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DIRECTIONS FOR DEVELOPING PRODUCTION INFRASTRUCTURE IN FREE ECONOMIC ZONES

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Abstract

This article examines the theoretical and practical directions for developing production infrastructure in free economic zones. The engineering and communication, transport and logistics, energy, digital, innovation, environmental, and social components of production infrastructure are systematically analyzed. The article also reviews studies conducted by foreign scholars between 2023 and 2025 on the development of free economic zones and industrial parks. The findings demonstrate that the investment attractiveness of free economic zones depends not only on tax and customs incentives but also on infrastructure reliability, logistics costs, energy efficiency, digital governance, environmental sustainability, and regional cooperation. The article proposes using smart and green infrastructure, public-private partnerships, clustering, the digitalization of infrastructure services, and performance-based management mechanisms to develop infrastructure in free economic zones.

Keywords: free economic zone, production infrastructure, investment, industrial cluster, transport and logistics, engineering networks, digital infrastructure, eco-industrial park, public-private partnership, industrial cooperation.

II. Introduction

The growing international specialization of production, the restructuring of global value chains, and intensifying interregional competition for investment are transforming free economic zones into an important instrument of industrial policy in the global economy. In addition to providing investors with tax, customs, and administrative incentives, free economic zones offer ready-to-use infrastructure sites that facilitate modern manufacturing activities. However, if electricity, natural gas, water supply, wastewater systems, roads and railways, warehouses, logistics terminals, and digital communication services are insufficiently developed within a zone, the effectiveness of financial incentives in attracting investment declines. Therefore, the competitiveness of free economic zones is increasingly determined by their level of infrastructure readiness.

The relevance of this topic is explained by the fact that the efficient allocation of production capacities, deep processing of local raw materials, manufacture of export-oriented products, and creation of new jobs in free economic zones directly depend on the condition of their infrastructure. In practice, some zones face imbalances between external utility networks and internal infrastructure, disruptions in energy supply, high logistics costs, shortages of shared production facilities, and the absence of sustainable financing mechanisms for infrastructure maintenance. These problems delay enterprises in reaching their designed production capacity and increase the costs and risks associated with investment projects.

The purpose of this study is to conduct a scientific analysis of the current state and structural components of production infrastructure in free economic zones and to develop priority directions for its effective development.

Based on the purpose of the study, the following objectives were established:

– to explain the economic nature of production infrastructure and its role in the operation of free economic zones;
– to summarize the principal findings of international studies conducted between 2023 and 2026;
– to systematize the factors influencing infrastructure development and the existing challenges;
– to identify directions for improving engineering, logistics, energy, digital, and environmental infrastructure;
– to propose effective mechanisms for financing and managing infrastructure.

III. Literature Review

Under contemporary economic conditions, free economic zones constitute an important instrument for attracting foreign and domestic investment, expanding industrial production, increasing export potential, and accelerating the economic development of regions. The effective operation of such zones primarily depends on the level of development of production, transport and logistics, energy, engineering and communication, and environmental infrastructure. In this regard, examining the international scientific studies presented in the table is essential for identifying priority directions for developing modern infrastructure in free economic zones, summarizing best practices, and developing scientifically grounded solutions to existing challenges.

Table 1

A generalized analysis of international scientific studies on the development of production infrastructure in free economic zones

Authors, year	Article title	Main scientific results	Significance for the research topic
S. A. Frick va A. Rodríguez-Pose, 2023[1]	What draws investment to special economic zones? Lessons from developing countries	It was found that, alongside tax incentives, strategic location, high-quality industrial infrastructure, and services provided within the zone play an important role in attracting investment to free economic zones. The effectiveness of fiscal incentives was shown to be limited in zones with inadequate engineering networks and transport facilities.	The study demonstrates that the quality of production infrastructure is one of the key factors influencing investors' decisions. It highlights the need for the integrated development of electricity, water and gas supply systems, roads, logistics, and business services.
J. Buba, M. D. Wong va N. Yazbeck, 2024[2]	Matching comparative advantages to special economic zones for industrial	It has been established that the specialization of free economic zones should align with the region's raw materials, labor resources, transport links, market	It indicates that infrastructure should not be developed uniformly across all zones but should instead be tailored to the technological and

[1] Frick S. A., Rodríguez-Pose A. What draws investment to special economic zones? Lessons from developing countries //Regional Studies. – 2023. – T. 57. – №. 11. – C. 2136-2147.

[2] Danja I. I., Wang X. Matching comparative advantages to special economic zones for sustainable industrialization //Heliyon. – 2024. – T. 10. – №. 14.

	development	opportunities, and existing industrial base. Without such alignment, the utilization rate of the developed infrastructure capacity may decline.	logistical needs of the selected industries.
O. Borzenko, N. Kuznietsova va A. Bilko, 2025[3]	China's special economic zones: from traditional labor-intensive industries to eco-industrial park development	The transformation of China's traditional labor-intensive free economic zones into eco-industrial parks based on green technologies, cleaner production, and circular economy principles has been examined. The importance of water reuse, waste recycling, and inter-firm resource exchange has been identified.	It substantiates the need to modernize energy and environmental infrastructure in free economic zones, develop industrial symbiosis, and transition to a "green zone" model.
Zhang H., Xu B. 2025[4]	Eco-industrial parks construction and industrial chain resilience	It was found that establishing eco-industrial parks improves industrial chain resilience by 1.56–2.75%. Green technological innovation and the upgrading of the industrial structure were identified as mediating factors driving this effect.	It demonstrates that environmental infrastructure enhances not only the environmental efficiency of production but also the resilience of industrial chains to external risks. It also substantiates the need for interregional infrastructure cooperation.

The research findings demonstrate that the effectiveness of free economic zones depends not only on tax and customs incentives but also directly on engineering and communication networks, transport and logistics services, a reliable energy supply, and the industrial specialization of the region. In particular, while high-quality infrastructure attracts investment and reduces business costs, green technologies, waste recycling, water reuse, and inter-firm resource exchange enhance the resilience of industrial chains. Overall, the scientific perspectives presented in the table substantiate the need to develop production infrastructure in free economic zones not as a collection of separate facilities, but as an integrated system combining technical, logistical, digital, innovative, and environmental components.

IV. Methodology

The study employed methods of systemic analysis, comparative analysis, induction and deduction, scientific abstraction, grouping, and expert logical assessment. Based on a systemic approach, production infrastructure in free economic zones was examined not as a collection of separate facilities, but as an integrated mechanism interconnecting production, logistics, energy, digital services, environmental systems, and human resources. Comparative analysis was used to summarize international experience in developing special economic zones and eco-industrial parks.

[3] Borzenko O., Kuznietsova N., Bilko A. China's special economic zones: from traditional labor-intensive industries to eco-industrial park development //Buketov Business Review. – 2025. – Т. 11730. – №. 1. – С. 17-29.

[4] Zhang H., Xu B. Eco-industrial parks construction and industrial chain resilience //Frontiers in Sustainable Cities. – 2025. – Т. 7. – С. 1663273.

The effectiveness of infrastructure was assessed using criteria such as reliability, accessibility, service costs, capacity utilization, environmental efficiency, and the convenience provided to investors. Since the study relied primarily on secondary data and the findings of scientific articles published between 2023 and 2025, its conclusions should be regarded not as empirical-statistical forecasts, but as the results of theoretical and comparative analysis.

V. Analysis and Results

5.1. The Economic Nature of Production Infrastructure

The production infrastructure of a free economic zone comprises a set of material and technical facilities, engineering networks, logistics systems, digital infrastructure, and service facilities that ensure the uninterrupted operation of zone residents. Its primary function is to reduce the initial costs and time required for investors to establish production. If, after obtaining a land plot, an investor is required to independently construct electricity and water supply networks, roads, internet infrastructure, and wastewater systems, the economic advantages of the free economic zone are significantly diminished.

Infrastructure affects production costs in three main ways. First, ready-to-use engineering networks reduce an enterprise's initial capital expenditures. Second, transport and logistics systems lower the costs of delivering raw materials and transporting finished products to markets. Third, the uninterrupted provision of energy and digital services reduces the risks of production downtime, defective products, and breaches of contractual obligations.

Accordingly, the infrastructure of free economic zones can be divided into three levels:

1. Basic infrastructure — roads and railways, electricity, natural gas, water supply, sewerage, and telecommunications networks.
2. Specialized production infrastructure — laboratories, testing centers, cold-storage facilities, customs terminals, waste-processing facilities, and shared technological equipment.
3. Knowledge-based infrastructure — digital management platforms, research centers, technology transfer offices, business incubators, and vocational training centers.

5.2. Key infrastructure challenges in free economic zones

5.2.1. Imbalances in engineering networks

In some zones, the amount of allocated land and the number of planned investment projects may grow faster than the available capacity of electricity, natural gas, and water supply networks. Consequently, even after production facilities have been constructed, enterprises may be unable to operate at full capacity. Since the chemical, metallurgical, textile, and food industries are particularly water- and energy-intensive, infrastructure capacity must be planned in coordination with the portfolio of investment projects.

The challenge is not limited to constructing new networks. The deterioration of existing infrastructure, increasing technical losses, and poor coordination of maintenance activities also affect production costs. Therefore, infrastructure development programs should adopt a full life-cycle approach encompassing construction, operation, preventive maintenance, and modernization.

5.2.2. High transport and logistics costs

The competitiveness of products manufactured in a free economic zone is determined not only by productivity within the enterprise but also by the speed and cost of delivering them to export markets. Limited connectivity to major highways, railway stations, airports, and customs terminals reduces the geographical advantages of the zone.

Priority should be given to multimodal transportation when developing logistics infrastructure. In such a system, the rapid transfer of cargo among road, rail, and air transport, as well as container terminals, customs warehouses, certification centers, and electronic tracking systems, operates as an integrated complex. In addition to shortening the duration of export operations, this approach increases supply chain transparency.

5.2.3. Constraints on infrastructure financing

Large-scale infrastructure projects require substantial amounts of long-term capital. Financing them solely from the state budget increases the government's financial burden, whereas relying exclusively on private funds may result in infrastructure facilities with long payback periods remaining unbuilt. Therefore, a blended financing system is required.

The government may finance external roads and electricity and water supply networks that generate significant socioeconomic benefits but provide relatively low financial returns. Internal warehouses, logistics terminals, solar power plants, and service centers, however, should preferably be developed through public-private partnerships or operated by private entities. Service fees collected from residents should be allocated to cover infrastructure operation, maintenance, and modernization costs.

5.3. Priority directions for developing production infrastructure

5.3.1. Integrated infrastructure planning

Before establishing a free economic zone, it is necessary to assess its geographical location, resource base, labor market, proximity to domestic and international markets, and environmental carrying capacity. Constructing standardized infrastructure without first determining the zone's specialization may result in inefficient capital expenditure. For example, a food industry zone requires cold-storage systems, a pharmaceutical zone needs certified laboratories, and an electrical engineering zone requires a reliable electricity supply and high-speed data transmission networks.

Therefore, a 10–15-year infrastructure master plan should be developed for each zone. It should include baseline, optimistic, and constrained scenarios concerning the number of residents, production volumes, and resource consumption. Constructing infrastructure facilities according to the modular principle would allow their capacity to be expanded gradually as demand increases.

5.3.2. Modernization of energy infrastructure

A reliable energy supply is an essential condition for the uninterrupted operation of industrial enterprises. Therefore, in addition to the main electricity source, zones should introduce backup capacity, small-scale solar power plants, energy-storage systems, and smart metering devices. Systems for forecasting energy demand and distributing loads over time would reduce the risk of system failures.

Energy audits should be conducted at enterprises, while the use of energy-efficient equipment and heat-recovery technologies should be encouraged. In addition to reducing production costs, this approach would improve the compliance of export products with environmental standards.

5.3.3. Establishment of transport and logistics centers

Modernizing the infrastructure connecting free economic zones to major transport routes is one of the primary priorities. Internal roads within zones should meet the requirements of heavy-goods vehicles, while loading and unloading areas should be located in proportion to production capacity.

The operation of a container terminal, temporary-storage warehouse, cold-storage facility, customs post, certification service, and electronic queueing system within a logistics center would facilitate the development of a "one zone–one logistics operator" model. As a result, the need to contact multiple organizations would be reduced, while export and import operations would be accelerated.

5.3.4. Digital infrastructure and the "smart zone" system

Integrating all services of a zone into a single digital platform would improve the efficiency of infrastructure management. The platform should provide information on land plots, vacant production facilities, the capacity of engineering networks, construction processes, permits, and requests submitted by residents.

The "smart zone" system would enable the real-time monitoring of electricity, water, and natural gas consumption, the early detection of technical failures, and the transparent allocation of

infrastructure costs among residents. Developing a digital map of roads, pipelines, and electricity networks using sensors and geographic information systems would reduce preventive maintenance costs.

5.3.5. Green and circular production infrastructure

Modern free economic zones should gradually adopt the principles of eco-industrial parks. Under this approach, waste generated by one enterprise becomes a secondary raw material or energy source for another. Coordinating water, heat, raw-material, and waste flows among enterprises would improve resource-use efficiency.

Zones should establish centralized facilities for wastewater treatment, industrial-waste sorting and recycling, and air-emissions monitoring. However, stringent environmental requirements should not merely result in polluting industries being relocated to neighboring areas. Therefore, environmental monitoring should be conducted across the relevant economic region rather than being limited to the boundaries of the zone.

5.3.6. Development of innovation and human-resource infrastructure

Production infrastructure should not be limited to providing enterprises with buildings and energy. Services for product testing, quality control, certification, the pilot-scale introduction of new technologies, and intellectual-property protection are also required. Establishing shared laboratories and technological centers aligned with the specialization of each zone would reduce unnecessary costs for individual enterprises.

It is advisable to establish dual-education centers in the zones through cooperation among higher education institutions, technical colleges, and enterprises. Curricula should be designed according to the needs of zone residents, while specialist training should be linked to specific investment projects. This would make it possible to provide new enterprises promptly with appropriately qualified personnel.

5.4. Infrastructure management and financing mechanism

The administration of a free economic zone should function not only as a permit-issuing authority but also as a professional infrastructure operator. The operator should be responsible for the technical condition of infrastructure networks, continuity of services, maintenance activities, tariff transparency, and responses to residents' requests. The performance of the management company should be assessed through specific performance indicators rather than by the number of services provided.

Table 2

Mechanisms for managing and financing production infrastructure in free economic zones

Direction	Main measure	Source of funding	Performance indicator
Transport and logistics	Multimodal terminal and bonded warehouses	Private investment, infrastructure bond	Delivery and customs time
Engineering networks	Modernization of water, gas, sewage and electricity networks	State budget and service fee	Power usage rate
Digitization	A single "smart zone" platform	Management company and private IT operator	Share of electronic services
Environmental infrastructure	Cleaning and waste processing complex	Green funds, public-private partnerships	Percentage of recycled waste
Innovation and	Laboratory and	Enterprises,	Localization and

personnel	dual education center	higher education institutions, grants	labor productivity

Infrastructure projects should be selected based not merely on their construction costs but on the total costs incurred throughout their operational life. A facility that is inexpensive to build but has high energy consumption and maintenance costs may prove more expensive in the long term. Therefore, projects should be evaluated using criteria such as life-cycle cost, economic return, job creation, impact on export volumes, and environmental efficiency.

Conclusion

According to the research findings, the development of production infrastructure in free economic zones is a fundamental prerequisite for locating industrial enterprises, attracting investment, and increasing export potential. Infrastructure should be developed not merely as a collection of engineering networks but as an integrated production ecosystem encompassing energy, transport and logistics, digital management, environmental services, innovation, and workforce training systems. International studies also demonstrate that high-quality infrastructure, specialization aligned with a region's comparative advantages, green technologies, and interregional cooperation determine the effectiveness of free economic zones. Therefore, alongside constructing infrastructure facilities, it is necessary to establish mechanisms for their sustainable financing, professional management, digital monitoring, and regular assessment of their economic and environmental performance.

Recommendations

1. Develop a 10–15-year infrastructure master plan for each free economic zone in accordance with its industrial specialization and portfolio of resident enterprises, and expand infrastructure capacity on a modular basis in response to demand.
2. Make extensive use of public-private partnerships, green bonds, and infrastructure funds to finance engineering and communication networks, logistics facilities, and renewable energy infrastructure.
3. Introduce a unified "Smart FEZ" digital platform to manage resource consumption, technical failures, vacant land plots, and services provided to residents.
4. Gradually transform free economic zones into eco-industrial parks by promoting water reuse, renewable energy, waste recycling, and industrial symbiosis among enterprises.

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