical systems, are characterized by a high degree of structural and dynamic complexity, which in the synthesis of the adaptation system leads to the following problems:

- the problem of lack of a priori information when the invariant model of the program for the reconstruction of engineering infrastructure and an adequate model of the management system cannot be built on the basis of available information;
- the problem of the impossibility of constructing an analytical mathematical model by traditional means (functions, differential equations).

In correlation with the constraints indicated by formulas (1; 2), these issues directly affect the content management processes in the context of the development of the application architecture. The architecture, in turn, affects the hierarchical structure of works, program scheduling, cost estimation, supply planning. Applying a standard approach to the planning and managing of programs for the reconstruction of engineering infrastructure increases the probability of risks, including cost risks: errors in the development of the program architecture and lack of adaptation to environmental disturbances can lead to exceeding the program budget and/or failure to achieve its strategic objectives. Schedule risks make it impossible to adapt to environmental disturbances when managing the program architecture, which can lead to overdue program implementation and increases the probability of cost risks. Operational risks may arise during the program implementation and are associated with the impact of external disturbances; the lack of a mechanism for adapting to such disturbances may adversely affect the effectiveness of the program implementation. Technological risks – the inability to adapt to changes in the implemented technologies, and the emergence of more effective technological means can lead to incomplete achievement of the strategic objectives of programs for the reconstruction of engineering infrastructure. Thus, for the effective development and management of the program architecture, it is advisable to use an adaptive approach to the management of programs for the reconstruction of engineering infrastructure.

F. Heylighen [11], considering the issue of self-organization of systems, defines adaptation as the achievement of a state of compliance between the system and the external environment. Simultaneously, the term "compliance" reflects the configuration of the system, in which the latter can maintain its state or grow under specific environmental conditions. The discrepancy, in turn, leads to an increase in entropy in the system and its destruction under current boundary conditions. For complex systems, adaptation is determined by the ability of the system to adapt to new boundary conditions, maintaining the highest possible level of stability of their organization. In cybernetics, adaptation is defined as the task of control, which consists in minimizing deviations from the target system configuration by responding to perturbations from the external environment before such perturbations jeopardize the basic organization of the system. Thus, adaptivity is a characteristic of the system that determines its ability to adapt.

Accordingly, an adaptive system can be understood as a system that adjusts to environmental changes to control the level of entropy. In the case of artificial systems, among the tasks of adaptivity can be distinguished: support for the ability of the system to perform its functions under the influence of external disturbances; the ability of the system to maintain the initial level of efficiency of its functioning in accordance with the conditions of the external environment. However, adaptivity could not be considered as a characteristic inherent in artificial systems that are not guided by humans or do not utilize artificial intelligence technology. Organizational and technical systems can adapt to disturbances of the external environment through the exercise of control action, such action can also be exercised by means of artificial intelligence.

Researchers distinguish the concepts of "adaptivity" and "adaptability" for intelligent information systems [12]. Adaptability differs from adaptivity by the need for the system parameters to be changed by the user, according to which the system is adjusted to the necessary conditions. An example of adaptability could be a user changing the interface of a software product. The system can be adaptive and adaptable, to a certain extent, depending on the degree of user participation in the initiation of changes. Full adaptivity implies the absence of human control over the initiation process, full adaptability, in turn, is its direct presence. Partial adaptivity, meanwhile, may involve both informing the user in advance about the initiation of changes and choosing the nature of the adaptation by the user.

Taking into account the above, a preliminary conclusion about the possibility of applying the concept of adaptability to technical systems as a whole can be made. The stable functioning of such systems provides for the regular exercise of control action over their elements. Independent initiation of changes is impossible in most cases. Organizational and technical systems, in turn, can be characterized as generally adaptive due to the exercise of control action, depending on the available information about the state of the system and the existing influence of the external environment on it. However, it should be noted that the adaptivity of the system directly depends on the presence of feedback between its elements. Program management systems belong to complex organizational and technical systems. Such a system can be considered potentially adaptive, provided that the principles of adaptive management are applied. The study by R.M. Argent [13] identifies four components of adaptive ecosystem management, as shown in Figure 2.

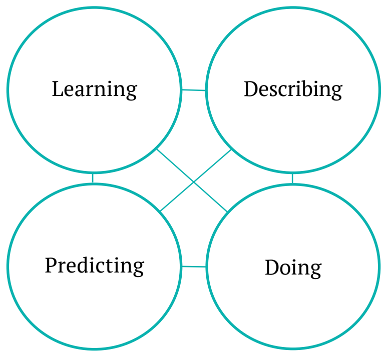

Figure 2. Set of program management processes
Source: developed by the authors based on [13]

In the context of systems management, O. Feldbaum [9] defines adaptation as the third hierarchy. The first hierarchy is management as the implementation of control action, the second is regulation as the implementation of control action using feedback. In the case of the first hierarchy, the management task can be formally expressed by formula (8) [17].

$$Q(x,\omega) \underset{x\in X}{\longrightarrow} \max(x), \tag{8}$$

where Q is the quality function of the system; x is the control influence; ω is the disturbance of the external environment. The main task of the management system is to find control actions that maximize the quality function of the Q system under the influence of external disturbances. The quality parameter of the system includes the suitability of programs for the reconstruction of engineering infrastructure for implementation and its value, that is, bringing the value of the index of implementation of strategic objectives to one $I_s = 1$; maximization of financial, technological and aggregated values of the program. In the case of an open system, the model should account for the impact on the object of the entire complex of environmental influences. This constraint leads to an excessive increase in the complexity of the management system. Reducing the requirements for the management system is possible with the introduction of feedback. Its application provides the management system with the information about a gap between the actual output of the system and the output required by the management task. The formal statement of the management task for the case of feedback application is as follows [17]:

$$Q(S, x, y, \omega) \xrightarrow[x \in X, y \in Y]{} \max(x), \quad (9)$$

where S is the task, a management plan; y is the state of the object of management. In non-stationary conditions, when the program is exposed to various external factors, the issue of management quality becomes significant. According to the method of modification variability, both a decrease in entropy and an expansion of the methodological base that forms the management algorithm lead to an improvement in the quality of management. Formally, the management task is converted into the following form:

$$Q(S, x, y, m, \omega) \xrightarrow[x \in X, y \in Y, m \in M]{} \max(x), \quad (10)$$

where m is the law or management algorithm. It is necessary to find a law or management algorithm that ensures the maximum value of the index of strategic goals in a given range of control actions. Simultaneously, external disturbances cause a violation of the optimum and a drop in the quality of management. A further decrease in the quality of management, due to the widening gap between the new optimal management law (the law that ensures the extreme value of Q) and the existing law, can lead to instability and uncontrollability of the system.

For programs for the reconstruction of engineering infrastructure, an adequate solution to this problem is the synthesis of an adaptive management system that restructures the management law (algorithm) depending on the disturbances [10]. Requirements for the quality of regulation of programs for the reconstruction of engineering infrastructure as organizational and technical systems necessitate optimization of the parameters of the management system, which is possible only if there is a well-formalized model of the object of management. The introduction of the adaptation loop (third hierarchy or quality feedback) enables modelling a management system that implements optimal management in the dynamics. The need for adaptation arises in conditions of incompleteness of information [18]. In the process of adaptation, knowledge is accumulated and the system is improved. In system management, adaptation consists in making changes to the parameters of the system, its structural elements, and relationships as well as management algorithms to ensure the required values of the quality criteria.

The above outlined problems related to the high structural and dynamic complexity of the programs for the reconstruction of engineering infrastructure can be solved by modelling the system, which is the object of management, using the "black box" modelling method. The dependencies (11) (statistical model), (12) (dynamic model) will be relevant for the inputs of the N system and the outputs of the Y system.

$$y_i = f_i(n_1, n_2, \ldots, n_i), n \in N, \quad (11)$$

where y_i is the I-th output of the object of management; n_i is the I-th input of the object of management.

$$y_i(T) = F(n_1(T), n_2(T), \ldots, n_n(T));$$
$$\forall T \in T^{max} = \{T^{St}, T^{Fin}\}, n \in N, \quad (12)$$

where T is the time of operation of the object of management; T^{max} is the maximum value of the time of operation of the object of management; T^{St} is the initial moment of operation of the object of management; T^{Fin} is the final moment of operation of the object of management. During the implementation of programs for the reconstruction of engineering infrastructure, the information on the inputs of the object of management is gathered and also information on its outputs is clarified. This information is accumulated in the knowledge base and transmitted both in the management system and in the adaptation system. Scholars distinguish active and passive adaptive management [14]. The essence of passive adaptive management consists in introducing the process of learning from the experience of program management into the existing approach, that of active management consists in the preliminary search and analysis of information to determine the best approach to management. A simplified diagram of the process of passive adaptive management of programs for the reconstruction of engineering infrastructure can be presented graphically (Fig. 3).

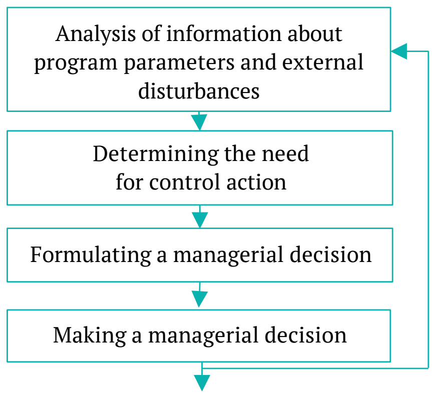

Figure 3. The process of passive adaptive management of programs for the reconstruction of engineering infrastructure

Source: developed by the authors based on [14]

A similar approach to managing programs for the reconstruction of engineering infrastructure involves the use of feedback to maximize the effectiveness of the control actions performed and the implementation of the program objectives. The data obtained are used to forecast the outcomes of future control actions, adjust the interim objectives of the program, etc. Thanks to the accumulated experience in managing an open dynamic system, which a program for the reconstruction of engineering infrastructure is, the passive adaptive approach provides for a better adaption to external disturbances and minimization of the negative impact of the external environment on the program implementation process. The scheme of the process of active adaptive management of programs for the reconstruction of engineering infrastructure is shown in Figure 4.

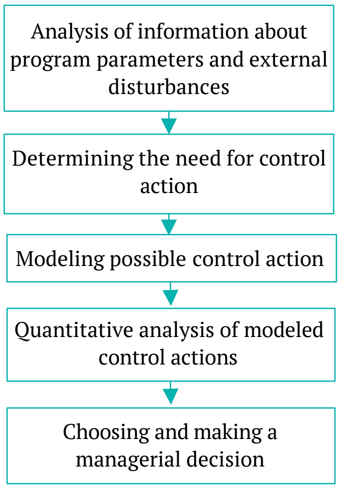

Figure 4. The process of active adaptive management of programs for the reconstruction of engineering infrastructure
Source: developed by the authors based on [14]

The main difference from the passive approach is the preliminary forecast of the outcomes of the exercise of control action and the choice of the best possible option. To maximize the effectiveness of the implementation of programs for the reconstruction of engineering infrastructure, it is advisable to use elements of both approaches: the application of both forecast and learning processes by the program management system. The scheme of this approach is shown in Figure 5.

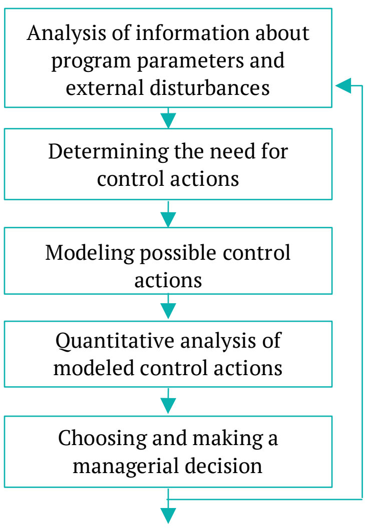

Figure 5. The process of combined adaptive management of programs for the reconstruction of engineering infrastructure
Source: developed by the authors on the basis of the data [14]

Thus, there is both the use of feedback and the accumulation of experience in the implementation of control actions during the implementation of programs for the reconstruction of engineering infrastructure and the application of this experience in their modelling and analysis. Thanks to the application of a combined approach to adaptive management, it is possible to achieve maximum efficiency of program management. Accordingly, the model of the program management system when applying the adaptive approach will have the following form:

$$PM = \{MD, MP, ID, K, AM\}, \quad (13)$$

where AM is a set of adaptive program management tools. The set of adaptive management tools is illustrated by the formula (14).

$$AM = AM_{learn} \cup AM_{omod} \cup AM_{for} \cup AM_{exp} \cup AM_{ADSS}, \quad (14)$$

with AM_{learn} being learning methods; AM_{omod} being models and tools for modelling the object of management; AM_{for} being methods and tools for forecasting; AM_{exp} being management experiments; AM_{ADSS} being adaptive means of supporting managerial decision-making.

Among the existing adaptive program management tools proposed by R. Bolling [19], it is advisable to apply adaptive logical-structural matrices, the use of real-time data, flexible program financial framework, structured learning cycles, action research for engineering infrastructure reconstruction programs. Adaptive logical-structural matrices differ from the usual matrices in that they allow the target indicators and the structure of the program to be adapted given the conditions of the external environment. The use of real-time data involves the continuous collection of information on the progress of the program. Flexible financial frameworks represent a variable cost structure and built-in opportunities to reallocate the budget during the implementation of the program. Structured learning cycles correspond to the concept of passive adaptive program management and include the introduction of a cyclical learning process based on feedback data. The essence of action research is the constant collection and analysis of data on the results of the control actions carried out to further optimize the management process.

Although other of the proposed tools can be used in the management of programs, but their application is inexpedient in the implementation of the programs considered in this study. An example of these tools is the evolutionary approach which is close to the concept of active adaptive program management and consists in testing control actions, scaling more effective and rejecting less effective ones. It provides for an analysis of already implemented actions, which is inappropriate in programs for the reconstruction of engineering infrastructure due to the high level of technical and financial risks. Inappropriate in the implementation of programs for the reconstruction of engineering infrastructure is also the inclusion of "bottom-up" – the involvement of beneficiaries and the program management team to obtain information on the implementation of the program and the formation of managerial decisions; this approach is important, but in the context of the management of programs for the reconstruction of engineering infrastructure cannot be fully applied due to the high level of technical and financial risks.

Such adaptive management tools can be applied throughout the life cycle of the program [15]. For different phases of the life cycle, there are characteristic features for the use of both the above mentioned means and elements of adaptive management in general. In the implementation phase, the principles of adaptive control can be used most comprehensively through learning and forecasting processes. To exert a control action, it is possible to conduct a preliminary analysis of the accumulated experience, information on the state of the object of management and the presence of external disturbances, the use of this data for further forecast of the effect of the action. In the absence of a description of the object of management, it can be created, but this process is more relevant for the program definition phase. For the closure phase, it is more relevant to analyse the accumulated information and formulate best practices, lessons learned, etc. These processes demonstrate the use of learning as an element of adaptive management, but at the level of the organization where the program is implemented. The information obtained can be used to adjust similar program management processes in the future, but for this program at the closure phase, this information will no longer be relevant. The program definition phase involves more likely the use of means that provide opportunities for adaptation in the future: adaptive logical-structural matrices and flexible financial frameworks. Learning can be applied solely on the basis of previous program implementation experience. However, among the elements of adaptive management described in [13], forecasting and description are relevant. A list of supporting activities for the PMI program definition phase is provided in Figure 6.

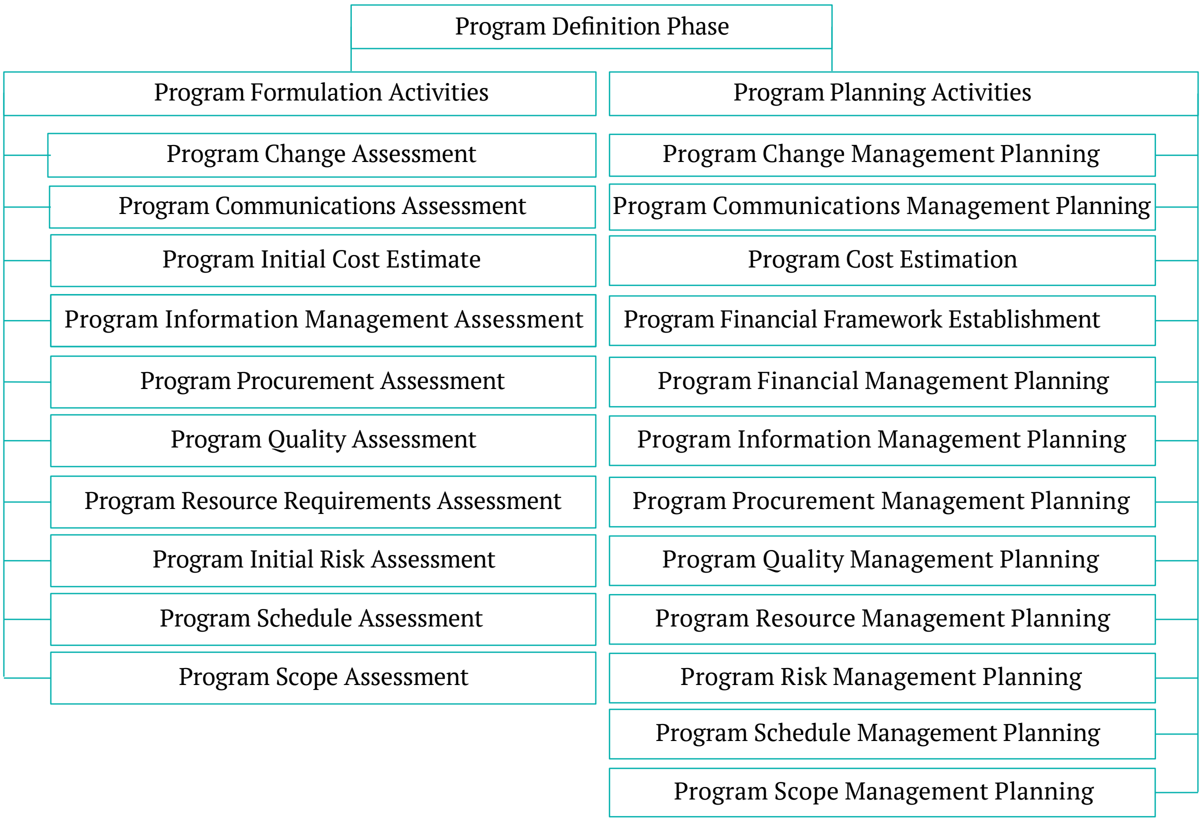

Figure 6. Structure of supporting activities of the program definition phase

Source: developed by the authors based on [15]

Forecasting methods can be applied to a large number of listed activities, including those related to managing quality, resources, schedule, scope, cost and finance, etc. The description of the object of management is also multifunctional in the context of the listed processes. The phases of program definition and implementation provide for the successful application of an adaptive approach, whereas it is necessary to note the importance of adaptivity for the definition phase. As mentioned earlier, scope assessment and program architecture development are the basis for assessing the program initial cost, changes, resources, risk and schedule. To select the optimal components of programs for the reconstruction of engineering infrastructure and their adaptation to environmental conditions, it is possible to use adaptive tools to support managerial decision-making.

The study by S. Canessa [20] is a good example of the application of an adaptive approach in the implementation of biodiversity protection projects, where the researchers' successful use of modelling and probabilistic analysis methods must also be highlighted. The approach was implemented by constructing a quantitative model of the system, the uncertainty of the model parameters was formulated using probability distributions, and the learning benefits were evaluated using simulations. The authors note an increase in the effectiveness of monitoring and changing actions within the project, as well as ensuring the possibility of a safer response to negative external influences. However, the findings of the study in the context of programs and projects for the reconstruction of engineering infrastructure can be used only in part due to the lack of consideration of their special features.

The article by L. Gutheil [21] systematically reviews 21 studies on adaptive project management in the field of civil society to systematize ideas about adaptive practices, their perceived effect, obstacles and recommendations for their implementation from the perspective of donors and implementers. The work provides a basis for further research as it contributes to the definition of adaptive practices, the systematization of existing experiences in the implementation of adaptive management of such projects and identifies gaps in the current theoretical framework. However, it does not include more practical means of adaptive project management. G.B. de Azevedo [22] proposed an adaptive project management model to create a professional doctorate in business management. As a result, an adaptive project management model has been developed that includes constant planning of activities in each interaction cycle, an incremental approach to project execution, regular review of interim results, and the ability to adapt to changes in project content during the implementation phase. This work is a good case study of the practical use of adaptive project management tools. However, the findings of the study cannot be fully applied to the management of the program, as the application of an incremental approach to their implementation is inappropriate.

R.A. Samrah [23] analyses 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 program model that takes into account the above variables and can be used for the management of large programs. The work presents a systematic approach to program management, provides an adaptive management tool that is valuable in terms of the possibility of further use of its findings, but does not take into account the specifics of programs and projects for the reconstruction of engineering infrastructure. The article by M. Wirkus [24] analyses the adaptive approach to project management and demonstrates the possibility of applying this approach to the implementation of a project for the reconstruction of a railway line. They discuss the issue of introducing adaptivity in infrastructure project management, but their main focus is placed on the development of project documentation within this approach. The findings of the study are useful given the general lack of disclosure of the processes of project documentation development in other sources.

The study by J.A. Thomann [25] is devoted to a critical assessment of strategies for adaptive groundwater management in urban water supply, agriculture and mining. The authors identified a number of problems with the application of adaptive management principles in the cases reviewed, including the lack of significant mitigation action and/or assessment of recovery potential. The need to develop clear definitions and guidelines for adaptive management is emphasized in order to ensure more transparent planning and efficiency in achieving objectives. The case analysis enabled the authors to identify the main problems in adaptive groundwater management and to develop appropriate recommendations that form the basis for the further development of management tools. In this paper, however, adaptive management is considered in a more general context, without a clear link to programs and projects.

The use of methods and tools for the adaptive management of programs and projects for the reconstruction of engineering infrastructure can therefore have a significant impact on the effectiveness of their implementation in turbulent conditions. By using learning methods, modelling of managerial influences, forecasting their results, etc. in different phases of the life cycle, it is possible to better adapt the management system to internal and external influences as well as a higher level of achievement of the program or project objectives.

CONCLUSIONS

Program and project management as a whole occurs under conditions of uncertainty in the external and internal environment, where uncertainty stems not only from social, political conditions in the country of the project or program implementation but also from technical, human, and other factors of the management system and beneficiary organizations. This particularly applies to programs and projects for the reconstruction of engineering infrastructure as complex organizational and technical systems. They are also characterized by problems such as: it is impossible to build an invariant model of the program for the reconstruction of engineering infrastructure and an adequate model of the management system due to the lack of a priori information; an analytical mathematical model cannot be built using traditional methods. Uncertainties in the environment are sources of operational, technical, cost and schedule risks. The occurrence of any risks directly affects the possibility of achieving the objectives of programs and projects and complying with the set constraints.

To reduce the probability of these risks, it is recommended to employ an adaptive approach to program and project management. Adaptivity in program and project management involves the introduction into the management processes of learning from the results of control actions, modelling of managerial influences and assessing the effectiveness of their implementation, describing the control systems-objects and conducting managerial experiments. There are passive and active adaptive approaches to management, with the passive approach relying on learning mechanisms, and the active approach involving preliminary modelling of managerial influences. A combined application of these approaches is necessary to maximize the effectiveness of adaptive management.

Within the framework of adaptive program and project management, various tools can be used, such as adaptive logical-structural matrices, flexible financial program frameworks, an evolutionary approach to implementing control actions, etc. It is found that different phases of program implementation involve the use of different methods of adaptive management. For the implementation phase of the program, it is advisable to use learning methods based on the managerial experience gained as well as forecasting to determine the best managerial influences. The closure phase enables the collection and analysis of information on the program progress for further learning for the implementation of future programs and projects. For the definition phase, it is important to provide possibilities for the application of adaptivity in the further implementation of the program through tools such as adaptive logical-structural matrices, etc. A promising area of research in the context of adaptive management of programs and projects for the reconstruction of engineering infrastructure is the development of new tools and methods of adaptive management, the study of ways to adapt the approach to the specifics of programs and projects in other areas of implementation – social, environmental, etc.

REFERENCES

[1] Yushchenko, N. (2020). Aspects of classification of network methods of planning of resources and expenses and their management during modernization of a municipal infrastructure of territorial communities in the conditions of decentralization. *Scientific Bulletin of the International Humanities University. Series: Economy and Management*, 43, 244-247. doi: 10.32841/2413-2675/2020-43-40.

[2] Ciapessoni, E., Cirio, D., Pitto, A., & Sforna, M. (2020). A quantitative methodology to assess the process of service and infrastructure recovery in power systems. *Electric Power Systems Research*, 189, article number 106735. doi: 10.1016/j.epsr.2020.106735.

[3] Nieviedrov, D. (2020). *Methods and models of environmental impact assessment in critical infrastructure facilities construction and reconstruction projects*. (PhD dissertation, National Transport University, Kyiv, Ukraine).

[4] Bespala, N. (2019). Main directions of the development of the regional energy systems. In *Energy. Ecology. Human: Proceedings of the XI scientific and technical conference of the Institute of Energy Saving and Energy Management* (pp. 14-25). Kyiv: Institute of Energy Saving and Energy Management.

[5] Çelik, M. (2016). Network restoration and recovery in humanitarian operations: Framework, literature review, and research directions. *Surveys in Operations Research and Management Science*, 21(2), 47-61. doi: 10.1016/j.sorms.2016.12.001.

[6] Yang, Y.C.E., Son, K., Hung, F., & Tidwell, V. (2020). Impact of climate change on adaptive management decisions in the face of water scarcity. *Journal of Hydrology*, 588, article number 125015. doi: 10.1016/j.jhydrol.2020.125015.

[7] Bennett, N.J. (2016). Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology*, 30(3), 582-592. doi: 10.1111/cobi.12681.

[8] Papke-Shields, K.E., & Boyer-Wright, K.M. (2017). Strategic planning characteristics applied to project management. *International Journal of Project Management*, 35(2), 169-179. doi: 10.1016/j.ijproman.2016.10.015.

[9] Feldbaum, A. (1960). Dual control theory I. *Automation and Remote Control*, 21(9), 1240-1249.

[10] Feldbaum, A. (1961). Dual control theory III. *Automation and Remote Control*, 22(1), 3-16.

[11] Heylighen, F. (1999). *The science of self-organization and adaptivity*. Retrieved from http://pespmc1.vub.ac.be/Papers/EOLSS-Self-Organiz.pdf.

[12] Oppermann, R., Rashev, R., & Birlinghoven, S. (1997). *Adaptability and adaptivity in learning systems*. Retrieved from https://www.geocities.ws/tgsrao/kt97_gmd.pdf.

[13] Argent, R.M. (2009). Components of adaptive management. In C. Allan, & G.H. Stankey (Eds.), *Adaptive environmental management* (pp. 11-36). Dordrecht: Springer. doi: 10.1007/978-1-4020-9632-7_2.

[14] Tervo-Kankare, K., Kaján, E., & Saarinen, J. (2017). Costs and benefits of environmental change: Tourism industry's responses in Arctic Finland. *Tourism Geographies*, 20(2), 202-223. doi: 10.1080/14616688.2017.1375973.

[15] Project Management Institute. (2008). *The standard for program management* (2nd ed.). Newtown Square: Project Management Institute.

[16] Project Management Institute. (2017). *The standard for program management* (4th ed.). Newtown Square: Project Management Institute.

[17] Sukhonos, M. (2016). *Dual energy infrastructure portfolio management in a dynamic environment*. Kharkiv: O.M. Beketov NUUE.

[18] Larson, E.W., & Gray, C.F. (2021). *Project management: The managerial process* (7th ed.). New York: McGraw Hill.

[19] Bolling, R., Van Wijk, K., & Goris, Y. (2019). *Adaptive programme management in fragile and complex settings*. Retrieved from https://www.thebrokeronline.eu/practice-note-adaptive-programme-management-in-fragile-and-complex-settings/.

[20] Canessa, S., Ottonello, D., Rosa, G., Salvidio, S., Grasselli, E., & Oneto, F. (2019). Adaptive management of species recovery programs: A real-world application for an endangered amphibian. *Biological Conservation*, 236, 202-210. doi: 10.1016/j.biocon.2019.05.031.

[21] Gutheil, L. (2020). Adaptive project management for the civil society sector: Towards an academic research agenda. *International Development Planning Review*, 43(3). doi: 10.3828/idpr.2020.17.

[22] Azevedo, G.B.D., Maccari, E.A., & Asgary, N. (2021). The use of adaptive project management practices and methodologies in the development of a professional doctoral program. *Revista de Administração da UFSM*, 14(1), 44-62. doi: 10.5902/1983465942849.

[23] Samrah, R.A., Shaalan, K., & Ali, A. (2017). System dynamics modelling for the complexity of knowledge creation within adaptive large programs management. In Á. Rocha, A. Correia, H. Adeli, L. Reis, & S. Costanzo (Eds.), *Recent advances in information systems and technologies* (pp. 3-17). Cham: Springer. doi: 10.1007/978-3-319-56535-4_1.

[24] Wirkus, M. (2016). Adaptive management approach to an infrastructure project. *Procedia – Social and Behavioral Sciences*, 226, 414-422. doi: 10.1016/j.sbspro.2016.06.206.
[25] Thomann, J.A., Werner, A.D., Irvine, D.J., & Currell, M.J. (2020). Adaptive management in groundwater planning and development: A review of theory and applications. *Journal of Hydrology*, 586, article number 124871. doi: 10.1016/j.jhydrol.2020.124871.

Адаптивний підхід до управління програмами і проєктами з реконструкції інженерної інфраструктури

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Анотація. Стандартні підходи до управління проєктами та програмами з реконструкції інженерної інфраструктури в умовах турбулентного зовнішнього середовища є малоефективними через брак можливостей адаптації до зовнішніх та внутрішніх впливів. Тому метою статті було охарактеризувати застосування концепції адаптивності в управлінні такими проєктами і програмами, проаналізувати засоби її застосування в процесах управління. Дослідження, наведене у статті, проведено за допомогою наукових методів критичного аналізу, системного аналізу, математичного моделювання, формалізації, аналізу, синтезу, графічного та абстрактно-логічного методів. Визначено основні обмеження при розробці архітектури програм. Досліджено вплив застосування стандартного підходу планування та управління програмами та проєктами з реконструкції інженерної інфраструктури на підвищення вірогідності виникнення ризиків впровадження. Сформульовано завдання управління програмами та проєктами при здійсненні управління як реалізації керівного впливу. Розглянуто концепції активного та пасивного методів адаптивного управління програмами, розроблено комбінований метод, що поєднує в собі попереднє моделювання управлінських впливів та навчання на досвіді здійснення таких впливів. Проаналізовано засоби адаптивного управління програмами, визначено доцільність їх застосування при управлінні програмами з реконструкції інженерної інфраструктури у різних фазах їх реалізації. Результати дослідження можуть застосовуватись менеджерами програм та проєктів з реконструкції або модернізації інженерної інфраструктури для визначення підходів до управління та підбору засобів адаптивного управління для різних фаз впровадження, а також являють собою методологічне підґрунтя для проведення подальших досліджень

Ключові слова: організаційно-технічні системи, керівний вплив, ризики, планування архітектури, прогнозування