

CRITICAL INFRASTRUCTURE RESILIENCE AS A DETERMINANT OF NATIONAL ECONOMIC STABILITY

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Abstract. *The purpose of the article* is to investigate the conceptual and economic foundations of critical infrastructure resilience and to determine its role in ensuring national economic stability under conditions of hybrid threats, systemic uncertainty, and large-scale disruptions. The study focuses on the transformation of scientific approaches to infrastructure and critical infrastructure from traditional technical interpretations toward resilience-oriented and economic security frameworks. Particular attention is devoted to the relationship between critical infrastructure functioning, macroeconomic stability, economic continuity, and adaptive governance in the context of geopolitical instability, cyber threats, military conflicts, and technological disruptions. *Methodology.* The research is based on theoretical generalization, comparative analysis, semantic mapping, and systematization of scientific approaches to infrastructure and critical infrastructure. The methodological framework combines economic, institutional, and resilience-oriented approaches presented in contemporary scientific literature and international policy documents. Semantic analysis was used to identify dominant conceptual descriptors and trace the evolution of infrastructure discourse toward categories associated with security, resilience, continuity, and systemic stability. *Results.* The study demonstrates that critical infrastructure should be interpreted not only as a set of strategically important facilities and services but also as a complex adaptive system that ensures economic continuity, institutional stability, and national resilience. It was established that disruptions of critical infrastructure generate multidimensional macroeconomic consequences, including GDP decline, production interruptions, supply chain disruptions, investment reduction, inflationary pressures, business interruption risks, labor market instability, and increasing fiscal burden on the state. The research additionally confirms the growing importance of resilience-oriented governance models, adaptive regulation mechanisms, integrated risk management, and intersectoral coordination in the field of critical infrastructure protection. *Practical implications.* The findings may be applied in the development of national strategies for critical infrastructure protection, economic security policy, resilience-oriented governance, and post-crisis recovery planning. *Value / originality.* The scientific contribution of the study lies in the conceptualization of critical infrastructure resilience as a determinant of national economic stability and in the integration of economic security, resilience, and infrastructure governance approaches within a unified analytical framework.

Keywords: critical infrastructure, economic resilience, national economic stability, economic security, hybrid threats, adaptive governance.

JEL Classification: H12, H54, O18, R40, F52, C38

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1. Introduction

The contemporary global environment is characterized by increasing geopolitical instability, hybrid threats, military conflicts, cyberattacks, and systemic crises that significantly affect the functioning of national economies. Under such conditions, critical infrastructure acquires strategic importance as a fundamental basis for economic stability, institutional continuity, and national resilience. The disruption or destruction of critical infrastructure facilities leads not only to technical or organizational failures but also to large-scale macroeconomic losses, destabilization of markets, interruptions in production and logistics chains, reduced investment attractiveness, and deterioration of social welfare.

The full-scale war in Ukraine has demonstrated the exceptional significance of critical infrastructure for maintaining the continuity of economic processes and ensuring the functioning of the state under conditions of extreme uncertainty. Large-scale attacks on energy systems, transport networks, communication facilities, and digital infrastructure have transformed critical infrastructure from a traditionally technical category into a central element of economic security and strategic resilience. In this context, infrastructure should be considered not merely as a supporting system for economic activity, but as a key mechanism for preserving the functional integrity of the national economy during crises and hybrid threats.

Modern scientific discourse increasingly focuses on the relationship between infrastructure development, economic resilience, and national security. Classical infrastructure theories emphasized the role of infrastructure as a prerequisite for economic growth, market integration, and industrial development (Jochimsen, 1966; Rosenstein-Rodan, 1961). Contemporary approaches significantly expand this perspective by interpreting infrastructure as a complex socio-economic and institutional system that ensures the continuity of critical services, stability of economic relations, and adaptability of national economies to external shocks (Frischmann, 2013; OECD, 2021).

Particular attention in recent studies is devoted to the resilience of critical infrastructure systems under conditions of uncertainty, hybrid warfare, climate risks, cyber threats, and pandemics. Researchers emphasize that the growing interdependence between energy, transport, financial, digital, and communication systems increases the vulnerability of national economies to cascading disruptions and systemic failures (Rathnayaka et al., 2022; Rehak et al., 2022; Shen et al., 2022). Consequently, ensuring the protection, adaptability, and sustainable functioning of critical infrastructure becomes one of the key priorities of state economic policy and strategic governance.

At the same time, despite the growing number of studies devoted to critical infrastructure, the conceptual understanding of its economic essence remains fragmented. Existing approaches often focus either on technical protection, security regulation, or legal mechanisms, while insufficient attention is paid to the macroeconomic functions of critical infrastructure, its role in ensuring economic continuity, and its influence on systemic economic resilience. This determines the relevance of further research aimed at conceptualizing critical infrastructure as a strategic component of national economic security and adaptive economic development.

The purpose of this study is to investigate the conceptual foundations of critical infrastructure within the framework of economic security and economic resilience, as well as to identify its key functions in ensuring the stability and continuity of national economic systems under conditions of hybrid threats and systemic uncertainty.

2. Conceptual Foundations of Infrastructure and Critical Infrastructure

The evolution of scientific approaches to the interpretation of infrastructure reflects the transformation of economic systems, institutional environments, and state priorities under conditions of technological development and increasing systemic risks. Initially, infrastructure was predominantly considered as a supporting component of economic activity that ensured the functioning of production processes, transportation systems, and public services. Classical economic theories emphasized the role of infrastructure in stimulating industrialization, market integration, and economic growth. In particular, Rosenstein-Rodan (1961) associated infrastructure development with the "Big Push" theory, considering large-scale infrastructure investments as a prerequisite for overcoming structural economic backwardness and accelerating national development. Similarly, Jochimsen (1966) interpreted infrastructure as a fundamental basis for the functioning of a market economy and territorial economic cohesion.

Subsequent scientific approaches significantly expanded the understanding of infrastructure beyond its exclusively technical and production-oriented functions. Infrastructure gradually began to be interpreted as a complex socio-economic system that integrates material assets, institutional mechanisms, communication networks, public services, and organizational structures. Frischmann (2013) emphasized the social value of infrastructure as a shared resource that creates conditions for economic interaction, innovation, and long-term societal development. Contemporary international approaches also conceptualize infrastructure as an integrated

system that ensures economic continuity, accessibility of essential services, and the stability of social and market relations (OECD, 2021).

The systematization of scientific approaches demonstrates that the semantic structure of infrastructure definitions has evolved from a narrow interpretation focused on physical facilities and support functions toward a multidimensional understanding that includes economic, institutional, social, technological, and strategic components. The dominant conceptual descriptors identified in the analyzed definitions include “system,” “economic functioning,” “services,” “development,” “networks,” “resources,” and “sustainability.” This transformation indicates that infrastructure is increasingly perceived not merely as a technical foundation of economic activity but as a strategic mechanism for ensuring macroeconomic stability and long-term economic resilience.

The growing complexity of global economic systems, digitalization, geopolitical instability, and hybrid threats contributed to the emergence and rapid development of the concept of critical infrastructure. Unlike traditional infrastructure approaches, the concept of critical infrastructure emphasizes not only functionality and economic support but also security, resilience, and protection against destabilizing influences. Modern studies define critical infrastructure as a system of interconnected physical and virtual assets, facilities, networks, and services whose disruption may cause significant economic, social, environmental, or national security consequences (Kizym et al., 2022).

The semantic analysis of contemporary scientific approaches to critical infrastructure demonstrates a noticeable shift in conceptual priorities from economic efficiency toward systemic resilience and national security. The most frequently occurring conceptual descriptors in critical infrastructure definitions include “security,” “system,” “resilience,” “critical services,” “protection,” “functioning,” “risk,” and “stability.” Such semantic transformation reflects the increasing recognition of infrastructure as a strategic component of national economic security and institutional sustainability.

Recent scientific discourse particularly emphasizes the interdependence and vulnerability of critical infrastructure systems under conditions of uncertainty and hybrid threats. Rathnayaka et al. (2022) highlight that the resilience of critical infrastructure has become one of the key determinants of societal and economic stability in the context of disasters, military conflicts, and technological disruptions. Rehak et al. (2022) focus on the robustness of energy infrastructure systems as a critical element of energy security and macroeconomic continuity. Shen et al. (2022) additionally underline the growing complexity of interdependent infrastructure risks, where failures in one sector may generate cascading effects across multiple economic systems.

Therefore, the evolution of scientific approaches to infrastructure and critical infrastructure demonstrates the transformation of these categories from auxiliary technical systems into strategic economic mechanisms that ensure the continuity of economic processes, institutional stability, national resilience, and adaptive capacity under conditions of systemic uncertainty. In the contemporary economic environment, critical infrastructure should be understood not only as a set of strategically important facilities but also as a fundamental component of economic security architecture and sustainable national development.

3. Critical Infrastructure and Economic Resilience

The transformation of contemporary economic systems under conditions of globalization, digitalization, hybrid threats, and geopolitical instability has significantly increased the strategic importance of critical infrastructure. Modern national economies increasingly depend on the uninterrupted functioning of interconnected infrastructure systems, including energy networks, transport corridors, logistics chains, financial systems, communication platforms, public utilities, and digital infrastructure (OECD, 2021; Frischmann, 2013). As a result, critical infrastructure has evolved from a supporting technical subsystem into one of the fundamental determinants of economic continuity and national resilience.

The semantic mapping of scientific approaches to infrastructure and critical infrastructure demonstrates a substantial transformation in conceptual priorities. The dominant descriptors identified in infrastructure definitions are primarily associated with economic functioning, production, services, interaction, and development. In contrast, the semantic structure of critical infrastructure definitions is increasingly concentrated around the categories of security, stability, resilience, protection, risk, disruption, and national sustainability (fig. 1). Such conceptual evolution reflects the growing understanding that infrastructure is no longer viewed exclusively as a factor of economic efficiency but also as a strategic mechanism for preserving macroeconomic stability under conditions of systemic uncertainty (Kizym et al., 2022; OECD, 2021).

The comparative analysis of the semantic structures presented in Figures 1 and 2 indicates a shift from the traditional perception of infrastructure as an instrument of economic support toward the interpretation of critical infrastructure as a key element of national economic security and adaptive resilience. While conventional infrastructure approaches emphasize production support, market functioning, and service provision, critical infrastructure concepts increasingly focus on ensuring the continuity of

systems, logistics facilities, and communication networks caused significant destabilization of economic processes and increased pressure on public finances, businesses, and households. Infrastructure disruptions generated cascading consequences through declining industrial productivity, interruptions in supply chains, increased transaction costs, and reduced investment activity. Under such conditions, the resilience of critical infrastructure became one of the key prerequisites for maintaining the operational continuity of the national economy (Kizym et al., 2022).

Contemporary approaches to economic resilience increasingly interpret critical infrastructure as a dynamic adaptive system capable of maintaining functionality under conditions of shocks, crises, and hybrid threats (Rathnayaka et al., 2022). In this context, resilience includes not only physical protection of infrastructure assets but also institutional adaptability, risk management capacity, rapid recovery mechanisms, continuity planning, and strategic coordination between public and private actors. Therefore, critical infrastructure resilience should be considered as an integral component of macroeconomic stability, national competitiveness, and long-term sustainable development (OECD, 2021).

4. Economic Risks of Critical Infrastructure Disruptions

The disruption of critical infrastructure generates complex direct and indirect economic consequences that affect all levels of the national economy. Due to the systemic interdependence of infrastructure sectors, infrastructure failures rapidly transform into macroeconomic instability, reducing economic productivity, investment activity, business continuity, and overall economic resilience (Shen et al., 2022). In contemporary economies, where production systems, logistics networks, digital communications, and financial operations are highly interconnected, infrastructure disruptions become a source of multidimensional economic risks (Rathnayaka et al., 2022).

One of the primary consequences of critical infrastructure disruption is the decline in gross domestic product caused by interruptions in industrial production, transport systems, energy supply, and market operations. Infrastructure failures reduce production capacity utilization, disrupt manufacturing processes, limit access to raw materials and distribution channels, and increase operational downtime. Such disruptions negatively influence both domestic economic activity and international trade relations, particularly in export-oriented economies dependent on logistics and transport infrastructure (OECD, 2021).

Infrastructure disruptions also generate significant business interruption risks. Enterprises operating under unstable infrastructure conditions face production

delays, increased operational uncertainty, supply shortages, and rising maintenance expenditures. Small and medium-sized enterprises are particularly vulnerable to prolonged infrastructure failures due to limited financial reserves and lower adaptive capacity. As a result, critical infrastructure instability contributes to declining business activity, reduced competitiveness, and lower entrepreneurial confidence (Frischmann, 2013).

An important macroeconomic consequence of infrastructure disruptions is the deterioration of the investment climate. Investors perceive infrastructure stability as one of the key determinants of economic predictability and long-term business sustainability (Gordon & Dion, 2008). The destruction or instability of energy systems, transport corridors, communication networks, and financial infrastructure significantly increases investment risks, reduces foreign direct investment inflows, and weakens economic modernization processes. Under conditions of military conflict and hybrid threats, infrastructure vulnerability becomes directly associated with the country's economic attractiveness and sovereign risk assessment.

Critical infrastructure disruptions additionally contribute to inflationary pressures through supply shortages, rising transportation costs, energy price volatility, and logistical inefficiencies. Interruptions in production and distribution chains reduce the availability of goods and services while simultaneously increasing operational costs for enterprises. Such processes generate inflationary effects that negatively influence household welfare, purchasing power, and overall economic stability (OECD, 2021).

The labor market is also significantly affected by infrastructure instability. Large-scale infrastructure disruptions may lead to temporary or permanent enterprise shutdowns, workforce displacement, declining employment opportunities, and labor migration. Energy shortages, transport interruptions, and destruction of production facilities create additional pressure on regional labor markets and increase social vulnerability, particularly in regions heavily dependent on industrial infrastructure (Kizym et al., 2022).

Another critical consequence of infrastructure disruption is the increasing fiscal burden on the state. Governments are forced to allocate substantial financial resources to emergency response measures, infrastructure restoration, compensation mechanisms, energy stabilization programs, and social support initiatives. Under conditions of prolonged crises or military conflicts, infrastructure recovery expenditures may significantly increase public debt and reduce fiscal sustainability. Consequently, the protection and resilience of critical infrastructure become not only security priorities but also essential components of long-term macroeconomic stability (Gordon & Dion, 2008).

Therefore, critical infrastructure disruptions should be interpreted as systemic economic shocks capable of destabilizing production systems, market mechanisms, financial stability, and public governance simultaneously. The scale and complexity of these risks require the development of integrated resilience-oriented economic policies focused on prevention, adaptation, rapid recovery, and strategic infrastructure protection (Rathnayaka et al., 2022; Shen et al., 2022).

5. Findings and Strategic Directions for Critical Infrastructure Governance

The conducted analysis demonstrates that the growing complexity of hybrid threats, cyber risks, military conflicts, technological disruptions, and systemic crises has substantially transformed contemporary approaches to critical infrastructure governance. Modern regulatory models increasingly move beyond reactive protection mechanisms toward integrated resilience-oriented governance aimed at ensuring the continuity, adaptability, and recoverability of critical infrastructure systems under conditions of uncertainty (OECD, 2021).

The findings of the study indicate that infrastructure resilience should be considered an integral component of national economic security and macroeconomic stability rather than solely a technical or security-related category (Gordon & Dion, 2008). In this context, critical infrastructure governance extends beyond the protection of individual facilities and increasingly focuses on the management of interconnected infrastructure systems, strategic risk coordination, institutional adaptability, and continuity planning.

The research additionally confirms that European approaches to critical infrastructure governance are primarily based on integrated coordination, intersectoral interaction, risk-oriented regulation, and resilience-building strategies. Contemporary European policy frameworks prioritize the protection of essential services, cyber resilience, continuity of economic functions, and the ability of infrastructure systems to withstand hybrid threats and large-scale disruptions. Within this framework, resilience is interpreted not only as resistance to external shocks but also as the capacity for adaptation, rapid recovery, and functional transformation under crisis conditions (European Parliamentary Research Service, 2021).

An important finding of the study is the increasing significance of adaptive governance mechanisms in the field of critical infrastructure protection. Adaptive regulation involves flexible management approaches capable of responding to rapidly changing geopolitical, technological, and economic conditions. Such approaches require continuous monitoring of infrastructure vulnerabilities, scenario modeling,

integrated risk assessment, public-private cooperation, and dynamic institutional coordination. Consequently, critical infrastructure governance increasingly integrates economic security instruments, digital monitoring technologies, crisis management systems, and strategic planning mechanisms (OECD, 2021).

The analysis also demonstrates that one of the key challenges for contemporary infrastructure governance is the high level of interdependence between infrastructure sectors. Energy, transport, ICT, financial, industrial, and public administration systems operate as interconnected economic networks, where disruptions within one sector may generate cascading destabilizing effects across the entire economic system. Therefore, effective governance requires integrated coordination mechanisms aimed at minimizing systemic vulnerabilities and preventing large-scale economic disruptions (Shen et al., 2022).

The experience of Ukraine under conditions of full-scale war additionally confirms the necessity of developing resilience-oriented governance models capable of functioning under prolonged uncertainty and military threats. The protection of energy systems, logistics corridors, digital infrastructure, financial systems, and public services has become a fundamental prerequisite for preserving economic continuity, institutional functionality, and macroeconomic stability. Under such conditions, state regulation of critical infrastructure should combine security measures, economic stabilization instruments, institutional flexibility, adaptive governance mechanisms, and long-term recovery strategies (Kizym et al., 2022).

Thus, the findings of the research confirm that contemporary critical infrastructure governance should be interpreted as a strategic component of economic resilience policy aimed at strengthening adaptive capacity, minimizing systemic vulnerabilities, and ensuring the continuity and stability of national economic systems under conditions of hybrid threats and large-scale uncertainty.

6. Conclusions

The conducted research demonstrates that the evolution of scientific approaches to infrastructure and critical infrastructure reflects a substantial transformation in the understanding of their role within contemporary economic systems. Traditional interpretations of infrastructure as a supporting element of production and service provision have gradually evolved toward a multidimensional understanding of critical infrastructure as a strategic component of economic security, national resilience, and macroeconomic stability. The semantic mapping of conceptual approaches confirmed the shift of dominant scientific discourse from categories associated with economic functioning and development toward

concepts related to security, resilience, protection, continuity, and systemic stability.

The study established that critical infrastructure performs not only technical and operational functions but also systemic economic functions that ensure the continuity of production processes, financial operations, logistics chains, institutional coordination, and public service delivery. The growing interdependence between energy systems, transport infrastructure, ICT networks, financial systems, and public administration significantly increases the vulnerability of national economies to cascading disruptions and hybrid threats. Under such conditions, the stability of critical infrastructure becomes one of the key determinants of economic continuity and adaptive resilience.

Particular attention was devoted to the macro-economic consequences of critical infrastructure disruptions. It was determined that infrastructure failures generate multidimensional economic risks manifested through GDP decline, production disruptions, business interruption, investment reduction, inflationary pressures, labor market instability, increasing transaction costs, and growing fiscal burden on the state. The experience of Ukraine under conditions of full-scale war clearly demonstrated that attacks on critical infrastructure rapidly transform

into systemic economic destabilization affecting all levels of economic activity and public governance.

The research additionally confirmed that contemporary approaches to critical infrastructure governance increasingly rely on resilience-oriented regulation, integrated risk management, intersectoral coordination, and adaptive governance mechanisms. Modern public policy in this field should focus not only on the physical protection of infrastructure facilities but also on ensuring the adaptability, recoverability, and continuity of interconnected infrastructure systems under conditions of uncertainty and hybrid threats. In this context, critical infrastructure resilience should be interpreted as an integral component of national economic security architecture and sustainable economic development.

Therefore, critical infrastructure should be understood as a complex adaptive system that combines economic, institutional, technological, and security dimensions and ensures the stability and continuity of national economic systems under conditions of systemic uncertainty. Further research should focus on the development of quantitative approaches to assessing infrastructure resilience, modeling cascading economic effects of infrastructure disruptions, and designing adaptive governance mechanisms for strengthening national economic resilience under hybrid threats.

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Received on: 10th of April, 2026

Accepted on: 27th of May, 2026

Published on: 26th of June, 2026