SECTION: TECHNICAL SCIENCES

DOI 10.70286/ISU-15.04.2026.020

JUSTIFICATION OF THE SYNERGY BETWEEN PROJECT MANAGEMENT AND ENVIRONMENTAL MONITORING IN THE SECURITY SYSTEM OF CRITICAL TRANSPORT INFRASTRUCTURE

Ziuziun V.
PhD in Technical Sciences, Associate Professor
Department of Management Technologies
Taras Shevchenko National University of Kyiv, Ukraine
orcid.org/0000-0001-6566-8798

Abstract. This paper presents a comprehensive analysis of the mechanisms for developing regional safety programs for critical transport infrastructure (CTI) facilities. It substantiates the scientific and practical necessity of integrating modern project management tools based on the P2M methodology with advanced environmental monitoring systems. Particular attention is given to the incorporation of environmental parameters into an iterative spiral project life cycle model, enabling continuous monitoring of infrastructure conditions.

An approach to forming project portfolios is proposed based on criteria that maximize asset value while reducing risks through the rational allocation of resources. It is determined that the implementation of a synergistic approach, along with parallel project combinations, not only minimizes the risks of secondary contamination but also significantly enhances the «dynamic resilience» of the transport system to emergencies of technological and anthropogenic origin.

Keywords: project management, critical transport infrastructure, environmental monitoring, synergy, critical infrastructure security.

Introduction and problem statement. Ukraine's transport infrastructure, encompassing bridges, ports, and pipelines, is a strategic asset whose performance directly underpins national security and the functioning of society. In current conditions, critical transport infrastructure (CTI) facilities are exposed to persistent risks, where any technical failure can trigger a «domino effect», escalating into a large-scale environmental disaster due to secondary contamination. Traditional approaches to safety assurance often prove limited, as they assess the technical condition of a facility in isolation from the dynamic changes in its environmental context.

The absence of an integrated management model that combines the organizational methods of the P2M methodology with tools for predictive environmental monitoring creates critical zones of uncertainty. This gives rise to an urgent need to develop new conceptual frameworks in which environmental monitoring becomes an integral

component of both feasibility studies and the life-cycle management of infrastructure projects.

The relevance of this research is further amplified by the fact that modern logistics hubs and transport corridors operate in high-entropy environments, where conventional deterministic safety management methods lose their effectiveness. The transition to value-oriented management is driven by the understanding that the safety of CTI facilities is no longer measured solely by the absence of accidents, but also by the system's ability to preserve its mission and functionality under the influence of unpredictable external factors. This necessitates the implementation of intelligent services capable of integrating large volumes of environmental monitoring data into a unified management cycle.

Environmental safety occupies a special place within the protection architecture, evolving from a secondary factor into a key indicator of the stability of technical systems. The relationship between the structural integrity of CTI facilities and the state of the natural environment is bidirectional: ecosystem degradation can accelerate infrastructure deterioration, while hidden defects in engineering structures are often masked by natural fluctuations in baseline environmental indicators.

Thus, the synergy between project management and predictive monitoring becomes the foundation for the development of «smart safety» systems capable of real-time adaptation.

Brief review of previous research. The theoretical foundations for protecting critical transport infrastructure (CTI) facilities have evolved over recent decades in response to the growing scale of technological and anthropogenic threats. In the scientific literature, the issue of CTI security is examined through the lenses of public policy, technical protection, economic resilience, and modern methodologies for managing complex systems.

The fundamental principles of public policy in the field of critical infrastructure protection in Ukraine are outlined in [1], where the necessity of legally defining the status of CTI facilities and establishing an integrated protection system is substantiated. The author emphasizes the importance of an institutional approach and coordination among government agencies to ensure an adequate level of security.

A significant contribution to the development of project and program management methods for CTI security has been made in studies [2; 3]. These works identify the strategic vulnerability of transport hubs and justify the need for a comprehensive approach to their protection. They also propose methods for managing security projects and programs based on a systems approach to identifying and mitigating infrastructure risks.

The mathematical foundation for managing regional CTI security programs is presented in [4], where models for optimizing project portfolios are proposed. The application of such models enhances the effectiveness of managerial decision-making and ensures the rational allocation of resources within security programs.

A distinct line of research is associated with the development of modern approaches to program management. Study [5] emphasizes the formation of project managers' competencies, particularly the role of emotional intelligence and strategic

thinking under conditions of uncertainty. The conceptual foundations of program management in the context of social innovation are explored in [6], which highlights the importance of shifting from managing individual projects to managing program missions – an approach that is especially relevant for complex infrastructure systems.

The integration of sustainable development principles into project management is examined in study [7], which proposes a value-oriented management model. This approach makes it possible to incorporate environmental and social considerations as key performance criteria for infrastructure projects, particularly in the field of CTI security.

Thus, the analysis of the cited sources indicates that contemporary research covers a wide range of aspects related to ensuring the security of critical transport infrastructure – from public policy and economic resilience to project management and sustainable development. At the same time, the integration of the project-based approach, environmental monitoring, and security management within a unified iterative life-cycle model for CTI remains insufficiently explored, which underscores the relevance of further research in this area.

The aim of the study is to provide a theoretical justification and to develop models of synergistic interaction between project management and environmental monitoring systems to ensure the security of critical transport infrastructure.

To achieve this aim, the following objectives are addressed:

- to examine the concept of synergy within the P2M methodology through the integration of schematic, systemic, and service-oriented management models;
- to propose a mechanism for incorporating the environmental component into each stage of the spiral life-cycle model of CTI (from planning to adjustment);
- to develop a mathematical approach to optimizing the portfolio of security projects, taking into account the minimization of environmental risks and the use of parallel project combinations to address environmental uncertainty.

Results of the study and their discussion. The study is based on the hypothesis that effective security of critical transport infrastructure (CTI) can only be achieved by moving beyond a narrowly technical approach. Within the framework of this research, security management is grounded in the P2M methodology, where regional safety is interpreted as a comprehensive mission. Synergy within such a system emerges through the integrated combination of schematic, systemic, and service-oriented management models.

In particular, the schematic model enables the development of a regional «security map», where environmental monitoring is integrated into the feasibility assessment of infrastructure facilities. The systemic model structures the relationships between engineering protection measures and environmental monitoring networks, while the service model ensures the operation of intelligent decision-support systems.

To ensure the «dynamic resilience» of CTI facilities, an iterative spiral life-cycle model (LCA), based on the PDCA cycle (Plan–Do–Check–Act), is proposed instead of linear approaches. In the planning stage, predictive analysis of accident scenarios and modeling of secondary contamination zones around bridges, ports, or terminals are carried out. The development stage involves the deployment of a network of intelligent

sensors that continuously monitor the condition of soil, water, and air in the vicinity of infrastructure facilities in real time. Validation of the results makes it possible to detect even minor deviations: if the system does not register micro-level environmental changes, the model automatically proceeds to the next spiral iteration to improve its algorithms.

An important aspect is the mathematical optimization of the process of forming regional programs. The selection of projects for the security portfolio is carried out based on the maximization of the value objective function:

$$J = \sum_{i=1}^{n} (V_i \cdot \Delta R_i - c_i) \rightarrow \max$$

where V_i is the strategic value of the CTI facility; ΔR_i is the integral risk-reduction indicator (including both technical and environmental threats) resulting from project implementation; c_i – represents the cost of implementing the measures.

This approach enables the rational allocation of limited regional resources, focusing on facilities with the highest level of potential losses caused by the «domino effect».

To mitigate the high level of environmental uncertainty, it is appropriate to employ a strategy of parallel project combinations. «Intentional overlap» makes it possible to simultaneously carry out the modernization of a transport hub and integrate a predictive environmental monitoring system into its structure. This not only reduces the overall duration of the facility's vulnerability but also creates a synergistic effect through the use of a shared information base. For example, bridge vibration data can be used simultaneously to assess structural integrity and to predict potential loss of sealing in nearby pipelines.

A comparative characterization of the traditional and the proposed synergistic approaches to CTI security management is presented below, which may be further transformed into a graphical system model (Table 1).

Table 1. Comparative analysis of approaches to ensuring CTI security

Comparison parameter	Traditional approach	Synergistic approach (P2M + Environmental monitoring)
Management model	Linear (Waterfall)	Iterative spiral model (PDCA)
Control focus	Technical condition of the facility	Interaction between the facility and the environment
Response to threats	Reactive (post-incident)	Predictive (preventive)
Decision justification	Economic costs	Value and resilience
Risk management	Isolated projects	Parallel combinations and project portfolios

The application of the above-described models enables the formation of a multilayered protection system in which environmental parameters serve as early indicators of technical failures. In particular, changes in the chemical composition of groundwater near a railway embankment may indicate the onset of destructive processes long before they become visually detectable. Thus, the synergy of project management methods and environmental monitoring transforms the safety system

from a passive barrier into an intelligent ecosystem capable of self-learning and adaptation at every stage of the life cycle.

The application of the above-described models enables the formation of a multilayered protection system in which environmental parameters serve as early indicators of technical failures. In particular, changes in the chemical composition of groundwater near a railway embankment may indicate the onset of destructive processes long before they become visually detectable. Thus, the synergy of project management methods and environmental monitoring transforms the safety system from a passive barrier into an intelligent ecosystem capable of self-learning and adaptation at every stage of the life cycle.

Conclusions. As a result of the conducted research, it has been substantiated that the synergy between project management and environmental monitoring is a necessary condition for ensuring the «dynamic resilience» of critical transport infrastructure. It has been established that the integration of schematic, systemic, and service-oriented management models within the P2M methodology enables the transformation of the safety system from passive protection into an adaptive ecosystem, where environmental parameters serve as leading indicators of technical risks. The incorporation of these parameters into an iterative spiral life-cycle model (the PDCA cycle) ensures continuous validation of CTI facilities, allowing the system to self-learn and adapt to new types of threats at each stage of the program.

The mathematical justification for selecting projects for the security portfolio, based on maximizing strategic value while minimizing costs and environmental risks, enables the rational allocation of limited regional resources. The use of a parallel project combination strategy («intentional overlap») significantly reduces the temporal vulnerability window of infrastructure and enhances the overall effectiveness of security program management under conditions of uncertainty. The final outcome of implementing the proposed synergistic approach is the minimization of the probability of large-scale environmental disasters and the assurance of sustainable development of the regional transport network.

References

1. Birjukov D.S. (2015). Zahyst krytychnoji infrastruktury v Ukrajini: vid naukovogo osmyslennja do rozrobky zasad polityky. Nauk.-inform. visn. Akad. nac. Bezpeky, 3-4, P. 155-170.
2. Khrutba V.O., Ziuziun V.I., Nevedrov D.S. (2019). Reiew of Scientific and Theoretical Aspects of Safety of Objects of Critical Infrastructure of Transport. Bulletin of NTU "KhPI". Series: Strategic management, portfolio, program and project management. – Kharkiv : NTU «KhPI», 2 (1327). P. 60-65. https://doi.org/10.20998/2413-3000.2019.1327.9
3. Khrutba V.O., Ziuziun V.I., Nevedrov D.S., Lysak R. (2019). Formation of methods of project management and critical infrastructure objects security program. Management of Development of Complex Systems, 40, P. 69-75. https://doi.org/ 10.6084/m9.figshare.11969007
4. Ziuziun V.I., Nevedrov D.S. (2019). As for the Development of Models of Management of Regional Security Programs of Critical Infrastructure of Transport

Objects. Visnyk National Transport University. Series «Technical sciences». Scientific and Technical Collection, 2 (44). P. 81-89. https://doi.org/2308-6645-2019-2-44-081-089
5. Bushuyeva N., Bushuiev D., Busuieva V., Achkasov I. (2018). IT Projects Management Driving by Competence. 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), Lviv, Ukraine, P. 226-229. https://doi.org/10.1109/STC-CSIT.2018.8526680
6. Molokanova V.M. (2021). Implementation of a Value-Oriented Strategy of the Organization through a Portfolio of Projects. In Investment Strategies in Emerging New Trends in Finance. IntechOpen. https://doi.org/10.5772/intechopen.94034
6. Tanaka H. Toward project and program management paradigm in the space of complexity: a case study of mega and complex oil and gas development and infrastructure projects. 27th IPMA World Congress, Dubrovnik, Social and Behavioral Sciences. 2014. P. 65-74.

ВИМОГИ ДО ЯКОСТІ ТА БЕЗПЕЧНОСТІ СОКІВ ДЛЯ ДИТЯЧОГО ХАРЧУВАННЯ

Хмельницька Євгенія Вікторівна
к.т.н., доцент
Кафедра товарознавства
і торговельного підприємництва
Лісний Дмитро Андрійович
здобувач вищої освіти бакалаврського рівня
ДЗ «Луганський національний університет
імені Тараса Шевченка», Україна

Раціональне та збалансоване харчування дітей раннього віку є визначальним чинником їх гармонійного фізичного розвитку, формування імунної системи та профілактики низки захворювань. У перші роки життя організм дитини перебуває у стані інтенсивного росту і розвитку, що супроводжується високими потребами у вітамінах, мінеральних речовинах та інших біологічно активних сполуках. Саме тому особливого значення набуває якість харчових продуктів, які вводяться до дитячого раціону.

Фруктові та овочеві соки традиційно розглядаються як важливий компонент дитячого харчування, оскільки вони є джерелом легкозасвоюваних поживних речовин, зокрема вітаміну С, органічних кислот, природних цукрів та антиоксидантів. Вони сприяють нормалізації травлення, покращенню апетиту та забезпеченню організму необхідними мікронутрієнтами. Разом із тим надмірне або неправильне споживання соків, а також використання продукції неналежної якості може мати негативні наслідки для здоров'я дитини.

Особливістю дитячого організму є незрілість ферментативних систем, підвищена проникність слизових оболонок та обмежені можливості