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Sustainability of industrial construction in the context of development life cycles of industrial parks

The authors address the sustainable construction of industrial parks (IP) in the process of its development. Towards this end, they simulate the life cycles of their operation. To accelerate the development of industrial infrastructure and ensure the competitiveness of its industrial potential in the age of economic turbulence, a model of environmentally friendly industrial development is proposed.
The research hypothesis is formulated as the implementation and management of sustainable industrial construction in the segment of industrial parks as a contemporary type of industrial parks (IPs). The following items were used as the main sustainability indicators of high-performance development systems applied to the industrial construction of industrial parks: construction intensity; the cumulative consumption of resources; the duration of local stages in the life cycle of the industrial construction of IPs; the reduction in the labour costs at the junction of cooperative relationships; the business continuity of the industrial construction of IPs within the framework of an ecologically friendly development system; the adaptability of the life cycle of a managing company to external conditions; the system of tax incentives in IPs and their transformation potential and efficiency; the sophistication of logistic and transport infrastructures of IPs; the efficiency of life cycle of business projects developed by the residents of Ips, patterns of public-private partnerships, and the life cycles of ecologically friendly industrial development of IPs.
A high demand for the development of current theoretical and practical approaches to high-performance industrial construction of industrial parks predetermines the relevance of this area of research. The evolvement of the IP market allows to establish the national industrial infrastructure to ensure the accelerated launch of competitive business projects. In this regard, models of industrial development of the innovative segment of industrial construction become a tool of state control focused on augmenting the country's competitive industrial potential and, hence, they assume high nation-wide importance for the national economy.
The research objective. The develop methodological approaches and practical recommendations for simulating the life cycles of industrial parks, the accelerated reproduction of their real estate based on the models of ecologically friendly industrial development and sustainable growth.
The object of research. The evolving national market of industrial parks as a special innovative market segment of construction focused on the accelerated and high-capacity industrial construction of IPs.
Results. An update of the problematic modernization of the industrial construction market of industrial parks as an innovative segment of the construction market in a turbulent economy; generalization of domestic and international experience in the field of sustainable development of territories based on models of eco-industrial parks, "green" construction and certification of projects; methodological author's approach to functional structuring and criteria-based assessment of managerial-engineering reliability, sustainability and efficiency of the life cycles of eco-development of industrial parks; modeling of multivariate and situational indicators of criteria-based assessment of the sustainability of the life cycles of eco-development of industrial parks.
Keywords: *industrial construction, life cycles, industrial parks, eco-industrial parks, industrial development, eco-development, organizational and technical reliability, sustainability, effectiveness, brownfield, greenfield, corporate alliance*
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INTRODUCTION

The relevance of the research is determined by the importance of identifying current trends in the industrial construction of industrial parks in Russia as an innovative segment of the construction market, and the formation of predictive measures of state regulation of accelerated high-performance industrial construction. Formation of an industrial infrastructure capable of ensuring the accelerated launch of competitive business projects involves the elaboration of models of sustainable industrial development. IP industrial construction should be considered as a kind of national strategy to accelerate the socio-economic national development.

The IP industrial construction market can be identified as a special variety of professional activity of a property developer. In this case, a specialized corporate target alliance of participants is formed as a system of business partners with the main performers — the management organization. It attracts to the partner alliance the residents, construction, logistics, transport, operational, service, resource companies and state as well as municipal authorities. The emergent qualities of corporate business partnership in industrial construction for the creation of industrial parks are resulting from the integration of business processes for the implementation of special purpose investment projects and resident programs.

IP industrial construction should be attributed to the actively developing innovative segment of the construction market. The establishment of this segment of construction is an effective case of the national strategy of stabilization and acceleration of socio-economic industrial growth in a turbulent economy. The IP market ensures accelerated

reproduction of large industrial real estate facilities to implement investment projects and resident programs, which provides a high-speed increase in the competitive industrial potential of the regional territories. One of the significant reasons for such acceleration to ensure the industrial competitiveness of the country is the application of the management concept of the entire life cycle of IP industrial construction. Among the main goals of the management company are actual structural and functional tasks — pre-investment feasibility studies of IP construction programs and modernization of state incentive strategies, with consideration to preparatory and main periods of construction, operation, renovation and liquidation.

IP industrial construction should be considered as a variety of the national strategy to accelerate the socio-economic growth of the country. This allows to generate specialized organizational and economic mechanisms for accelerated construction and efficient operation of industrial real estate facilities of residents using the methodology of sustainable industrial development.

Special attention is required to monitor and develop functioning organizational structures of IP management based on specialized corporate alliances and organizational and economic mechanisms of their interaction in the life cycles of industrial parks development and operation. The establishment of a partnership alliance is initiated by the management company, as the executor of the state industrial acceleration policy, at all stages of the life cycle of IP industrial construction. This management body is integrated into the public-private partnership system, is established by regional state structures and is responsible both for the investment attractiveness of IP for residents and for the effectiveness of all stages of the life cycle, that is, the final efficiency of the entire partner business system of the industrial park.

Clarification of the problematic situation and consideration of its essential content make it possible both to confirm the relevance of the chosen field of research, and to focus on promising managerial-engineering, economic and organizational mechanisms for improving IP industrial construction.

Research has revealed that the legal framework for the development and operation of IP is determined by the Federal Law "On Industrial Policy"[1] and by a number of Orders of the Government of the Russian Federation[2, 3] [1]. The focus on accelerated rates of industrial construction makes it possible to reduce the regulatory terms of investment cycles for the capital construction facilities two-fold, and the timing of the launch of residents' business projects and reaching their project capacity is significantly reduced compared to traditional local schemes of such construction.

The investment appeal and economic efficiency of the industrial parks projects are confirmed by the data of analytical reports provided by the Association of Industrial Parks[4]. It has been ascertained that the main trend of the Russian industrial parks market is a steady increase in their number, an increase in the number of residents, jobs and investments [2–4].

Some authors point out [5] that the economic feasibility of IP development has passed the stress test due to the pandemic period of 2020–2021, and Western sanctions against Russia related to Ukraine, but studies conducted on the number of residents and jobs in industrial parks show that, on the contrary, there is no negative dynamics.

The author's research suggests that there is a steady growth in the number of national industrial parks from 80 in 2013 to 334 in 2020. The annual growth rate of jobs is 18.4 %, resulting in an increase from 56,773 to 185,395 in 2020. A steady increase in the number of IP residents from 958 to 3,498 with an average annual growth of 20.3 % is provided. The total value of investments in industrial parks amounted to 1.6 trillion rubles in 2020, twice exceeding the statistics of 2013.

As the analysis has demonstrated, one of the most important trends in domestic and global economic development is the use of the concept of sustainable development[5]. Similar domestic sustainable development goals have been approved for Russia. This is confirmed by the report of the Analytical Center under the Government of the Russian Federation "On the goals of sustainable development of Russia" [6].

The Government of the Russian Federation has updated the priority of sustainable development on the basis of Order of the Government of the Russian Federation No. 1587 of September 21, 2021 and specific Order No. 1912 of July 14, 2021[6, 7]. Criteria in the field of financing sustainable development projects are approved here, official terminology in the field of implementation of sustainable development projects is given, the institutional state development tool — the State Development Corporation "VEB.RF" — has been approved. According to federal legislation[8], it is assigned the function of a methodological center in the field of preparation and implementation of investment projects of sustainable development with contributing of non-budgetary funds to competitive projects.

Industrial construction is a priority of sustainable development. This is confirmed by the Order of the Government of the Russian Federation No. 1912-r dated July 14, 2021[7]. No doubt, the variety of the industrial development market in the segment of the construction of industrial parks is a sphere of transformation into sustainable industrial IP construction. This circumstance determines the relevance of theoretical and practical simulation of sustainable industrial construction of industrial parks based on eco-development models.

The performed studies of the mechanisms of sustainable development [7] implementation, taking into account modern regulatory requirements of town-planning [8], prove the emergence of a new evolutionary stage in the development of industrial construction, including one via construction of industrial parks based on the simulations of eco-oriented reproduction of industrial real estate.

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1 On Industrial Policy in the Russian Federation : Federal Law of December 31, 2014 No. 488-FZ.

2 About Industrial (Industrial) Parks and Managing Companies of Industrial (Industrial) Parks : Order of the Government of the Russian Federation as of August 4, 2015 No. 794.

3 About strategic planning in the Russian Federation : Order of the Government of the Russian Federation as of October 30, 2014 No. 1119 and of August 11, 2015 No. 794, FZ-172 of June 28, 2014.

4 Association of industrial parks of Russia. URL: https://indparks.ru/upload/iblock/5b4/Blok2021_WEB_4.compressed.pdf (Accessed August 23, 2022).

5 Sustainable development goals. URL: https://www.un.org/sustainabledevelopment/ru/sustainable-development-goals/ (Accessed August 23, 2022).

6 On approval of criteria of sustainable development projects (including "green") in the Russian Federation and requirements to the system of verification of sustainable development projects (including "green") in the Russian Federation : Order of the Government of the Russian Federation as of September 21, 2021 No. 1587. URL: http://government.ru/docs/all/136742/ (Accessed August 23, 2022).

7 The national goals and the main directions of sustainable (including "green") development of the Russian Federation : Order of the Government of the Russian Federation of July 14, 2021 No. 1912-r. URL: http://government.ru/docs/42795/ (Accessed August 23, 2022).

8 About the state corporation of development "ВЭБ.РФ" amended and revised, in accordance with the Federal Law No. 332-FZ of July 2, 2021 "On amendments to certain legislative acts of the Russian Federation and recognizing void Part 11 of Article 8 of the Federal Law." On the innovation center Skolkovo : The Federal Law of May 17, 2007 No. 82-FZ. URL: http://pravo.gov.ru/proxy/ips/?docbody=&firstDoc=1&lastDoc=1&nd=602263689 (Accessed August 23, 2022).

The literature review has shown that in the IP industrial construction market segment, there is now a trend for the construction of environmentally oriented industrial parks. Among others, the paper of A.V. Dubovchenko is interesting, analyzing the subject of the development of eco-industrial parks [9], and the article by V.I. Tochka and S.V. Rantner [10] studying issues of environmental aspects of industrial park management.

The global priority of sustainability and "greenness" determines the need for the creation of models and state strategies to boost the competitive industrial potential of the country based on IP eco-development models.

This type of industrial construction market is a specialized sort of project financing and public-private partnership. It is established that modern national trends in the development of industrial potential determine the strategic vector of high-performance reproduction of industrial real estate in industrial parks as a special set of industrial investment projects and sustainable development programs.

The identification of the problematic situation updates the theoretical and practical need to improve the prevailing models of eco-evelopment of IP industrial real estate from the perspective of sustainable development projects. The task of developing industrial parks in Russia that operate on the principles of a closed-loop economy or a cyclical economy is quite justified and acceptable. This type of economic doctrine requires compliance with the principle of resource renewal based on the concept of effective waste management. A transition from a simplified procedure involving the collection, sorting and disposal of waste to a complex sustainable business system is required. It should include both the design of industrial products in industrial parks, and at the same time the renewal of production resources. The procedures of eco-industrial parks should include waste management, their cyclic processing, taking into account the projecting of the service life, the principles of waste reduction and the production of by-products. Such a business approach in the functioning of IP considers waste as a valuable secondary resource. In this regard, the experience of China [11] and the achievements of this country in the field of eco-industrial parks functioning are interesting. Traditional industrial parks do not focus on creating an industrial ecology. In eco-industrial parks, on the contrary, the activities of industrial enterprises of various industries are considered. At the same time, benefits are generated from the exchange of resources based on the closed value chains while reducing waste, reusing it and increasing environmental efficiency. The priority of such eco-IP is the use of the principles of "clean" production, industrial ecology and circular economy. It has been identified that typical eco-industrial parks of the People's Republic of China include both industrial production, research, residential and business zones, and a service area. The application of the waste management principle and the exchange of by-products are mandatory. China's waste management practice using innovative sources of financing for these types of "green" projects is very interesting. They actively attract non-budgetary resources issuing "green" bonds, loans or credit lines. China has a program National Demonstration Eco-Industrial Park, created in the early 2000s. As of 2020, there are 55 national eco-industrial parks in the country and 52 more eco-industrial parks are under development. This experience is undoubtedly interesting for implementation in Russia [12, 13].

The issues related to the development of eco-industrial parks both in Russia and abroad are the promotion of a "clean" city, "clean" territories, "clean" industries, "clean" investment projects and investment programs, as well as the intensification of the implementation of domestic and international environmental management standards in all development areas.

These prerequisites determine the need to improve the accelerated industrial construction of all types of industrial facilities, including industrial parks and industrial zones as "clean" territories, "clean" productions etc. It is this approach that should be ensured when structuring sustainable territorial business systems of IP industrial construction as a special type of models of ecological industrial development.

In Russia, this field of activity began to develop rapidly relatively recently. The need for nationwide "clean" standards in all types of activities is becoming more and more obvious every year.

The scope of problems of such "clean" sustainable development reinforces the need to model and manage the entire life cycle of IP eco-development. Currently, there is no unified eco-development assessment system neither in design, construction, nor in operation. There is also no unified legal framework for the large-scale implementation of the eco-development principles, "green" and "clean" cyclical construction in the investment and construction sector. The problematic issues of this approach include the inevitable increase in the cost of "green" industrial construction projects boosted by supplementary eco-development standards requirements. This necessarily requires new approaches to the definition of project efficiency, taking into account the "green" construction.

One of the factors restraining the development of ecological construction, including industrial, is the cost of certification. This undoubtedly increases the costs of "green" capital construction projects. Most developers in Russia do not consider these additional costs appropriate. In addition, "green" standards require the eco-friendly construction materials, which also increases the investment cost of eco-development. In this regard, stimulating the priorities of the expansion of "green", "clean" industrial construction in Russia becomes the top priority. The statement of research objectives in the field of ensuring the competitiveness of "green" construction with a circular economy, as well as competitive ecosystems of industrial construction and eco-development of industrial parks, becomes a national economic problem.

A review of the performed domestic research studies on the subject of eco-development, "green" construction [14–18], as well as foreign sources of information [19–27], indicates a profound lack of elaboration of the issues studied. The review confirms the prospects of structuring eco-oriented life cycles of sustainable industrial eco-development IP models, the relevance of assessing their value and managing this type of value, taking into account the economy of closed cycles.

Domestic practice of ecological, "green" development in our country is at the start. Whereas in such countries as the USA it occupies already 20 % of the market, and in the European countries about 15 %, in Russia it doesn't exceed 1 %. The relevance of the research is determined by the importance of identifying current trends in the industrial construction of industrial parks in Russia as an innovative segment of the construction market, and the formation of predictive measures of state regulation of accelerated high-performance industrial construction.

THEORETIC RESEARCH APPROACHES

When simulating the life cycle structure W_j of industrial park (IP) industrial construction projects in the eco-development system GD_{ip}, it is necessary to use the principles of functional system modeling. This suggests using as functional constituent of GD_{ip} a functional four-dimensional space consisting of subsystems:

1. *Firstly*, a set of specialized functions-tasks Q_o focused on the target results of ensuring integrated sustainability of both certain stages of the GD_{ip} life cycle and the entire W_j.

Various types of sets of local q_i functions form particular subsystems of the GD_{ip} eco-development, implemented at different stages T^{i-j} of the GD_{ip} life cycle. Ultimately, the integrated set of T^{i-j} forms an integral life cycle of eco-development in the form of the continuance of T_o.

In the most general form, the integral value of Q_i is equal to the sum of the local functions of q_i (1), which concurrently means the functional synthesis of an integral GD_{ip} system that strives to ensure maximum effectiveness D according to the reliability criteria s of the D_s type.

$$Q_o = \sum q_i = q_1 + q_2 + ... + q_i = f\left(GD_{ip}\right) \rightarrow D_s\left(\max\right). \quad (1)$$

The following nine basic GD_{ip} subsystems are suggested as separate local functions for the formation of GD_{ip} subsystems:

GD_{ip1} — environmental management functions for the implementation of IP eco-management, monitoring and environmental optimization of design solutions in the life cycles of T_o and development of qualification requirements of sustainability according to the GD_{ip1} criterion for their assessment implementation and optimization;

GD_{ip2} — functions of ensuring infrastructure reliability and external environment quality;

GD_{ip3} — functions of ensuring reliability in the field of architectural, space-planning and design solutions of IP;

GD_{ip4} — functions of ensuring reliability in the field of comfort (aerothermal, light, acoustic) and the indoor environment;

GD_{ip5} — functions of ensuring reliability in field of sanitary protection quality and recycling, implementation of closed cycle economy;

GD_{ip6} — functions of ensuring reliability in the field of rational water use and regulation of wastewater disposal;

GD_{ip7} — functions of ensuring reliability in the field of energy saving and energy efficiency (Reduction of heat energy consumption for heating and ventilation of building; reduction of heat energy consumption for hot water supply; reduction of electricity consumption; reduction of specific total primary energy consumption by engineering systems; use of secondary energy resources);

GD_{ip8} — functions of ensuring reliability on environmental protection in the process of industrial construction and the subsequent demolition of capital construction facilities in order to minimize the impact of materials used in construction, waste generation during construction works, as well as the implementation of measures to protect and restore the environment during construction;

GD_{ip9} — functions of ensuring the life safety in terms of providing backup infrastructure for power, water and heat supply, as well as other elements of industrial, transport, social and logistics infrastructure of IP.

The implementation of the entire set of GD_{ip1-9} tasks forms the structuring of the GD_{ip} integrated system at all stages of T_o local functional tasks of industrial eco-development.

In this study, the authors consider the implementation of particular local functional tasks. The entire set of functional tasks of GD_{ip1-9} in the process of their implementation forms the integrated sustainability of industrial IP construction in the GD_{ip} system at all stages of the IP development system life cycle.

In the criteria simulation of the local and complex efficiency of GD_{ip} sustainability processes, it is suggested to apply the methodological apparatus for the formation of sustainability effeciency through the organizational and technical reliability of GD_{ip} processes. At the same time, we also consider it necessary to use indicators to minimize the total ownership cost of a portfolio of industrial real estate, considered as part of IP for residents who may be owners and tenants.

2. *Secondly*, the research paradigm applied provides for the necessity and possibility of considering the life cycle of industrial eco-development IP as a functional and reliable system consisting of separate life cycle phases or stages of the industrial status of eco-development T^{i-j}, the sum of which forms an integral monolith T_o of the GD_{ip} life cycle. In the most general form, the entire T_o life cycle equals to the fractional sums of T_{ij}, which is shown in (2).

$$T_o = \sum T^{i-j}. \quad (2)$$

Thus, the basics of the structuring of stages and their duration within the life cycles of industrial eco-development IP are determined by the rational expediency of singling out separate T_o stages, which are formed as functions-stages responsible for a separate discrete target function of the entire T_o structuring. The number of *i-j* stages is the subject of forecasting and methodological modeling. It is suggested to simulate the structure of life cycles W_o through the singling out of local functions-stages (w^{i-j}), i.e. $W_o = \sum w^{i-j}$. Hereby:

$$T_o\left(W_o\right) = \sum\left(T^{i-j}\left(w^{i-j}\right)\right). \quad (3)$$

3. *Thirdly*, it is suggested to use eight levels of managing industrial eco-development IP (φ_{1-8}) when simulating organizational structures of sustainability regulation:

φ_1 — international level of sustainability management of industrial ecosystems of IP construction;

φ_2 — state level of sustainability management (national);

φ_3 — state level of sustainability management at the regional level of constituent entities of the Federation;

φ_4 — municipal level of sustainability management;

φ_5 — level of sustainability management of individual specialized IP projects;

φ_6 — level of sustainability management of IP withing the framework of special economic zones;

φ_7 — procedural sustainability management of IP based on corporate, national and international standards;

φ_8 — sustainability management as the expanding eco-development system based on business partnership and integrated initiatives;

φ_9 — business process level of sustainability management of IP investment projects.

4. *Fourthly*, the spatial-temporal functional organization of IP reproduction processes in industrial eco-construction requires singling out of a special functional type of capital construction facilities in the form of territorial specialized systems by types of cluster portfolios of reproducible industrial real estate (Ω^x). This is predetermined by the specialization of IP residents' activities and the targeted territorial specialization of the IP themselves.

The presented four-component elements of the research paradigm of theoretical and practical simulations of methodological approaches and recommendations for structuring the life cycles of accelerated industrial construction and the efficient functioning of industrial parks based on sustainable eco-development model, allowed us to develop a fundamental functional GD_{ip} model. The authors define it as an integral dynamically adaptive structure composed of consolidated interacting local functional-target subsystems presented in formula (4), controlled by four main criteria of mini-max:

$$GD_{ip}(W_o) = \left[\left[(Q_o) \cap (W_o) \cap (\varphi_{1-8})\right] \cap \left[\left(w^{i-j}\right) \cap \left(\Omega^x\right)\right]\right] \rightarrow \left(E_{ij}^{nm};\ E_{PDij}^{sf};\ R_{pd}^{m}\right) \rightarrow \left(C_{own}^{\min}\right), \quad (4)$$

where E_{ij}^{nm} — the organizational and economic reliability of W_o life cycles of IP industrial construction indicator that demonstrates a maximizing tendency; E_{PDij}^{sf} — the organizational and economic reliability of operation of an industrial eco-development system indicator that demonstrates a maximizing tendency; R_{pd}^{m} — the overall GD_{ip} sustainability performance indicator that demonstrates a maximizing tendency; $C_{own}^{\min}$ — total cost of ownership of industrial real estate for IP residents' indicator that demonstrates a minimizing tendency.

Thus, taking into account the formulated research paradigm, it is determined that to simulate the structure of the life cycle stages of an industrial eco-development W_o type IP, it is necessary to identify four target functional subsystems GD_{ip}:

- sustainability function-task Q_o;
- functions-stages w^{i-j} on structuring common life cycles — W_o;
- functional-stages of sustainability management — φ_{1-8};
- the functional types reproduced a cluster-portfolios of the industrial real estate Ω_x.

The quantitative assessment of the criteria applied to organizational and economic reliability of GD_{ip} life cycles is methodically defined by the authors as the extent of mutual compliance between key investment and construction decisions consistently designed by both the IP management company and residents at various stages of the GD_{ip} life cycle. Other criteria assessments were also accomplished within the framework of the initiative study and are based on existing methodological approaches to their calculation, with view of the specifics of the subject of study. To determine the integral values of organizational and technical reliability, sustainability and efficiency, the authors used the *T.* Saati method and the theory of reliability. Within the framework of this approach, an appropriate methodological apparatus has been worked out for the quantitative assessment of all accepted criteria of GD_{ip} functioning.

The authors' methodological approaches represent their research position, do not pretend to be complete and are intended for further testing and elaboration.

RESULTS

One of the particular results of the study is the implementation of conceptual clarifications in relation to the accepted subject of research. In the most general form, it is proposed to identify the concept of industrial eco-development of industrial parks as a system of professional activity in the field of accelerated high-performance industrial construction, consisting of a specialized management company and residents involved in public-private partnership, with targeted activities based on sustainability functions-tasks, functions-stages of structuring life cycles, functional levels of sustainability management and functional cluster portfolios of reproducible industrial real estate facilities, regulated by indicators of reliability, sustainability, performance and cost of ownership.

IP industrial eco-development models allow for accelerated industrial construction and the establishment of corporate target alliances of business partners (residents, management company, construction, logistics, transport, operational, etc. companies) united by the process of ecological and sustainable reproduction of industrial land and property real estate complexes.

At the same time the target criteria for the efficient accelerated industrial construction of large complex industrial facilities in IP are the maximum ecological and economic efficiency, productivity, reliability at a minimum total cost of the industrial real estate ownership for various residents.

The most important trends of the national market for the construction of industrial parks features a steady increase in this market segment with an average annual growth of about 23 % per year over last 8 years. At the same time industrial parks were established in 66 regions, which means a twofold increase compared to 2013.

It's a fact that the market capacity of the national market of industrial construction of IP increased from 789 billion rubles in 2013 to 1,700 billion rubles in 2021 featuring a total growth index of 2.1 times for this period and an average growth index of 14.2 % per year.

The steady trend of development of industrial parks is also backed by both growth in the number of jobs, and total area of industrial parks in operation. The analysis shows that the number of jobs rose from 16,315 in 2013 to 41,627 in 2020 with average annual growth rate of about 20 %. Also, the total areas of existing parks demonstrate an average annual increase of 24 %. It grew from 56,773 ha in 2013 to 165,395 ha in last year.

A study of industrial parks by their types showed that in Russia there is a predominant development of industrial parks of the greenfield type — it is about 60 %.

Most industrial parks are private in Russia (about 70 %). The efficiency of IP investments is in line with the ratio of infrastructural costs to production investments that equals 1 to 10.

The study of statistic data proves the success of the national market of industrial parks. It is assumed that its current growth may be limited to 310, and this number will meet the current demand for this type of industrial construction.

Moreover, a promising trend in the development of IP is the development of ecological industrial parks in Russia, functioning on the principles of a closed-loop economy. For these purposes, it is necessary to elaborate a special national standard and test it in one of the Russian regions.

When adding the life cycle sustainability indicator to the GD_{ip} structuring methodology, authors pilot-tested it at Severny Almaz industrial park in the East Siberian region at the early stages of its design.

It is assumed that GD_{ip} performance and the mini-max criterion adherence can ensure the maximally efficient sustainable accelerated industrial construction of IP. It means that efficiency, reliability, integral sustainability is maximized, and cost of ownership of industrial real estate in IP is minimized for residents. For initial testing, the authors focused on the criteria of organizational and economic reliability of life cycles as variety of the sustainability index GD_{ip}.

When calculating the organizational and economic reliability of the life cycle of industrial eco-development IP, calculations are made at various stages of W_o. At the same time, the unit indices of the E_{ij}^{nm} of the GD_{ip} system at the final stage of commissioning W^{V} always dissipate (decrease) compared to the unit base value at the zero stage. Four stages are used in calculations — from the stage of prospective preparation of industrial construction IP W^{I}, land development IP W^{II}, investment and construction development IP W^{III} to the operational development IP cycle W^{V}.

As a methodological basis for E_{ij}^{nm} calculations related to the life cycles of industrial construction, indicators of the intensity of construction and installation works are calculated with regard to their mutual correspondence (I–II–III–IV). The correspondences

system was defined via 2 components. Firstly, through indicators of the terms of construction *T*. Secondly, through the indicators of the value of investments *V*. The obtained values can be illustrated by the following calculations with L^{O}_{rel} system (III–II) data:

$$E^{nm}_{ij}[T] = \{T(0)[W^{I}] = 5.25\ years\} / \{T(0)[W^{III}] = 7.75\ years\} = 0.72;$$

$$E^{nm}_{ij}[V] = (V(0)[W^{I}]\} / \{V(0)[W^{III}]) = 0.85;$$

$$E^{nmO}_{ij}[W^{I-III}] = 0.72 \cdot 0.85 = 0.61.$$

Thus, the reliability according to the indicator of organizational and economic reliability for the first stage of the construction life cycle of the Severny Almaz industrial park in terms of construction intensity was 0.61.

Additionally, the integral efficiency of GD_{ip} was calculated using the T. Saati method, a synthesis of seven local subsystems: organizational and economic reliability of construction in GD_{ip}; business activity; potential capacity; innovation; system performance; profitability; environmental potential of IP investment projects. Eventually, the final efficiency of P_{pd} for the first stage of industrial construction was estimated at 2.822, which is illustrated by the formula (5):

$$R^{norm}_{PD(t)} = 0.9 \cdot 1.1 \cdot 1.2 \cdot 1.1 \cdot 1.8 \cdot 1.25 = 2.822. \quad (5)$$

According to the calculations, the actual complex efficiency was 2.912, which confirms the efficiency of GD_{ip} management.

The pilot-testing of this technique is experimental and incomplete due to problems in collecting some data. The interpretation of the obtained results and the essence of the methodology require further elaboration and doesn't aspire to be complete.

DISCUSSIONS

The research has proven the relevancy and complexity of theoretical and practical task to simulate the development of the national market of industrial construction of IP from the viewpoint of eco-development and sustainable development. In this regard, this diversity determines the multiplicity of the evolution of the methodological approach.

Debatable issues are the following.

1. The relevance of updates in the field of national standards applicable to ecological industrial parks and the corresponding models of eco-development IP. It is also necessary to provide for the upgrade of industrial parks in operation into the ecological ones using a closed-loop economy.
2. The need to upgrade GD_{ip} models corresponding to four types of industrial parks: a private park of greenfield type; a private park of Brownfield type; state park of greenfield type; a state park of Brownfield type; mixed models.
3. The application of the theory of organizational and technical reliability and efficiency of the industrial construction IP life cycles requires further adjustments from the modeling positions in GD_{ip} of its individual subsystems and the mechanism of their integrative synthesis in a single indicator.
4. Performance indicators of the ecological and economic efficiency of the IP cyclical economy, as well as the relevance of the formation of specific models of efficiency and productivity, require update at the national and international level of standards for the verification of industrial construction to assess the “greenness”, reliability and integrated sustainability of IP life cycles.
5. We assume that a promising area of research is the need for more detailed studies on the theory of the ownership cost of industrial real estate for IP residents in the early pre-investment phases of the feasibility study of industrial parks construction.

The controversial issues mentioned in this article reflect only a small part of the problems of the development of IP industrial construction management methodologies. The authors express confidence that these studies will provide an opportunity to develop a creative approach for all interested parties to the issues in focus.

CONCLUSIONS

The research conducted has proven the importance of studying issues of the industrial construction development of industrial parks based on simulating life cycles of their functioning as sustainable models of industrial development. This will ensure accelerated development of industrial infrastructure in order to create competitive industrial potential in a turbulent economy. Perfecting the industrial parks market allows to establish national industrial infrastructure ensuring the accelerated start of competitive business projects. In this regard, studies on modelling government tools to regulate the growth of competitive industrial potential of the country, gain high national economic significance.

The author's vision of the national market of industrial parks growth is proposed, the author's methodology of eco-industrial development is elaborated. This enables to identify potential for accelerated industrial construction of IP. Undoubtedly, the establishment of corporate target alliances of business partners (residents, management company, construction, logistics, transport, operational, etc. companies) united by the process of ecological and sustainable development will ensure stabilization of national economy in the context of present-day challenges.

The studies performed made it possible to specify the concept of industrial eco-development of industrial parks as a system of professional activity for accelerated and high-performance sustainable industrial construction. We consider very perspective to model activity of a specialized management company, residents and public-private partnership system based on sustainability functions-tasks, functions-stages of structuring life cycles, functional levels of sustainability management and functional cluster portfolios of reproducible industrial real estate, regulated by integral indicators sustainability and cost of ownership.

It is quite evident that author's vision of sustainable development enables to generate an additional eco-development value chain for the state regulating systems, managing companies and resident investors who would benefit from the accelerated construction of large industrial real estate facilities featuring the environmental priority of cyclic economy.

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Устойчивость промышленного строительства в жизненных циклах девелопмента индустриальных парков

Исследована проблематика устойчивого развития промышленного строительства индустриальных парков (ИП) на основе моделирования жизненных циклов их функционирования. С целью ускоренного формирования промышленной инфраструктуры для создания конкурентоспособного промышленного потенциала в условиях турбулентной экономики предложена модель промышленного экологического девелопмента.

Научная гипотеза исследования — создание и управление устойчивым промышленным строительством по сегменту индустриальных парков как современная разновидность ИП. В качестве основных индикаторов устойчивости высокопроизводительных девелоперских систем промышленного строительства ИП приняты: интенсивность строительства; уровень потребления совокупных ресурсов; продолжительность локальных этапов жизненного цикла промышленногостроительстваИП;сокращениетрудозатратнастыках кооперированных связей; уровень устойчивости функционирования промышленного строительства ИП в системе экодевелопмента; адаптивность функционирования жизненного цикла управляющей компании к внешним условиям; наличие системы налоговых преференций в ИП; степень развитости логистических и транспортных инфраструктур ИП; результативность жизненных циклов бизнес-проектов резидентов ИП и моделей государственно-частного партнерства, и жизненных циклов промышленного экодевелопмента IP.

Актуальность данной области исследований предопределяется значительной востребованностью проблематики развития действующих научно-практических подходов в области высокопроизводительного промышленного строительства индустриальных парков. Формирование рынка индустриальных парков позволяет создавать национальную промышленную инфраструктуру, которая обеспечивает ускоренный запуск конкурентоспособных бизнес-проектов. В этой связи, модели промышленного девелопмента инновационного сегмента промышленного строительства являются инструментарием государственного регулирования по наращиванию конкурентоспособного промышленного потенциала страны, таким образом приобретают высокую народнохозяйственную значимость.

Цель исследования. Разработка методических подходов и практических рекомендаций по моделированию жизненных циклов ускоренного промышленного строительства и эффективного функционирования индустриальных парков на основе моделей устойчивого экологического девелопмента.

Объект исследования. Развивающийся национальный рынок индустриальных парков как особый инновационный сегмент строительства, ориентированный на ускоренное и высокопроизводительное промышленное строительство ИП.

Результаты. Актуализация проблемной модернизации рынка промышленного строительства индустриальных парков как инновационного сегмента строительного рынка в условиях турбулентной экономики; обобщение отечественного и зарубежного опыта в области устойчивого развития территорий на основе моделей экологических индустриальных парков и систем зеленого строительства и сертификации проектов; методический авторский подход по функциональной структуризации и критериальной оценке организационно-технической надежности, устойчивости и результативности жизненных циклов экологического девелопмента индустриальных парков; моделирование многовариантных и ситуационных показателей критериальной оценки устойчивости жизненных циклов экологического девелопмента индустриальных парков.

Ключевые слова: *промышленное строительство, жизненные циклы, индустриальные парки, эко-индустриальные парки, промышленный девелопмент, экологический девелопмент, организационно-техническая надежность, устойчивость, результативность, вторичная застройка, строительство «с нуля», корпоративный альянс*

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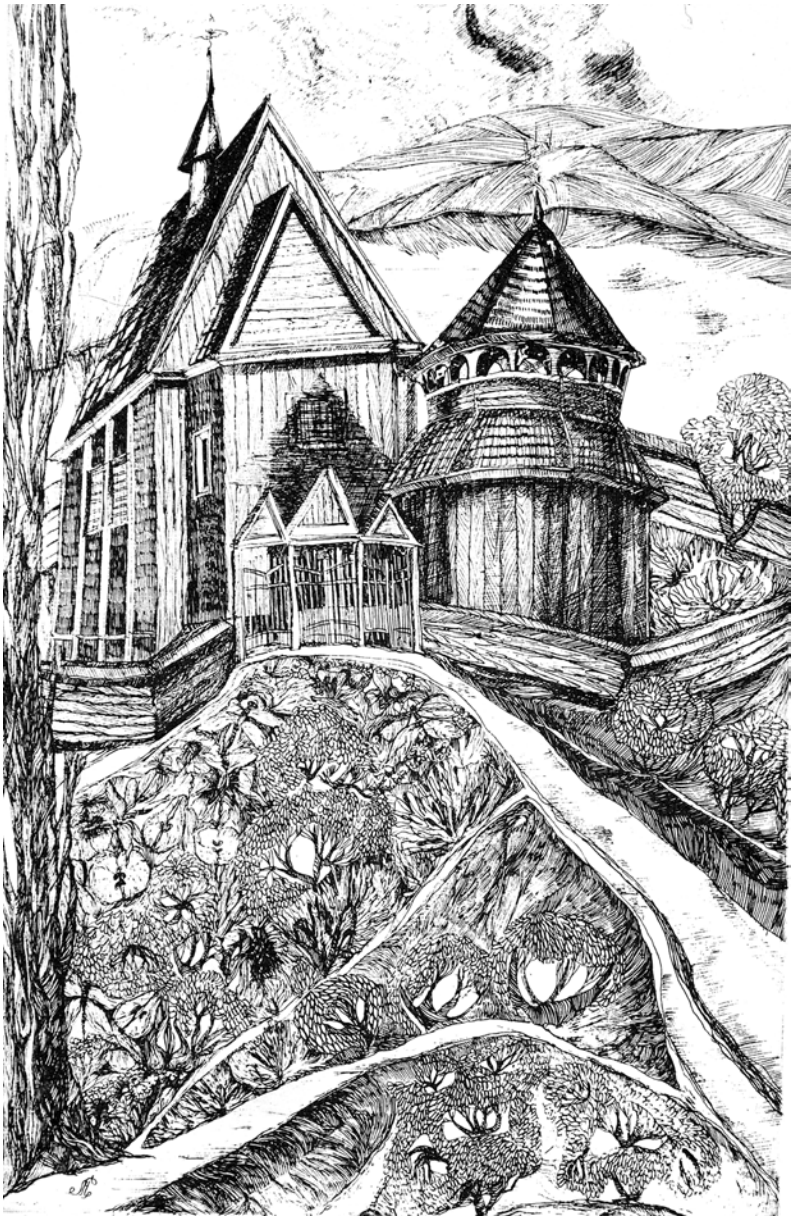

Л.И. Павлова. Игналина. Деревянная церковь. Офорт.