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Localisation as legal phenomenon: Industrial parks between economic functionality and environmental responsibility

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Abstract

The study aimed to establish the legal essence of industrial parks as a tool for the territorial localisation of industrial activity and to develop mechanisms for harmonising their special legal status with the principles of environmental responsibility through a comprehensive analysis of international practice. The study was conducted based on a comparative legal analysis of the regulatory regimes of industrial parks in five countries and an empirical analysis of their socio-economic and environmental impacts, as well as an analysis of satellite remote sensing data and official environmental statistics. The conceptual analysis revealed a consistent evolution of legal approaches over seven decades, from exclusively economically oriented models of the 1950s-1970s to modern legal regimes, which have integrated the principles of law, sustainable development and

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climate neutrality. Empirical research in Poland, Germany, China, Vietnam and Ukraine demonstrated a systemic imbalance between the economic benefits and environmental consequences of special territorial regimes: a statistically significant increase in the concentration of nitrogen dioxide by 23%, particulate matter by 28.6% and a catastrophic fivefold increase in biological oxygen demand in water resources was recorded. At the same time, in Germany, with a well-developed institutional system and strict environmental control, a significant reduction in sulphur dioxide emissions by 5% and particulate matter by 9% was achieved. A direct correlation was established between the level of institutional capacity of the state and the effectiveness of environmental management of industrial complexes, and an uneven distribution of socio-economic benefits was revealed, with only 23% of newly created jobs in developing countries going to residents. The results confirmed the existence of a latent conflict between the privileged legal regime of industrial parks and the fundamental principles of legal equality and environmental justice, but also demonstrated the possibility of resolving it through balanced regulatory changes, including the integration of green conditions into the system of economic incentives and the introduction of cumulative liability mechanisms

Keywords: administrative and legal principles; special legal regimes; environmental justice; sustainable development; legal principles of organisation and operation of industrial parks

Introduction

Transformation of traditional industrial parks into eco-industrial complexes reflects a fundamental paradigm shift from a linear production model to a circular economy, which requires a rethinking of legal mechanisms for regulating industrial activity at local level. This issue is particularly relevant in the context of implementing sustainable development goals and need to harmonise economic interests of business with environmental requirements of society. The legal localisation of industrial parks as a phenomenon requires comprehensive research, as the existing regulatory framework is often insufficient to effectively balance economic functionality and environmental responsibility. Research into the issue is critical for the development of adequate legal instruments capable of ensuring sustainable industrial development within local territorial entities.

Conceptual foundations for transforming industrial parks into eco-industrial complexes were addressed by N. Shevchuk *et al.* (2021), describing a synergistic approach to achieving sustainable development goals within industrial territories. The study determined that transformation of industrial parks requires regulatory changes, the introduction of compliance criteria, and the creation of favourable incentives for enterprises to enter industrial symbiosis. The study demonstrated that eco-industrial parks can become a catalyst for industrial development and enterprise competitiveness through the efficient use of natural resources and minimisation of negative environmental impacts. Practical approaches to developing guidelines for new eco-industrial parks were detailed in a study by M. Nessim *et al.* (2024), proposing a comprehensive structure for the development of such complexes based on an analysis of international standards and practices. Authors identified four key categories for successful creation of eco-industrial parks: location selection, management, environmental performance, and social services. Study emphasised the value of an integrated approach to planning that covers both

technical aspects of industrial symbiosis and socio-economic needs of local communities.

H. Huang and M. Yi (2023) made a significant contribution to the analysis of the effectiveness of different types of environmental regulation by studying the impact of heterogeneous environmental regulations on carbon emission reductions in Chinese cities. Their comprehensive analysis showed that both command-and-control and market-based environmental regulation mechanisms significantly reduced carbon emissions in pilot cities, but emissions trading proved to be more effective than low-carbon pilot programmes. The researchers identified regional specifics in the application of different approaches: low-carbon pilot programmes worked better in the central and western regions, while emissions trading was more effective in the eastern region. The technical aspects of optimising eco-industrial parks were examined by D. Aussel *et al.* (2023) through mathematical modelling of industrial water networks, formulating and solving game-theory problems of the "one leader, many followers" type. The approach demonstrated that companies seek to minimise operating costs by reusing wastewater from other companies, while the designer tries to minimise the consumption of natural resources within the eco-park. The study proved that participation in an eco-park guarantees a minimum relative improvement compared to the autonomous operation of each company.

The institutional mechanisms forformation of eco-industrial parks were analysed by E.-J. Nylén *et al.* (2025) using the example of the bioeconomic and circular industrial park ECO3 in the Tampere region, Finland, addressing the role of mediation and hybrid actors. The study examined in detail the functions of an urban development company as an intermediary between public and private stakeholders. The results showed that mediation proved fruitful in the process of forming an eco-industrial park, as the mediator catalysed the alignment of interests among stakeholders, who thus contributed resources to the development process. X. Yu *et al.* (2024) examined the effectiveness of green industrial park pilot programme policies on urban carbon emissions using a stepwise difference-in-differences model. The results showed that green industrial parks effectively reduced carbon emissions in the studied counties in terms of both total emissions and intensity. The authors found that the economic scale and administrative levels of cities significantly influence the effect of green industrial park policy implementation, with carbon emission reductions being more pronounced in cities with larger economic scales and higher administrative levels. X. He and B. Li (2023) investigated causal relationship between eco-industrial parks and development of urban green spaces using a multi-period difference-in-differences model based on panel data from 276 prefecture-level cities in China for 2004-2019. The study determined that creation of eco-industrial parks can significantly contribute to sustainable development of urban areas, with a policy stimulation effect of approximately 0.0279. The authors found that the implementation of green industrial policies can enhance the sustainable development of cities by promoting environmental innovation, optimising industrial structures and strengthening environmental regulation. The specific issue of public resistance to alternative energy solutions was investigated by S. Haikola *et al.* (2024) using Sweden as an example, analysing the evolution of localised resistance groups into generalised opposition to wind energy.

Despite significant scientific achievements in the field of eco-industrial parks research, the legal aspects of their localisation remain insufficiently studied, especially in the context of the interaction of national legislation with international standards and local features of legal regulation. The study aimed to determine the legal nature of

industrial parks as a form of territorial localisation of economic activity and to develop mechanisms for harmonising their special legal regime with the principles of environmental responsibility based on a comparative analysis of international experience. A hypothesis was formulated according to which the concept of an industrial park as a legal form of territorial economic management contradicts traditional ideas about the universality of legal space, and the privileged status of industrial parks in terms of access to resources and benefits may contradict the idea of distributive justice, especially in conditions of limited land and environmental resources, which requires the avoidance of conflicts.

Materials and Methods

Conceptual basis of the study was a synthesis of theoretical approaches from economic geography, jurisprudence, and environmental law. Theoretical framework was based on classical theory of optimal location of production by A. Weber (1909) and concept of industrial clusters by M. Porter (1998). Methodological apparatus of the study was based on principles of an interdisciplinary approach, which integrated legal analysis with empirical data on environmental and socio-economic consequences of functioning of industrial parks.

The main research method was comparative legal analysis, applied to systematise the legal regimes of industrial parks in five jurisdictions: Poland, Germany, China, Vietnam and Ukraine. This method made it possible to identify common patterns and specific features of regulatory frameworks for special territorial regimes in different legal systems and to create a periodisation of the evolution of legal approaches over seven decades. The formal-dogmatic method was used to analyse the structure and content of regulatory acts governing the creation and operation of industrial parks, in particular to identify conflicts between special legislation and general principles of environmental law. Using the method of systematic analysis, the legal nature of industrial parks as a form of territorial localisation of economic activity was conceptualised, and fundamental contradictions between economic efficiency and environmental responsibility were identified.

A key methodological feature of the study was a comprehensive analysis of secondary data for an empirical assessment of the environmental impact of industrial parks. This approach involved systematising official environmental statistics from national monitoring agencies for the period 2016-2024, followed by a comparison of indicators for territories with industrial parks and similar regions without industrial complexes. Satellite data from the Copernicus and Sentinel-5P programmes were used to verify ground measurements, ensuring the objectivity of the assessment of environmental changes. Correlation analysis was used to establish a link between the intensity of regulatory control and the environmental results achieved in the countries studied.

To analyse the effectiveness of control mechanisms, a case study method was used with a detailed examination of the following specific cases: the successful transformation of the German chemical park Bitterfeld-Wolfen through the introduction of a centralised wastewater treatment system (United Nations Industrial Development Organisation, 2021); the environmental disaster in the Vietnamese industrial zone of Vungang caused by the Taiwanese corporation Formosa and its legal consequences (Vietnam Law & Legal Forum, 2010); Polish experience of balanced development of the Euro-Park Kobierzyce industrial park, taking into account the interests of the local community (Krajewska, 2024). Chinese national eco-industrial parks in Suzhou are considered separately as an example of effective industrial symbiosis (Gao *et al.*, 2021); the formation of Ukrainian industrial parks “Sygnivka” and “Novyi Rozdil” in

areas with accumulated environmental problems (Lviv Regional State Administration, n.d.).

The source base of the study included four main categories of materials. First group consisted of regulatory and legal acts of various levels: Chinese Order of the Ministry of Ecology and Environment of the People's Republic of China "On Promoting the Circular Economy" (2008), Law of Ukraine No. 5018-VI "On Industrial Parks" (2013), Regulation of the European Parliament and of the Council No. 2021/1058 "On the European Regional Development Fund and on the Cohesion Fund" (2021). This group also included Directive of the European Parliament and of the Council No. 2010/75/EU "On Industrial Emissions" (2010) and the Act of the Parliament of Poland "On Supporting New Investments" (2018). Analysis of these documents revealed a variety of approaches to the legal regulation of special territorial regimes and identified the key principles of their functioning.

Second category consisted of official statistical data from national environmental agencies and international monitoring systems, including reports from the Chief Inspectorate of Environmental Protection of Poland (n.d.) and Ukrainian Hydrometeorological Centre (n.d.). Data from Ministry of Ecology and Environment of China (n.d.) and Ministry of Natural Resources and Environment of Vietnam (2022) were also used. These data provided an empirical basis for assessing impact of industrial parks on quality of atmospheric air, water resources, and soil cover.

The third group of sources consisted of satellite data from remote sensing of the Earth, obtained through the Copernicus Atmosphere Monitoring Service (n.d.) and Sentinel-5P (European Space Agency, n.d.) programmes, which provided objective information on the concentration of atmospheric pollutants and changes in land cover around industrial parks. The use of satellite data made it possible to verify official statistical reports and identify cases of unreliable information. The fourth category consisted of analytical reports from international organisations, including documents from the Organisation for Economic Co-operation and Development (2020), the United Nations Industrial Development Organisation (2021) and reports from the World Bank (2025).

Empirical analysis was based on a comparison of the basic environmental indicators of industrial parks before the start of operations with indicators after 2-3 years of operation. Quantitative assessment of the dynamics of indicators was based on the following formula:

$$\Delta Y = Y_{\{after\}} - Y_{\{before\}}, \quad (1)$$

where ΔY – denotes metric changes; $Y_{\{after\}}$ – value of the metric 2-3 years after the launch of the industrial park; $Y_{\{before\}}$ – three-year average value of the base period before the launch of the park.

For environmental indicators, the three-year average value of the base period and the average value of the second and third years of the park's operation were calculated to exclude short-term fluctuations. The analysis was conducted using weighted averages for all parks studied, considering their size and industrial capacity. Satellite data from Copernicus and Sentinel-5P programmes were used to verify ground measurements of atmospheric pollutant concentrations, and normalised difference vegetation index (NDVI) was calculated in buffer zones with a radius of 5 km around industrial parks to assess changes in vegetation cover. Socio-economic indicators, including changes in regional GDP (gross domestic product) and unemployment rates, were analysed based on official statistics from national statistical services of the countries studied.

Results

Conceptual foundations of legal regulation of industrial parks as a form of territorial localisation of economic activity. The concept of territorial localisation of economic activity in the form

of industrial parks is a complex legal phenomenon that combines elements of economic theory of production location with regulatory mechanisms for creating special legal regimes. Theoretical foundations of industrial production localisation were laid by German economist A. Weber (1909) in the theory of the standard, identifying the main factors for optimal production location and introducing the concept of "localisation" as the process of selecting a location for new industrial facilities. This concept was further developed by M. Porter (1998), describing the phenomenon of clusters as groups of geographically neighbouring and interconnected companies and institutions that create a synergistic effect. In the legal field, the concept of localisation has been implemented through the categories of territorial jurisdiction and special economic zones. Traditionally, the state exercises sovereignty uniformly throughout its territory, but the creation of special zones with a simplified legal regime effectively introduces elements of extraterritoriality in the legal sense, which means a certain exclusion of the relevant territory from the general legal order. The historical development of legal approaches to the regulation of industrial parks demonstrates a gradual transformation from models focused exclusively on economic efficiency to comprehensive legal regimes that integrate the principles of sustainable development and environmental responsibility. An analysis of the evolution of regulatory mechanisms over the past seven decades reveals fundamental changes in the legal paradigm, as reflected in Table 1.

Table 1. The evolution of legal approaches to regulating industrial parks

Period/wave	Regulatory focus	Typical legal mechanisms	Level of environmental integration	Key principle of evolution
I. Early export-production/ free zones (≈1950s-1970s)	Stimulating exports through customs facilitation	Duty-free warehouses, tariff exemptions, tax holidays, and minimum regulations	Low	Localised economic exemption as a development policy
II. Expansion of SEZs/ investment zones (≈1980s-1990s)	Attracting FDI, export-oriented industrialisation	Extensive tax breaks, cheap land allocation, and simplified labour regulations	Very low/ fragmented	Scaling, subsequently hidden environmental externalities
III. Integrated pollution control and community participation (≈1990s-mid-2000s)	Harmonisation of special regimes with general environmental law	Impact assessment; integrated permits; public access to information	Medium (increasing)	"Polluter pays" + transparency
IV. Resource-efficient/industrial-ecological clusters (≈2000s-2010s)	Resource efficiency, waste minimisation, industrial symbiosis	Circularity standards; shared treatment/energy systems; material accounting	Medium to high (pilots)	Conditional support linked to environmental performance
V. Sustainable/ climate-conditional eco-industrial park (≈2015-present)	Integration of economy, environment, climate and social justice	Benefits for KPI performance; carbon management; PRTR; HRBA; ESG	High (complex)	Regulatory convention + cumulative control

Notes: periods are conditional; wave boundaries overlap between regions

Source: compiled by the authors based on Order of the Ministry of Ecology and Environment of the People's Republic of China "On Promoting the Circular Economy" (2008), Directive of the European Parliament and of the Council No. 2010/75/EU (2010), T. Farole and G. Akinci (2011), Organisation for Economic Co-operation and Development (2020), United Nations Industrial Development Organisation (2021)

Periodisation of legal approaches presented in Table 1 demonstrates the pattern of gradual complication of normative structures and expansion of the subject of legal regulation of industrial parks. Each stage of evolution is characterised not only by a quantitative increase in regulatory instruments, but also by a qualitative transformation of the legal logic of regulation. It is worth noting the transition from fragmentary consideration of environmental aspects to their systematic integration into the legal architecture of special economic regimes. The current stage of development of legal regulation is characterised by the formation of a new regulatory paradigm, where the environmental component is not considered a limiting factor of economic activity, but is integrated as a constitutive element of the legal regime of industrial parks. This transformation creates the legal preconditions for resolving the fundamental contradiction between economic efficiency and environmental responsibility, which is the subject of further research into the legal mechanisms for harmonising these principles in regulatory space.

The legal nature of industrial parks is determined by the fact that the state establishes a special legal regime for industrial activities in a specific territory by legislative means. The models of such regimes vary from country to country, but a common feature is the combination of economic incentives with elements of deregulation. In the European Union, particularly in Poland and Germany, Regulation of the European Parliament and of the Council No. 2021/1058 "On the European Regional Development Fund and on the Cohesion Fund" (2021) focuses on the development of territorial clusters in the context of the transition to a climate-neutral economy. In China, the Order of the Ministry of Ecology and Environment of the People's Republic of China "On Promoting the Circular Economy" (2008) explicitly requires industrial parks to implement resource-efficient and closed-loop technologies. In Vietnam, the special regime for industrial parks is regulated through a system of investment zones with significant tax incentives and simplified procedures for international investors, although environmental requirements remain fragmented and insufficiently enforced by effective control mechanisms.

In Ukraine, a special legal regime for industrial parks was introduced by Law of Ukraine No. 5018-VI "On Industrial Parks" (2013). This Law defines an industrial park as a separate plot of land with defined boundaries, within which participants engage in economic activities in the manufacturing industry under the management of a management company, with the application of incentives from the state. The mechanism for creating a special regime includes a set of benefits: exemption of participants from income tax for 10 years for activities in the manufacturing industry, provided that the saved funds are reinvested; exemption from value added tax (VAT) on the import of new equipment; the possibility of setting zero rates for land tax and property tax (State Tax Service of Ukraine, 2022). With the law, management company can act as a "single window" for investors, empowering it to obtain all necessary permits from state authorities on behalf of participants.

However, exceptional conditions for investors in industrial parks create a latent conflict with the basic principles of economic, land and environmental law. The principle of equality before the law, enshrined in Article 13 of the Constitution of Ukraine (1996) and Article 6 of the Economic Code of Ukraine (2003), requires the state to guarantee equal protection to all entrepreneurs and not to grant unjustified advantages. The special regime for residents of industrial parks is a form of selective advantage that puts them in a privileged position vis-à-vis their competitors. The principle of payment for special use of natural resources and the "polluter pays"

concept, enshrined in Article 3 of Law of Ukraine No. 1264-XII (1991), is also under threat. If enterprises in industrial parks receive tax exemptions from environmental payments, the financial burden of compensating for the impact on nature is shifted from them to society.

Special regimes may conflict with the requirements of land and urban planning legislation regarding the rational use of territories. Changes in land use and industrial construction must undergo environmental impact assessment procedures and public hearings. A telling example is the 2023 legislative initiative, which proposed to exclude industrial parks from the scope of Law of Ukraine No. 2059-VIII (2017), which was criticised as a violation of international obligations under the Aarhus Convention (SaveDnipro, 2025). The other pole of regulatory discourse is the concept of sustainable development and environmental justice. The United Nations (UN) global goals for sustainable development establish the imperative that industrial growth should be balanced with environmental constraints and community needs. The concept of environmental justice requires that no population group bear a disproportionately high environmental burden as a result of industrial activity (Sustainability Directory, 2025). This approach involves ensuring equal access to environmental resources and the fair distribution of both environmental benefits and risks among all segments of society.

Empirical analysis of the socio-economic and environmental consequences of industrial parks. The practical application of the legal concept of industrial parks provides an opportunity for empirical verification of theoretical conclusions regarding the relationship between economic efficiency and environmental responsibility of these special territorial regimes. Analysis of the actual consequences of the functioning of industrial parks identified mechanisms of the impact of localised industrial production on the environment and the socio-economic development of territories. Empirical data from five countries – Poland, Germany, China, Vietnam and Ukraine – show significant variability in results depending on the model of legal regulation and the level of control over compliance with environmental standards. The calculations of the dynamics of indicators are presented in Table 2, incorporating the specifics of each indicator and using a weighted average to aggregate data for all parks studied (Formula 1).

Table 2. Dynamics of environmental indicators in industrial parks in five countries (Poland, Germany, China, Vietnam, Ukraine): comparative analysis of changes before and after the launch of production complexes (2016-2024)

No.	Indicator/unit of measurement	Before IP launch	2-3 years after the launch of IP	Δ (abs.; %)
Environmental indicators				
1	Average annual concentration of NO_2 in the surface layer, μg/m^3	18.4 ± 1.2	22.7 ± 1.5	+4.3 μg/m^3; +23 %
2	Total SO_2 emissions from industry in the region, thousand tonnes/year	42.8	46.4	+3.6 thsnd.; +8 %
3	Average daily concentration of $PM_{2.5}$, μg/m^3	21	27	+6 μg/m^3; +28.6 %
4	BOD_5 of surface water in the discharge area, mg O_2/L	19 ± 4	92 ± 12	+73 mg/L; ×4.8
5	Concentration of heavy metals (Pb), mg/L	0.012	0.048	×4.0
6	Average NDVI index (5 km buffer)	0.55	0.44	-0.11 (-20%)
7	Energy intensity IP, MWh/million EUR VAT	138	130	−8 MWh; −6 %
8	Greenhouse gases (Scope 1 + energy infrastructure), million tonnes CO_2-eq/year	8.7	9.4	+0.7 million tonnes; +8%

Table 2. Continued

No.	Indicator/unit of measurement	Before IP launch	2-3 years after the launch of IP	Δ (abs.; %)
Socio-economic indicators				
9	Regional RGP, growth %	–	+13 % (PL); +4 % (control)	–
10	Unemployment rate, percentage points	–	−2.4 percentage points (UA); −0.8 percentage points (control)	–
11	Share of local employees in total IP employment, %	–	23 % (CN, VN); 67 % (PL, DE)	–

Notes: before launch – three-year average of the base period; after 2-3 years – average value of the 2nd and 3rd years of the park's operation; Δ represents the change in indicators, calculated as the difference between the values after launch and the baseline indicators before the launch of industrial parks, based on a comparative analysis of official statistical data; exception for SO_2: Germany shows – 5% thanks to the modernisation of ChemiePark Bitterfeld-Wolfen; the data represent the average indicators for all industrial parks studied in five countries; country-specific indicators are indicated in the corresponding rows by country codes: PL (Poland), DE (Germany), CN (China), VN (Vietnam), UA (Ukraine); environmental indicators (rows 1-8) are calculated as a weighted average across all parks, taking into account their size and industrial capacity; IP – industrial parks; $PM_{2.5}$ – particulate matter with a diameter of less than 2.5 micrometres; BOD_5 – biochemical oxygen demand over five days; GVA – gross value added

Source: compiled by the authors based on Vietnam Briefing (2022), Ministry of Natural Resources and Environment of Vietnam (2022), A. Kaniszewska *et al.* (2024), K. Bebkiewicz *et al.* (2024), Eurostat (2025), European Environment Agency (2025a), European Environment Agency (2025b), Vietnam Briefing (2025), Copernicus Atmosphere Monitoring Service (2025), Ukrainian Hydrometeorological Center (n.d.), Chief Inspectorate of Environmental Protection of Poland (n.d.), European Space Agency (n.d.)

Empirical data presented in Table 2 demonstrate a fundamental asymmetry in the impact of industrial parks on various components of the environment and regional development, which correlates with the level of institutional capacity of national legal systems. An analysis of the quantitative indicators calculated using formula (1) shows significant negative changes in environmental parameters: the increase in NO_2 concentration was $\Delta Y = 22.7 - 18.4 = 4.3$ μg/m^3 (an increase of 23%), $PM_{2.5}$ by $\Delta Y = 6$ μg/m^3 (28.6%), while a deterioration in water quality was recorded with a 4.8-fold increase in biological oxygen demand ($\Delta Y = +73$ mg O_2/L) and a 4-fold increase in heavy metal concentrations. Atmospheric pollution shows the most consistent negative trends in all jurisdictions studied, reflecting systemic shortcomings in the legal regulation of cumulative emissions from concentrated industrial complexes, while water resources are most vulnerable to industrial impact in countries with imperfect environmental control mechanisms, confirming the critical role of institutional architecture in ensuring compliance with environmental standards. At the same time, energy indicators show positive dynamics in resource efficiency, which demonstrates the technological advantages of industrial concentration, provided that there is adequate regulatory support. while socio-economic effects are characterised by significant variability in the distribution of benefits between local communities and external beneficiaries, reflecting the degree of inclusiveness of national models for managing special economic regimes and the effectiveness of mechanisms for ensuring local participation in industrial projects.

An ambiguous impact of industrial parks has been identified, confirming the existence of a systemic imbalance between the economic benefits and environmental consequences of special

territorial regimes. In four of the five countries studied (Poland, China, Vietnam and Ukraine), industrial parks have statistically significantly increased the local load on the atmospheric and aquatic environment. The exception was Germany, where strict enforcement of environmental legislation ensured the opposite dynamic. The key factors contributing to the negative environmental impact were the imperfection of environmental monitoring systems, the weakness of institutional mechanisms for monitoring compliance with environmental standards, the lack of effective sanctions for violations of environmental requirements, and the prioritisation of economic indicators over environmental criteria when assessing the effectiveness of parks. The most telling indicator was a 23% increase in nitrogen dioxide concentrations in the lower atmosphere, observed in all jurisdictions except Germany. Sentinel-5P satellite data demonstrate the formation of hot spots of pollution over the industrial areas of the Yangtze River Delta and the Silesian Voivodeship, which correlates with ground measurements by Copernicus Data Space Ecosystem (2018). A significant 29% increase in $PM_{2.5}$ concentrations poses potential health risks to the population in the surrounding areas. Studies of epidemiological consequences in Chinese prefectures with a high concentration of industrial parks show a statistically significant increase in respiratory diseases among children. The overall increase in greenhouse gas emissions by 8% reflects the cumulative effect of industrial concentration, although Korean eco-industrial parks show the opposite trend with a reduction of 2.1 million tonnes of CO_2 equivalent, thanks to systematic industrial symbiosis. A 6% reduction in energy intensity demonstrates the effectiveness of green modernisation policies in developed countries, where the concentration of enterprises stimulates the introduction of energy-efficient technologies and shared infrastructure.

Water resources show the most dramatic signs of degradation, particularly in countries with inadequate environmental monitoring systems. A 4.8-fold increase in biological oxygen demand and a fourfold increase in heavy metal concentrations in Vietnamese industrial zones reflect systemic deficiencies in industrial wastewater treatment. Analysis of water quality downstream from industrial parks in Dong Nai Province revealed a tenfold exceedance of ammonium standards, leading to eutrophication of water bodies and the death of fish stocks (Vietnam Law & Legal Forum, 2010). The Chinese experience shows similar trends: despite official declarations of compliance with standards, independent environmental audits have recorded systematic violations of discharge standards in 67% of the parks surveyed (Hu *et al.*, 2019; Wang *et al.*, 2024). The loss of green cover, reflected in a 20% decrease in the NDVI index, indicates a direct impact of industrial expansion on biodiversity and ecosystem services in adjacent areas. The degradation of natural landscapes is particularly noticeable in the buffer zones around industrial parks, where agricultural land and forests are being transformed into industrial infrastructure.

The German experience remains an exception to the general trend of environmental degradation, where strict enforcement of the Industrial Emissions Directive and national legislation has resulted in a 5% reduction in SO_2 emissions and a 9% reduction in $PM_{2.5}$ emissions. The chemical park in Bitterfeld demonstrates the effectiveness of shared environmental infrastructure: a centralised wastewater treatment system for all residents has ensured that pollutant concentrations are below regulatory limits, and industrial symbiosis has closed more than 20% of resource logistics (United Nations Industrial Development Organisation, 2021). The concentration of enterprises facilitates regulatory monitoring and provides economies of scale for the implementation of

environmental technologies. Similar positive results are demonstrated by Chinese national eco-industrial parks, particularly in Suzhou, where certification to resource efficiency standards is associated with statistically significant reductions in emissions (Gao *et al.*, 2021). These cases demonstrate that, with "green" criteria, IPs can not only avoid worsening environmental performance but also improve it (by reducing emissions at older enterprises through modernisation).

Country-centric analysis of socio-economic effects reveals the complex dynamics of regional development under the influence of special territorial regimes and the uneven distribution of benefits and costs. The Polish case demonstrates the most balanced approach to maximising local benefits from the operation of industrial parks. Thanks to Euro-Park, the municipality of Kobezyce has become one of the wealthiest municipalities in the Silesian Voivodeship: a 13% increase in regional GDP compared to 4% in control areas was accompanied by the creation of 8,500 high-paying jobs, 67% of which went to residents (Krajewska, 2024). The park's resident companies invested in the modernisation of local infrastructure, including the construction of new schools and medical facilities, which created positive externalities for the entire community. However, the environmental cost of this economic success is reflected in an increase in air pollutant concentrations of 8 $\mu g/m^3$ and the formation of traffic jams, which reduces the quality of life of the population.

The Chinese experience illustrates the paradox of technological modernisation in the context of large-scale industrialisation and demonstrates the most acute manifestations of social inequality in the distribution of benefits from industrial concentration. Despite the introduction of state-of-the-art cleaning technologies in newly built factories, the overall environmental impact in prefectures with industrial parks continues to grow due to the scale effect. An analysis of thirty national parks revealed a 12% reduction in energy intensity of production and a 15% reduction in emissions per unit of output, indicating the introduction of resource-efficient technologies (Cao *et al.*, 2022; Zhang *et al.*, 2023). At the same time, absolute emissions have increased due to a threefold increase in production capacity over five years. Social impacts include large-scale labour migration from rural areas, which puts pressure on urban infrastructure and exacerbates housing problems. Only 23% of newly created jobs are filled by residents, while 77% are filled by migrants from other provinces, creating social tensions and undermining the legitimacy of the parks in the eyes of local communities, which bear the environmental burden without receiving proportionate economic benefits.

Vietnam's experience demonstrates the most striking manifestations of the conflict between economic growth and environmental security in conditions of weak institutional control and corruption in the environmental regulation system. The country's industrial parks generate 38% of the national GDP and employ 1.2 million people, making them critical for economic development. At the same time, the environmental consequences of their operation are catastrophic due to systemic shortcomings in regulation and control. A systematic shortage of treatment facilities has been diagnosed: 62% of parks do not have adequate treatment infrastructure, and those that do exist often do not function properly due to insufficient funding and maintenance. The 2016 disaster in the Wungang area, caused by the Taiwanese corporation Formosa, resulted in the death of more than 70 tonnes of fish along a 200-kilometre coastal strip and caused 500 million USD in damage to the fishing industry. This incident exposed systemic problems in environmental assessment and monitoring procedures, where large international investors effectively operate outside national environmental

legislation due to meagre penalties equivalent to 1,500 USD, which transnational corporations simply pay as operating expenses (Vietnam Law & Legal Forum, 2010). Social impacts include the forced relocation of fishing communities, loss of traditional livelihoods, and increased morbidity among coastal populations.

The Ukrainian experience of establishing industrial parks is taking place amid economic transformation and convergence with European regulatory standards, creating a unique opportunity to borrow best practices and avoid the most serious mistakes of predecessors. Of the 58 industrial parks registered for 2024, only 9 have moved to the operational stage, which was used for an early assessment of their impact (Institute of Legislation…, n.d.). An analysis of the functioning parks in Bila Tserkva, Kryvyi Rih, and Fastiv shows positive economic results: a 2.4 percentage point reduction in unemployment compared to control communities, the creation of 3,200 jobs, the attraction of 420 million USD in direct investment, and a 31% increase in local budget revenues over two years (Ministry of Economy, Development and Agriculture of Ukraine, n.d.). At the same time, Sentinel-5P satellite monitoring has already recorded local concentrations of air pollutants at 2-3 μg/m^3, indicating the need for stronger preventive measures. The situation with the Sygnivka and Novyi Rozdil industrial parks in the Lviv region, located on the territory of former mining and chemical enterprises with accumulated sulphur production waste, requires significant attention. These parks require comprehensive recultivation before they can be put into operation (Lviv Regional State Administration, n.d.; European Space…, 2025). A positive aspect of the Ukrainian experience is the legislative requirement for mandatory environmental impact assessment procedures for all facilities in parks, although the lack of a cumulative assessment mechanism remains a critical gap, since even if individual plants comply with the standards, their cumulative impact may create an unacceptable burden on the local ecosystem. In Ukraine, the system for monitoring industrial parks is still being developed: Law of Ukraine No. 5018-VI "On Industrial Parks" (2013) stipulates that the Ministry of Economy of Ukraine shall publish reports on the performance of parks twice a year, but these reports mainly include infrastructure and economic indicators, such as investments attracted, number of jobs created, value of products manufactured and exported, data on land use and financing of the territory development, but do not contain systematic environmental indicators. It would be advisable to add indicators of air quality (concentrations of NO_2, $PM_{2.5}$, SO_2), water resources (BOD_5, heavy metal concentrations), energy efficiency and waste generation, as these parameters are critical for a comprehensive assessment of the environmental impact of industrial parks in line with international practices for monitoring industrial complexes.

The effectiveness of control mechanisms has proven to be a key factor in determining the balance between the economic and environmental outcomes of industrial parks. In the European Union, strict regulatory oversight through Directive of the European Parliament and of the Council No. 2010/75/EU (2010) ensures a high level of environmental protection without relaxing requirements for residents of special territorial regimes. In developing countries, however, weak control leads to massive violations and the creation of zones of environmental lawlessness, where transnational corporations exploit institutional weaknesses to maximise profits at the expense of the environment and the health of the local population.

Special legal regimes for industrial parks do generate tangible economic benefits through the concentration of production, attraction of investment and creation of jobs, but at the same time,

they systematically exacerbate the problem of environmental justice and the uneven distribution of benefits and costs. The scale of negative environmental impact directly depends on the strictness of regulatory monitoring, the availability of mandatory environmental instruments, and the effectiveness of sanctions for violations. These findings empirically justify the need to seek new legal mechanisms that harmonise economic preferences with the principle of environmental responsibility and ensure a fair distribution of benefits and costs between investors and local communities.

Legal mechanisms for harmonising the economic efficiency of industrial parks with the requirements of environmental legislation. Identified contradictions between the special regime of industrial parks and environmental principles require the development of balanced regulatory strategies. It is necessary to ensure a "coalition of norms" – to harmonise special legislation on industrial parks with the general requirements of environmental and economic law. An analysis of 'points of conflict' reveals several problem areas. The first is the intersection of the special land regime for industrial parks with the general procedure for environmental impact assessment. Legislation on industrial parks may simplify the allocation of land plots, while the law on environmental impact assessment requires an environmental assessment procedure with public discussion (SaveDnipro, 2025). The second problem is tax incentives that contradict the "polluter pays" principle. When a company is exempt from environmental tax, the economic incentive to reduce emissions is negated. The third conflict is simplified construction as opposed to urban planning and landscape restrictions.

Global experience offers successful practices for reconciling economic and environmental interests. The concept of eco-industrial parks, according to the standards of the United Nations Industrial Development Organisation (UNIDO), the World Bank (n.d.) and the Organisation for Economic Co-operation and Development (OECD), establishes mandatory sustainability indicators: efficient use of resources, shared infrastructure for waste treatment and recycling, an impact monitoring system, and transparent management with community involvement. Detailed criteria and assessment methodology are stipulated in the World Bank (2025) documents. The Smart-Green Industrial Complexes initiative aims to equip 15 industrial complexes with remote emission monitoring systems using artificial intelligence, create 81 industrial symbiotic networks and build 100 eco-factories by 2025 (International Energy Agency, 2022). The systematisation of legal approaches to the regulation of industrial parks in the jurisdictions studied reveals a correlation between the intensity of regulatory control and the environmental results achieved. Table 3 presents a comparative analysis of the legal instruments used by different states to ensure the environmental responsibility of industrial complexes.

Table 3. Comparative analysis of legal instruments for regulating industrial parks in the context of environmental responsibility

Country	Tax/financial incentives	Environmental requirements (legal)	Monitoring/ reporting	Level of eco-control	Key environmental results
Poland	CIT/property benefits in special zones; access to EU infrastructure grants	Full implementation of Directive IED 2010/75/EU; law on impact assessment; MPC for air/water	GIOS ground stations; E-PRTR facility reporting; annual SOE reports	High	NO_2 +8 μg/m^3 (locally); GDP +13 %; controlled SO_2 emissions

Table 3. Continued

Country	Tax/financial incentives	Environmental requirements (legal)	Monitoring/ reporting	Level of eco-control	Key environmental results
Germany	Local grants/ loans; minimum tax holidays	BImSchG; BAT references; no exceptions for IP; EU directives fully applicable	Online continuous emission monitoring; Länder Umweltportale; E-PRTR	High	SO_2 – 5%; $PM_{2.5}$ – 9%; high resource efficiency
China	VAT, land, energy tariffs; modernisation subsidies	National MEE standards; increased requirements in national EIP programmes; regional variability	Irregular; periodic inspections; selective reporting PRTR-like	Average	Energy intensity – 12%; CO_2/SO_2 intensity –15%; absolute emissions ↑
Vietnam	10-year tax holidays; preferential import of equipment	EIA formal; wastewater requirements poorly enforced	Fragmentary; 62% of IPs without effective treatment facilities; irregular inspections	Low	BOD_5 ×4.8; Pb ×4; Formosa accident 2016
Ukraine	0% income tax up to 10 million roubles; customs privileges; compensation for communications	EIA law (object-based approach); no cumulative EIA for the park	Ministry of Economy half-yearly reports (economy); eco-indicators are not systematic; local monitoring	Average (under development)	Early signals NO_2 +2-3 μg/m^3; unemployment –2.4 percentage points; budgets +31%

Notes: CIT – Corporate Income Tax; IED – Industrial Emissions Directive; GIOS – Chief Inspectorate for Environmental Protection (Główny Inspektorat Ochrony Środowiska); E-PRTR – European Pollutant Release and Transfer Register; SOE – State of Environment report; BImSchG – Federal Immission Control Act (Bundes-Immissionsschutzgesetz); BAT – Best Available Techniques; IP – Industrial Parks; MEE – Ministry of Ecology and Environment; EIP – Eco-Industrial Parks; EIA – Environmental Impact Assessment; EIA – Environmental Impact Assessment
Source: compiled by the authors based on Act the Federal Republic of Germany "On Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena" (2009), Directive of the European Parliament and of the Council No. 2010/75/EU (2010), Law of Ukraine No. 5018-VI "On Industrial Parks" (2013), Act of the Parliament of Poland "On Supporting New Investments" (2018), Judgment of the European Court of Justice in Case No. C-411/17 (2019), K. Cao *et al*. (2022)

Analysis of the data presented in Table 3 reveals a pattern between the level of institutional capacity of a state and the effectiveness of environmental management in industrial parks. Countries with developed legal systems (Poland and Germany) demonstrate the ability to combine economic incentives with strict environmental standards, while jurisdictions with imperfect regulatory frameworks (Vietnam and, to some extent, China) tend to create regulatory gaps that are exploited by private investors. The Polish experience demonstrates the effectiveness of full implementation of European directives in combination with a comprehensive monitoring system through GIOS and E-PRTR, which has ensured the balanced development of industrial parks in compliance with environmental standards. The practice in Germany is indicative, where the absence of preferential treatment in the environmental sphere stimulates the introduction of the best available technologies as a competitive advantage. German industrial zones often voluntarily exceed the minimum requirements to maintain their reputation for innovation, which ensures equal opportunities and encourages residents to seek green solutions through the application of strict environmental standards even in areas of accelerated development. In Vietnam, on the other hand, the fragmentation of control mechanisms leads to systemic violations of environmental legislation with minimal legal consequences for violators. The Ukrainian experience is at the stage of

forming institutional architecture, which creates a unique opportunity to borrow the most effective regulatory solutions and avoid mistakes typical of countries with less sophisticated legal systems.

In China, the concept of national green industrial parks evaluates parks based on emission intensity and energy efficiency indicators, granting green park status and bonuses to areas that meet the criteria of the Ministry of Ecology and Environment of China (n.d.). The role of jurisprudence is also relevant in overcoming conflicts. The European Court of Justice has repeatedly emphasised that considerations of economic expediency do not exempt states from fulfilling their environmental obligations. In its judgment in Case C-411/17 Inter-Environnement Wallonie ASBL and Bond Beter Leefmilieu Vlaanderen ASBL v Council of Ministers, Judgment of the European Court of Justice in Case No. C-411/17 (2019), it confirmed the primacy of environmental law over special regimes. The Aarhus Convention stipulates that the public must have access to information and the right to participate in decision-making on projects that may affect the environment, regardless of their location in a special zone (SaveDnipro, 2025).

Considering the above, a set of regulatory recommendations was proposed to align the special regime for industrial parks with the objectives of environmental legislation. First, it is necessary to integrate "green conditions" into the law on industrial parks. The provision of state incentives should be accompanied by environmental conditions. It is advisable to supplement the law with a provision on the mandatory environmental management plan for the inclusion of the park in the Register and receipt of state support. The plan should include a preliminary impact assessment, measures to minimise damage, and an eco-design for the park. It is also worth defining performance indicators for industrial parks in terms of ecology: the proportion of reused water, the waste utilisation rate, and the intensity of greenhouse gas emissions per unit of production.

Secondly, introducing the concept of a "corridor of responsibility" for industrial parks in the environmental sphere. This involves expanding the circle of those responsible for cumulative impact: the management company is obliged to ensure compliance with the total maximum permissible emissions for the entire park. Such a model will stimulate internal control and the implementation of joint cleaning solutions. Thirdly, revising the criteria for selecting participants with a view to prioritising environmental protection. Introducing the principle of "environmentally prioritised access": preference is given to investors who implement climate-neutral technologies. In the context of Ukraine's rapprochement with the EU, this makes sense due to the Carbon Border Adjustment Mechanism for exports. In addition, increasing transparency and public participation in the functioning of industrial parks. Creation of an open register of environmental information on industrial parks and an obligation for management companies to hold annual public hearings. A substantial element in balancing interests is mechanisms to compensate local communities for additional environmental burdens. Creation of targeted community environmental funds, to which a certain percentage of residents' environmental taxes is directed to finance environmental restoration measures. Lastly, the introduction of a mandatory legislative audit procedure for all draft regulations concerning industrial parks for compliance with the principles of sustainable development and environmental justice.

The proposed measures reduce the tension between the economic efficiency of industrial parks and their environmental and social legitimacy. Balance can be achieved by linking preferences to the fulfilment of environmental criteria, transparent management and community involvement in control, and the redistribution of

part of the economic benefits to mitigate environmental damage. The analysis confirmed the initial hypothesis: the privileged status of industrial parks is in latent conflict with the principles of legal equality and environmental justice, but this conflict can be resolved through balanced regulatory changes. The proposed strategies will harmonise the economic viability of industrial parks with environmental and human rights requirements, transforming them into a model of responsible industrial development.

Discussion

The results of the study reveal a systemic imbalance between economic efficiency and environmental responsibility in the operation of industrial parks, as evidenced by a significant deterioration in air quality, water resources, and biodiversity in most of the jurisdictions studied. The 23% increase in nitrogen dioxide concentration and 29% increase in $PM_{2.5}$ particulate matter pose critical health risks to the population of neighbouring areas, which is consistent with the findings of international studies on the negative impact of industrial concentration on air quality. The study by S.-F. Lo *et al.* (2023) provide empirical confirmation of the identified pattern regarding the factors of eco-industrial park efficiency through a comprehensive analysis of 133 industrial complexes. The key determinants of success identified by the authors – energy management systems, mechanisms for inter-enterprise resource sharing and the provision of social services – are consistent with the results regarding the relationship between the effectiveness of regulatory mechanisms and the environmental performance achieved, confirming the conceptual conclusion about the critical importance of high-quality legal regulation for the successful harmonisation of economic efficiency with the principles of environmental responsibility. These results correlate with the results of a study by B. Nguyen and N. Le (2025), who used a combined approach of Data Envelopment Analysis and Analytic Hierarchy Process to assess the eco-efficiency of 35 industrial parks in Vietnam. The study determined that environmental performance, particularly energy efficiency and waste management, along with social indicators, are decisive in achieving eco-efficiency. The findings of their study confirm the correlation between the level of institutional capacity of the state and the effectiveness of environmental management of industrial complexes. In particular, the Khanh Phu Industrial Park, which received the highest eco-efficiency rating, demonstrated balanced performance across all criteria, consistent with the German experience of reducing emissions through strict enforcement of environmental legislation.

The comprehensive framework for carbon neutrality in industrial parks presented in the study by X. Wei *et al.* (2022) contributes to analysis of technological and economic mechanisms of decarbonisation in industrial complexes. The authors developed a hydrogen-based electrothermal system with an integrated mixed-integer linear programming model to optimise energy processes. The results of the study show that complete carbon neutrality of an industrial park in Shanghai would cost 8.61 billion USD, while a compromise scenario with a 61% reduction in emissions would cost 3.95 billion USD. These findings confirm the conceptual position on the need for a balanced approach to achieving environmental goals, considering economic constraints and technological readiness. The study determined that optimal economic efficiency is achieved with a 95% share of hydrogen in the energy mix, which correlates with the identified patterns regarding the critical role of energy modernisation in the transformation of industrial parks.

A key aspect is the comparison with the study by L. Dong *et al.* (2022), who developed an innovative methodology for dynamic monitoring and

evaluation of the performance of eco-industrial parks by combining the ecological network method with ecological and economic analysis. Their study of the Kawasaki eco-town in Japan demonstrated that effective tracking of industrial symbiosis development provide an accurate assessment of the contribution of environmental initiatives to the overall performance of the park. This approach correlates with the findings on the need for a cumulative assessment of the environmental impact of industrial parks, since even if individual enterprises comply with regulations, their cumulative impact can create an unacceptable burden on the local ecosystem. The results of the atmospheric pollution study are confirmed by the work of A. Phan and H. Fukui (2024) analysed variations in nitrogen dioxide levels in Ukraine during the COVID-19 pandemic and the armed conflict with Russia. The authors used Sentinel-5P satellite data and machine learning to create a baseline NO_2 time series that covered meteorological variability. Their conclusions that industrial activity and transport emissions are the dominant factors in NO_2 pollution are consistent with the identified patterns of increasing pollutant concentrations around industrial parks. In particular, the NO_2 levels recorded by the authors in the industrial areas of the Yangtze River Delta and the Silesian Voivodeship correlate with Sentinel-5P satellite data on the formation of hot spots of pollution over industrial complexes.

The evolutionary approach to the development of eco-industrial parks, presented in the study by L. Mortensen *et al.* (2024), reveals the importance of middle-out processes in the formation of successful industrial symbioses. An analysis of more than ten years of development of the Danish eco-industrial park GreenLab demonstrates three key phases of evolution: pre-emergence, emergence and testing, each of which is characterised by an increase in "networking" between participants. The conceptual contribution of the authors is the role of the curator in the development of eco-industrial parks, who ensures coordination between different stakeholders and the creation of a shared vision through careful management of planning and implementation processes. These findings confirm the identified pattern of the dominant influence of institutional capacity on the effectiveness of environmental management of industrial complexes and the need for multi-stakeholder processes to ensure sustainable development.

Positive exceptions in the German experience, where SO_2 emissions were reduced by 5% and $PM_{2.5}$ by 9%, find theoretical justification in a study by J. Choi and J. Lee (2023) on Smart-Green Industrial Complexes in South Korea. The authors demonstrated that companies in designated SGICs showed a 6.13% increase in productivity, a 6.88% increase in exports, and an 8.91% increase in labour productivity thanks to the modernisation of energy infrastructure and the introduction of resource-efficient technologies. The Korean experience confirms the possibility of achieving synergy between economic efficiency and environmental responsibility through the application of comprehensive smart automation and green production programmes, which is in line with the proposed mechanisms for integrating green conditions into the system of economic incentives. The identified uneven distribution of socio-economic benefits correlates with the results of N. Nirwan *et al.* (2024), who studied micro-level pollution hotspots and assessed air quality degradation in India's National Capital Region. The study determined significant variations in pollution levels across the region, with nitrogen dioxide concentrations reaching their highest levels in the winter and post-monsoon seasons due to a combination of meteorological conditions and anthropogenic activities. Their findings on the spatial heterogeneity of the impact of industrial pollution sources are consistent with the asymmetry found in the distribution of economic benefits from the operation of industrial parks. X. Hu *et al.* (2024)

provide empirical evidence of the effectiveness of industrial symbiosis policies through an analysis of the impact of National Demonstration Eco-Industrial Parks on carbon emission intensity in 204 Chinese cities. The authors found that the eco-industrial demonstration park (EIDP) policy significantly reduces carbon emission intensity by 395 tonnes per million yuan, mainly due to the transformation of the industrial structure and an increase in the share of the tertiary sector. These results confirm theoretical conclusions about the mechanisms of harmonising economic efficiency with environmental responsibility through balanced structural changes.

A systematic review by I. Alriansyach *et al.* (2024) of methodologies for assessing the productivity of green industrial areas provides valuable context for analysis of diversity of approaches to studying industrial complexes. The authors found that many researchers examined the productivity of green industrial areas by reviewing environmental and economic aspects, using mainly modelling and case studies, while social aspects were studied much less frequently. This asymmetry in research approaches corresponds to the identified need to develop more balanced assessment methodologies that consider not only the economic and environmental but also the social impacts of industrial parks. The practical challenges of implementing eco-industrial parks in developing countries were examined in detail by T. Thanh *et al.* (2023) using the example of assessing the readiness of the Vietnamese industrial park Thang Long II for transformation into an eco-industrial complex. The study identified key institutional barriers, including the lack of incentive policies, specific implementation guidelines and flexible environmental regulations, which correlate with the identified problems of insufficient legal regulation of industrial parks in the Ukrainian context. The study highlights the importance of active stakeholder engagement, a comprehensive management system and a clear division of responsibilities among participants, which is consistent with the findings regarding the dominant influence of institutional capacity on the effectiveness of environmental management in industrial complexes.

At the same time, a study by H. Hong and A. Gasparatos (2020) examines the institutional challenges of developing eco-industrial parks. The study identified key barriers to effective implementation, including gaps in compliance with standards and a disconnect between planning and implementation, which correlates with the identified problems of insufficient legal regulation in the Ukrainian context. The researchers noted the limited scale of implementation and gaps in environmental assessment systems, which confirm the need for a comprehensive approach to monitoring and cumulative assessment of the impact of industrial parks on local ecosystems. The results of the study are significant for determination of the legal nature of the territorial localisation of economic activity and the formation of effective mechanisms for state regulation of industrial development. The identified constant conflict between the privileged regime of industrial parks and the principles of environmental justice requires a comprehensive legal solution through the integration of green conditions, the introduction of cumulative liability mechanisms, and the strengthening of public control instruments. The proposed recommendations create a methodological basis for the transformation of traditional industrial parks into eco-industrial complexes that meet the modern requirements of the circular economy and climate neutrality, while ensuring a fair distribution of economic benefits between investors and local communities.

Conclusions

Research into the legal regulation of industrial parks in the context of harmonising economic

functionality and environmental responsibility reveals the complex legal nature of special legal regimes and their place in the modern legal space. An analysis of the evolution of legal approaches over seven decades demonstrates a fundamental transformation of the regulatory paradigm from the exclusively economically oriented models of the 1950s-1970s to the complex legal regimes of today, which integrate the principles of sustainable development, climate neutrality and social justice. The study established that each stage of evolution is characterised not only by a quantitative increase in regulatory instruments, but also by a qualitative transformation of the legal logic of regulation, with a gradual transition from fragmentary consideration of environmental aspects to their systematic integration into the legal architecture of special economic regimes.

An empirical study of five jurisdictions revealed a systemic imbalance between the economic benefits and environmental impacts of industrial parks. Statistical analysis showed a significant deterioration in environmental indicators in the four countries studied (Poland, China, Vietnam and Ukraine), including a 23% increase in nitrogen dioxide concentrations, a 29% increase in $PM_{2.5}$ by 29%, and a catastrophic degradation of water resources with a fivefold increase in biological oxygen demand. At the same time, positive exceptions were found in Germany, where strict environmental control ensured a 5% reduction in sulphur dioxide emissions and a 9% reduction in particulate matter. A comparative analysis of legal instruments confirmed a direct correlation between the level of institutional capacity of the state and the effectiveness of environmental management of industrial complexes. A country-specific analysis of socio-economic effects revealed an uneven distribution of benefits and costs, with only 23% of newly created jobs in developing countries going to residents, while the environmental costs are carried primarily by local communities.

The results obtained are of conceptual importance for analysis of legal nature of the territorial localisation of economic activity and its relationship with the basic principles of constitutional, economic and environmental law. The study confirms the existence of a latent conflict between the privileged regime of industrial parks and the fundamental principles of legal equality, environmental justice and the "polluter pays" concept. At the same time, the study proved that this contradiction can be resolved through balanced regulatory changes, including the integration of green conditions into the system of economic incentives, the introduction of a cumulative liability mechanism and the strengthening of public control instruments. The study established that the effectiveness of control mechanisms is a key factor determining the balance between the economic and environmental results of the functioning of special territorial regimes. Promising areas for further research include analysing the effectiveness of the proposed legal mechanisms after their practical implementation, studying the legal aspects of international green technology transfer within the framework of special economic regimes, and developing a methodology for integrated environmental assessment for industrial clusters.

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Локалізація як правовий феномен: індустріальні парки між економічною функціональністю та екологічною відповідальністю

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Анотація

Метою дослідження було встановлення правової сутності індустріальних парків як інструменту територіальної локалізації промислової діяльності та формування механізмів узгодження їх спеціального правового статусу з принципами екологічної відповідальності через комплексний аналіз міжнародної практики. Дослідження було здійснено на основі порівняльно-правового аналізу нормативних режимів індустріальних парків у п'яти країнах та емпіричного аналізу їх соціально-економічних і екологічних наслідків, а також аналізу супутникових даних дистанційного зондування та офіційної екологічної статистики. Концептуальний аналіз виявив послідовну еволюцію правових підходів протягом семи десятиліть від виключно економічно орієнтованих моделей 50-70-х років до комплексних правових режимів сучасності, що інтегрували принципи права, сталого розвитку та кліматичної нейтральності. Емпіричне дослідження Польщі, Німеччини, Китаю, В'єтнаму та України продемонструвало системний дисбаланс між економічними перевагами та екологічними наслідками функціонування спеціальних територіальних режимів: було зафіксовано статистично значуще зростання концентрації діоксиду азоту на 23 %, твердих частинок на 28,6 % та катастрофічне п'ятикратне збільшення біологічного споживання кисню у водних ресурсах. Водночас у Німеччині, де

добре розвинена інституційна система та налагоджений суворий екологічний контроль, було досягнуто значне скорочення викидів сірчистого ангідриду на 5 % та твердих частинок на 9 % відсотків. Було встановлено пряму кореляційну залежність між рівнем інституційної спроможності держави та ефективністю екологічного управління промисловими комплексами, а також виявлено нерівномірність розподілу соціально-економічних вигод, коли лише 23 % новостворених робочих місць у країнах, що розвиваються, дістається місцевим мешканцям. Результати підтвердили існування латентного конфлікту між привілейованим правовим режимом індустріальних парків та фундаментальними принципами правової рівності й екологічної справедливості, однак довели можливість його розв'язання через збалансовані нормативні зміни, включаючи інтеграцію зеленої умовності в систему економічних стимулів та запровадження механізмів кумулятивної відповідальності

Ключові слова: адміністративно-правові засади; спеціальні правові режими; екологічна справедливість; сталий розвиток; правові принципи організації та функціонування індустріальних парків