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Olena Barabash
Doctor of Technical Sciences, Professor of the Department of Ecology and Safety of Vital Functions
barabashelena29@gmail.com, orcid.org/0000-0001-5206-2922
National Transport University, Faculty of Automotive and Mechanical Engineering, Ukraine

Vadim Ziuziun
PhD in Technical Sciences, Associate Professor at the Department of Management Technologies
vadim1489z@gmail.com, orcid.org/0000-0001-6566-8798
Taras Shevchenko National University of Kyiv,
Faculty of Information Technologies, Ukraine

Lyubov Kubiavka
PhD in Technical Sciences, Associate Professor at the Department of Management Technologies
liubov.kubiavka@knu.ua, orcid.org/0000-0002-5141-9886
Taras Shevchenko National University of Kyiv,
Faculty of Information Technologies, Ukraine

ON THE DEVELOPMENT OF MANAGEMENT MODELS FOR REGIONAL PROGRAMS OF ENVIRONMENTALLY SAFE OPERATION AT CRITICAL TRANSPORT INFRASTRUCTURE FACILITIES

Abstract. The objects of the critical transport infrastructure are located in all regions of Ukraine, and the question of the safety of these objects is extremely relevant. A functional approach should be used to form an effective safety management unit for critical transport objects. Therefore, in order to achieve an acceptable level of safety of the critical transport infrastructure, it is necessary to have an effective mechanism for achieving this result, which can be achieved through the formation and efficient management of regional programs for the safe operation of critical transport infrastructure objects. Management models for regional safety programs at critical transport infrastructure facilities based on the existing approaches to construction of models of program and project management are proposed in the article. Critical transport infrastructure includes highways, state-owned transport enterprises, subway facilities, gas stations, bridges, sea and river ports, airports, and pipelines. These facilities are strategic for the state and, consequently, vulnerable, so they require special protection. In order to form an effective apparatus for environmental safety management in critical transport infrastructure facilities, the application of a program approach is proposed in the article. And to assess the life cycle of regional environmental safety programs of critical transport infrastructure facilities based on the Deming cycle, a spiral model was developed, which is the environment for the operation of schematic, system, and service models of the environmental safety management program. Development of approaches to the management of regional programs for the environmentally safe operation of critical transport infrastructure facilities, based on the formation of strategic objectives and their decomposition, will be aimed not only at solving existing problems of critical transport infrastructure in the region but factors related to the occurrence of dangerous events for them and the elimination of the causes leading to these problems. A system model for managing regional safety programs for objects of critical transport infrastructure is proposed.

Keywords: development of management, regional programs, environmental, transport infrastructure facilities, transport enterprises, environmental safety management, critical transport infrastructure facilities, management of regional programs, environmental safety, management program, system analysis, system models.

Introduction

The term "critical infrastructure" typically covers those facilities whose dysfunction or destruction will lead to the most serious consequences in the socio-ecological and economic development of the state, negatively affect its level of defense and national security, as well as maintaining vital functions in society.

Critical transport infrastructure facilities include highways, transport enterprises of state importance, subway facilities, gas stations, bridges, sea and river ports, airports, pipelines, etc. These facilities are strategic but vulnerable, so they require special protection [1].

In Ukraine, critical transport infrastructure facilities are located in all regions, respectively, the issue of environmental safety of these facilities is extremely important. In order to form an effective apparatus for environmental safety management in critical transport infrastructure facilities, a program approach shall be applied.

Therefore, to increase the level of environmental safety in critical transport infrastructure facilities, namely its natural and man-made components, it is necessary to have an effective mechanism to obtain this result, which can be achieved through the formation and effective management of regional programs of environmentally friendly critical infrastructure.

Therefore, the study aims to develop management models for regional environmental safety programs in critical transport infrastructure.

Literature review and problem statement

In recent years, the functioning of critical infrastructure and its protection has been considered in the next works. D.S. Biryukov, in his research [1], carried out a general classification of objects of critical information and proposed the main criteria for its division. The study [2] suggests possible ways to improve the protection of Ukraine's critical infrastructure, taking into account world experience. The scientific article [3] solves the current scientific–applied task of developing models of infrastructure projects safety management at the planning stage. A system model of management of regional safety programs for objects of critical transport infrastructure, as well as a template for the presentation and analysis matrix of regional safety programs for objects of critical infrastructure of transport, is proposed in the article [4].

The main aspects of program management were considered in the scientific work of S.D. Bushuyev, N.S. Bushuyev, F.A. Yaroshenko, and H. Tanaka [5].

Environmental safety issues are covered in the work of V. I. Liashenko, Yu. M. Kharazishvili [6]. Strategic scenarios for the structural development of industrial regions of Ukraine are considered.

The scientific work [7] explores the issue of the importance of environmental security as a factor in the state's national security. In scientific work [8], studies were carried out on the relationship between environmental pollution, transport development, and urbanization in general. A direct dependence on these three concepts is revealed. The conclusion is made about the importance of studying it in a complex. The scientific work [9] examines the concept of threats to environmental security in the national security system of Ukraine. The safety of critical transport infrastructure is defined as one of the most important criteria.

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The aim and objectives of the study

The study aims to develop effective approaches and mechanisms for managing environmental safety programs for critical transport infrastructure facilities to improve the efficiency of their functioning.

The object of the study is the processes of ensuring the environmental safety of critical transport infrastructure facilities.

Materials and methods

The following research methods were used: analysis and synthesis, analytical modeling, systems theory, comparison and analogy, generalization and abstraction, graph theory and set theory, transport systems theory and transport theory, system and process analysis, parametric analysis, morphological matrix construction method, multicriteria analysis method; project and program management.

Most proposed methods have been applied to develop mechanisms for managing environmental risks in transport development projects [10]. Environmental risk management is an important condition for overall environmental safety management. Thus, this confirms the effectiveness of the selected research methods.

Information on the features of functioning and planned activities and critical transport infrastructure facilities were used as materials.

Result and discussion of result

The program is a group of projects, management of which is carried out in complex with the aim of achieving certain results, since these results cannot be achieved through individual management. Business ideas that form the program, or concepts developed or presented by investors or owners as a mission of the program, are embodied in the group of projects that make up the program.

The program is usually created to solve complex problems, so it intertwines various branches of knowledge that fill the program with rich content and context, formulating a road map for problem solving. In this variety, various elements are synthesized – political, economic, social, technological, and ethical, and as a result, through the dynamic combination of these elements, the boundaries, the subject area and structure appear in the programs. Since the program is an organic combination of projects, it can encounter difficulties that are caused by the uncertainty of the boundaries between projects, the crossroads of projects and the integration of their life cycles. Along with the fact that the program has all the main characteristics of the project, it is characterized by a higher level of uncertainty, as it requires a relatively longer period for its completion and overcoming the challenges of the environment.

The creation of a regional safety management system for objects of critical infrastructure of transport may be the basis for developing an interactive system of regional software office that will allow conducting research on the effectiveness of implementing regional projects of various purposes and levels of management.

Development of management approaches to the regional programs for the environmentally safe operation of critical transport infrastructure facilities (CTIF), based on the formation of strategic objectives and their decomposition, aimed not only at solving existing regional problems but at eliminating factors associated with dangerous events for CTIF and elimination of the reasons leading to these problems, both locally and at the regional level. The general understanding of program management, according to P2M [5], is to understand the process of program and management system implementation, which covers the whole set of management objectives, is considered as a whole, and is the basis for assessing the regional program and its integration into a single environmental safety system.

The description of the project management principles formalizes the typical structure of the program presentation, planning, creation, and implementation, as well as the model of program cost management within the framework of program integration management and program community management, which are considered in the P2M standard [11].

The effectiveness of program management is determined by the process of forming the program life cycle (LC). The idea of creating a program should be based on the concept of building a mission of programs (in our case, the focus is on environmental safety). It should be characterized by multi-vector and diversity of context, as opposed to what is determined by the model or at least the obvious content of a particular project.

The main concept, the mission of the program is the formation of a system to increase the level of environmental safety in critical transport infrastructure facilities at the regional level and the implementation of a set of projects to prevent or reduce the possible natural and man-made hazardous processes factors associated with the CTIF functioning.

The system of program measures should provide the solution for the following tasks: definition of management methods for ecological safety of CTIF operating in separate territories and industrial zones; development of the optimal scheme for step-by-step management of ecological safety of the above-mentioned facilities; creation of a system of ecological, economic, political and social mechanisms focused on the development of the regional program for the ecologically safe CTIF functioning.

The project or program life cycle model reflects the phases the project (program) will undergo during its formation and implementation. Each phase of the program can be characterized by certain features within the defined mission and tasks to be solved. The project management standard PMBoK (Project Management Body of Knowledge) [12] defines 5 LF phases – initiation, planning, execution, control, and completion. According to the PRINCE2 standard (PRojects IN Controlled Environments) [13], a typical project (program) life cycle has 4 phases – project initiation, design, implementation, and closure. Control and monitoring of the project are not allocated in a separate phase but are carried out throughout the life cycle. Each phase of the project life cycle is determined by a certain list of input and output documents reflecting both the processes and features of their management and control.

The initial parameter of each phase of the life cycle is the decision to move to the next phase. Each project can be characterized by duration – the period from the project idea formation to the project completion; as well as its life cycle model.

The life cycle (LC) of the regional program for environmentally safe CTIF operation is built “from top to bottom”, as the main initiator of the program is local governments. Therefore, the program LC at the stage of implementation is a project’s LC association, which makes up the program. As a result, the LC of each project should be developed jointly with the program LC [14].

The IID model involves dividing the project (program) life cycle into a sequence of iterations, each of which resembles a “mini-project”, including all development processes used to create smaller pieces of functionality compared to the project as a whole. The purpose of each iteration is to obtain a specific result of the system, which includes the current iterations and the functionality defined by the integrated content of all previous iterations. The result of the final iteration contains all the necessary functionality to increase the environmental safety level. Thus, the level of environmental safety increases at the end of each iteration – the increment – to its capabilities, which is added to its capabilities.

Another mechanism is the construction of the spiral model, which was proposed by Barry Boehm in 1988. It is based on the classic PDCA (plan-do-check-act) Deming cycle. When using this model, the project (program) is performed in several iterations (turns of the spiral) by the prototype method. This principle was applied to build a spiral model that will assess the

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regional programs' life cycle for environmentally safe CTIF operation based on the Deming cycle (Fig. 1). Each iteration corresponds to the achievement of a certain result. It specifies the project goals and characteristics, evaluates the quality of the results, and plans for the next iteration. At each iteration, the risk of exceeding the terms and cost of the project, the need to perform the next iteration, the degree of completeness and accuracy of understanding the requirements for the system, and the feasibility of terminating the project are assessed.

The spiral model defines the following set of control points:

1. Concept of Operations (COO) – concept (use) of the system;
2. Life Cycle Objectives (LCO) – goals and content of the life cycle;
3. Life Cycle Architecture (LCA) – life cycle architecture; here we can speak about the readiness of conceptual architecture of the target program for the system;
4. Initial Operational Capability (IOC) – the first version of the desired environmental safety level, suitable for experimental operation;
5. Final Operational Capability (FOC) – the optimal level of environmentally safe CTIF operation.

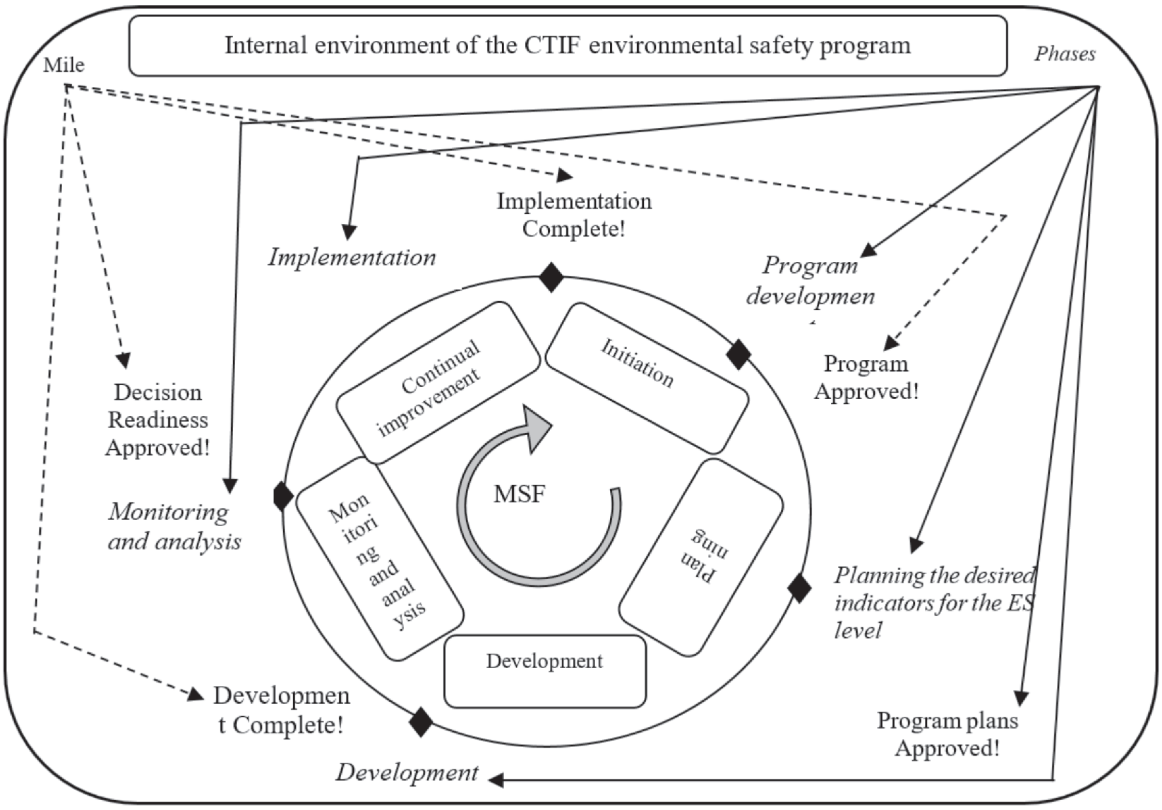

Figure 1. Spiral model for assessing the regional programs life cycle for environmentally safe CTIF operation based on the Deming cycle

Program integration management consists of a series of management actions in which the mission of the program is divided into components – projects managed as a single organic structure. The projects included in the program are combined to increase its overall value. The program integration management structure includes mission definition; program architecture management; program strategy management; program evaluation management [5].

Management of regional programs integration for environmentally safe CTIF functioning unites schematic, system, and service models of programs. This template is shown in Fig. 2 and can be used in the management of regional CTIF safety programs.

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The main features of the schematic model are the following: high probability of feasibility, the well-established internal structure of the program and external relationships, as well as the flexibility of processing requests for changes made by the program owner in response to changes in the environment. The products of the schematic model are the main documents of the program concept: a feasibility study (which analyzes the technology, financing schemes, investment structures, and the economic and socio-political environment that will achieve the desired level of environmentally safe CTIF operation).

The evaluation of the program value is first carried out according to the schematic model, then – according to the system model, and afterward – according to the service model. The assessment is based on indicators obtained as a result of monitoring and analysis of the CTIF internal and external environment and their impact on the environment.

The program consists of many interconnected projects. Standard P2M project models are reference models that can be used to compile a program. These models are included in the program at its various stages and are characterized by a specific functional focus aimed at improving the CTIF environmental safety level.

Let's model the regional program for CTIF's environmentally safe operation in general.

Assume that the program consists of n projects, each of which is implemented for a single critical transport infrastructure facility of the region (ES). We will mark many projects as $i = \{1, 2, ..., n\}$. A strategy to increase the level of environmental safety for *i-th* ES is the choice of action $y_i \in A_i$ – a segment of the positive half-axis, including zero, $i \in I$. Let s_i – a non-negative non-decreasing function equal to zero in zero and *j-th* the center evaluates the effectiveness of the program by the indicators (the aggregate result of ES activities) $z_j = Q_j(y)$, where Q_j: $A' \rightarrow \Re^{m_j}$, $m_j \leq n$ – aggregation function, $j \in K = \{1, 2, ..., k\}$ – many factors of the effect. Let's mark $H_j(z_j)$ – reduction for the impact of the j-th factor of the program effect on the environment, $j \in K, z = (z_1 z_2, ..., z_n) \in \Re^m$ – vector of activity results, $t = \sum_{j \in K} m_j$. Suppose that each of the effect factors affects the outcome of the regional program for CTIF's environmentally safe operation. The relationship between the effect factors and the ES results is called the stimulus function and is denoted $\sigma_{ij}(z_{ij}), i \in I, j \in K$. Thus, the total stimulation $\upsilon_i(z)$ receiving *i-th* ES, is equal to $\upsilon_i(z) = \sum_{j \in K} \sigma_{ij}(z_i), i \in I$, and the objective functions of the effect factors and ES are:

$$
\begin{aligned}
& f_j(z_j, \{\sigma_{ij}(\cdot)\}_{i \in I}) = H_j(z_j) - \sum_{i \in I} \sigma_{ij}(z_j), j \in K \\
& f_i(y, \{\sigma_{ij}(\cdot)\}_{j \in K} = \sum_{j \in K} \sigma_{ij}(z_j) - c_i(y_i), i \in I
\end{aligned} \tag{1}
$$

In a formalized form, the task of forming a projects portfolio (a set of projects) can be written as follows. Let Q_i – many strategic environmental goals of the region, $i = 1, 2, \ldots, I$ a C_{jz} – a set of sets of strategic eco-goals $j = 1, 2, ...,$ desired results environmentally safe operation CTIF $z = 1, 2, ..., Z$. Then the intersection of sets Q and C there will be goals of projects P_{ijz} sent to a potential portfolio (set of projects).

$$P_{ijz} = Q_i \bigcap C_{jz} \, . \tag{2}$$

It should be noted that there may be several compatible or incompatible projects in the potential portfolio to achieve the goal *i*. Therefore, at the next stage, the portfolio should be optimized according to the criterion of the environmental safety level, which in our case will be expressed in minimizing the negative impact of the studied CTIF on the environment:

$$\sum_{i=1}^{I} Q_i - \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{z=1}^{Z} P_{ijz} \longrightarrow \min. \tag{3}$$

The specifics of project portfolio management for CTIF environmentally safe operation is, including the fact that the feasibility of individual projects is assessed in terms of achieving strategic environmental development goals and improving the environmental safety level of the region as a whole. That is, in the general case – by several criteria, unambiguous evaluation of the project is not always possible.

In addition, projects use at least several types of resources. Therefore, classical optimization problems (linear programming, etc.) cannot be used in the formation of an effective environmental projects' portfolio. Accordingly, the program approach is the most effective tool to achieve the goal of environmentally safe operation in critical transport infrastructure facilities.

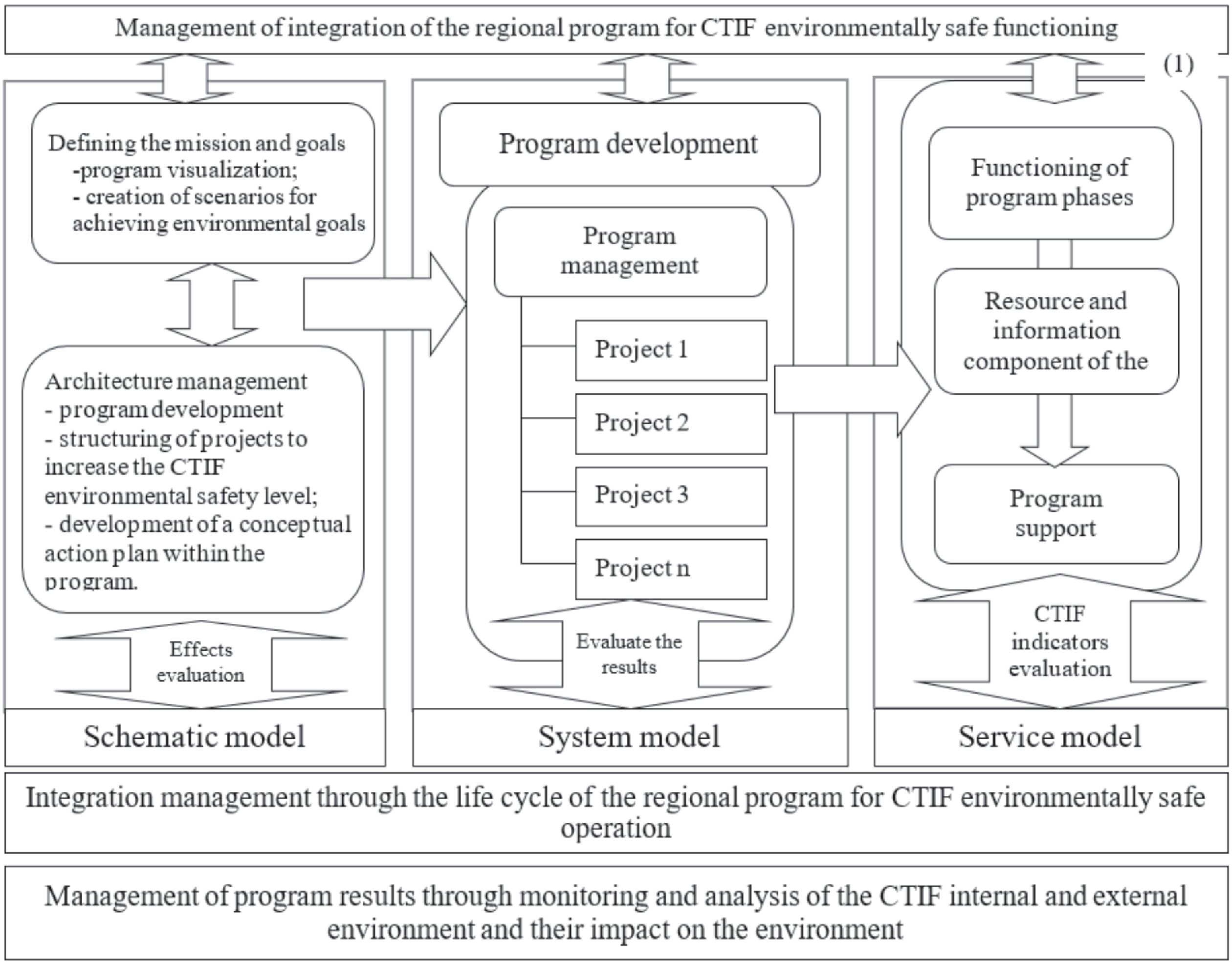

Figure 2. Integration management of the regional program for CTIF environmentally safe functioning (interconnection diagram)

To develop an effective regional program of environmentally safe operation at critical transport infrastructure facilities, it is necessary to formulate the following:

- the purpose of the implementation of the regional program of environmentally safe operation at critical transport infrastructure facilities;
- scope of the program;

- terms of implementation of individual program projects;
- role and conditions of project teams;
- responsible (coordinator) for the implementation of each local project and its authority.

System analysis is the most constructive direction, which is used for the practical application of the theory of systems to control devices. Constructiveness of the system analysis is related to the development of a method of conducting work, which allows taking into account all essential factors that enable the construction of effective management systems in specific conditions [4].

System analysis for transport objects was used in the research. Especially this method is relevant for the construction of system models for the development of various processes, including the level of the regional programs for the environmentally safe operation of CTIF.

System analysis involves a consistent transition from general to partial, where the analysis is based on the specific ultimate goal for which the logistics system is created. With a system approach, each system can be represented as an integrated whole, even when it consists of separate subsystems.

An object is a system consisting of naturally structured and functionally organized elements. A systematic approach is used to systematize and combine objects or knowledge about them by establishing significant links between them. Such synthesis requires foresight, the ability to link close-ups with far-reaching, technical and economic factors with environmental and social. The above-mentioned peculiarities of system analysis are best suited for the processes of management of the regional programs for the environmentally safe operation of CTIF, since in the study of these objects, there is a need for a clear understanding of the factors, processes and elements that are at the entrance to the functioning of the system, program and project final results. A clear understanding of all the processes that determine the factors and criteria for the safety of critical infrastructure objects of the regional programs for the environmentally safe operation of CTIF (shown above in Figure 3) is also very important.

Thus, based on the above, we have proposed a system model for managing the regional programs for the environmentally safe operation of CTIF (see above, Figure 3).

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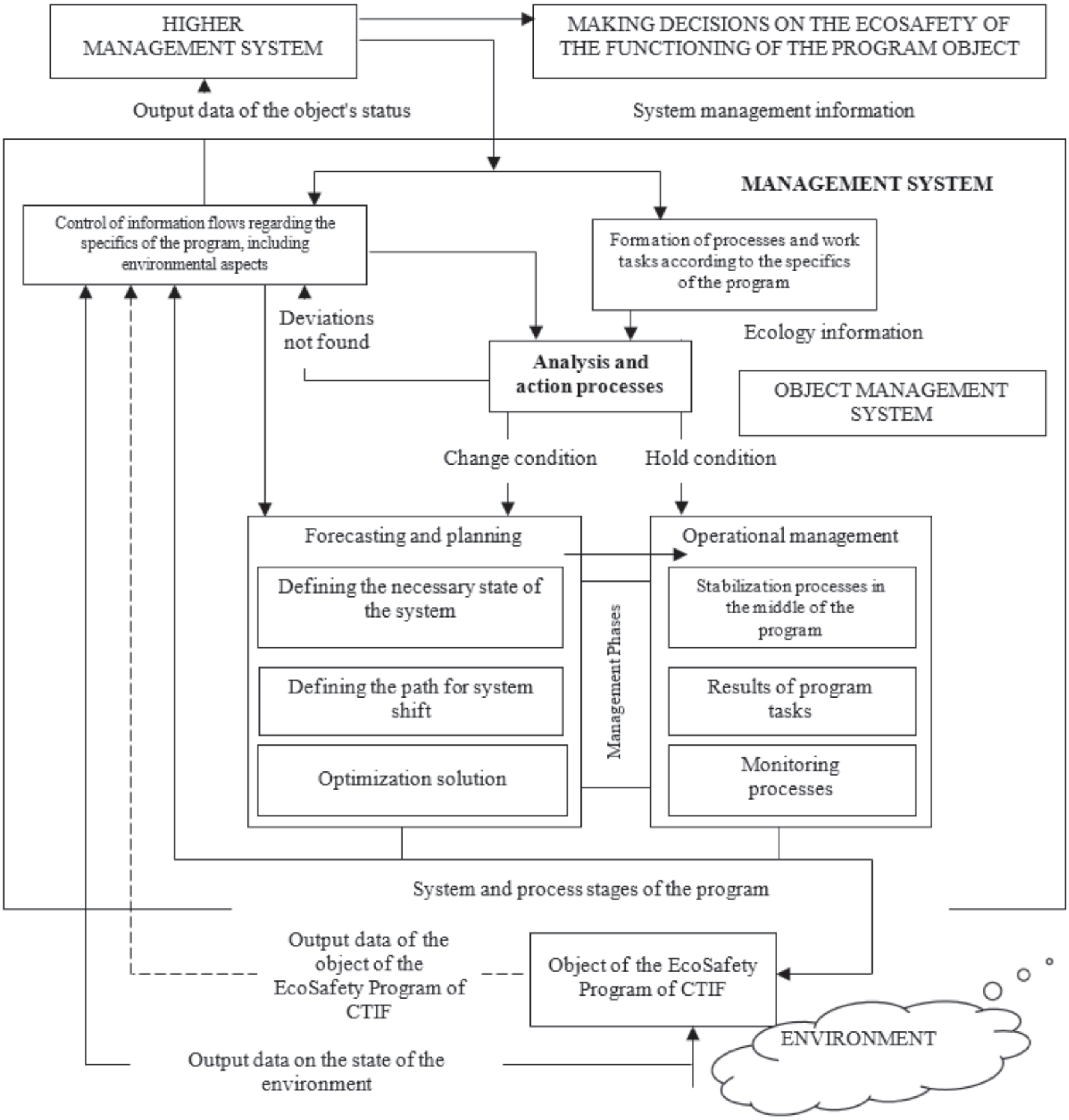

Figure 3. System model of management of regional programs of environmentally safe operation at critical transport infrastructure facilities

Conclusion

Thus, the models ensuring the movement of our state to the environmentally safe operation of critical transport infrastructure facilities and contributing to the effective implementation of regional programs for CTIF environmentally friendly operation can be the schematic, system, and service models operating on a spiral model of the program life cycle based on the Deming cycle. The implementation of these programs will improve both the reliability of the facilities in terms of their environmental safety in general and reduce the likelihood of adverse events for the environment from the operation of the critical transport infrastructure facilities. A system model for managing regional safety programs for objects of critical transport infrastructure is proposed. The developed algorithms and models will contribute to the effective management of environmental safety programs for critical transport infrastructure facilities.

Further scientific research will be aimed at developing project management algorithms to improve the environmental safety of critical infrastructure facilities. An industry approach will be applied to the separation of critical infrastructure facilities. Such an approach will contribute to the effective improvement of environmental safety management in practical aspects since it will take into account the specifics of each critical infrastructure facility.

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