



Environmental transformation in post-industrial urban contexts: An analysis of urban development models in Belarus

Vera Sysoyeva¹, Olga Sysoyeva², Polina Vardevanyan³

ABSTRACT:

This study investigates the environmental transformation of post-industrial cities in Belarus by developing and evaluating spatial models that integrate ecological principles into urban planning processes. The research identifies critical challenges associated with this transformation through case studies of Baranovichi, Soligorsk, and Zelva. The paper introduces diagnostic and modeling frameworks designed to assess urban ecosystems, delineate contact zones, and improve the integration between natural and built environments. Particular emphasis is placed on the redevelopment of industrial zones and specifically coastal areas, using linear, perpendicular, and nodal planning models that facilitate the implementation of green infrastructure, biodiversity preservation, and the adaptive reuse of industrial land. The findings demonstrate how environmentally oriented spatial restructuring can enhance resource efficiency, mitigate environmental impacts, and foster the emergence of new urban identities. The proposed models offer practical tools to advance sustainable development initiatives within post-industrial urban settings.

KEYWORDS:

environmental transformation; post-industrial city; urban model

1. Introduction

As previously observed, the ecological structuring of urban environments serves to strengthen their distinctive urban identity [1]. In this context, environmental transformations in post-industrial cities serve as key catalysts for the sustainable development of urban areas in Belarus. The investigation and implementation of environmental transformations in urban settings are essential for facilitating the emergence of a new economic structure based on the principles of the green economy. This includes the development and application of green urban planning strategies, circular economy practices, sustainable transportation systems, clean energy provision, and the integration of underutilized or inefficiently used properties into the economic cycle [2]. The challenges associated with developing such models in the Belarusian context arise from a limited and superficial examination of strategic and tactical green economy issues at the municipal level. Furthermore, innovative approaches aimed at improving quality of life are often developed and implemented in a fragmented manner, lacking robust interdisciplinary collaboration. An analysis of the revised regulatory framework governing urban planning procedures in Belarus indicates a continued reliance on methodologies characteristic of the industrial

¹ Belarusian National Technical University, Department of Urban Planning, prosp. Niezalezności 65, Minsk, Belarus, e-mail: vera.sysoyeva@gmail.com, orcid id: 0000-0001-8386-1567

² Belarusian National Technical University, Department of Architecture of Production Facilities and Architectural Structures, prosp. Niezalezności 65, Minsk, Belarus, e-mail: poak.af@bntu.by

³ Belarusian National Technical University, Department of Urban Planning, prosp. Niezalezności 65, Minsk, Belarus, e-mail: vard_p@mail.ru

development era. For instance, strategic planning documents frequently depict cities merely as points on a map or as entries in a list of planned investment projects, reflecting a limited and outdated conceptualization of urban spaces.

2. A multi-tiered approach to urban environmental transformation

2.1. Diagnostic evaluation

In Belarus, urban planning has evolved beyond a solely theoretical comprehension of the socio-economic processes linked to post-industrial urbanization. It is acknowledged that formulating a universal model for environmental transformation is unfeasible due to the heterogeneous nature of urban planning contexts. Nonetheless, the imperative for urban planning reforms aimed at enhancing living environments in alignment with green urban planning principles is pertinent to the majority of Belarusian urban settlements, which confront environmentally detrimental conditions. A system of models has been devised to typify Belarusian cities that have entered the post-industrial development stage. For the purpose of modeling environmental transformations, specific cities and urban areas were selected as prototypes, wherein infrastructural changes receive financial support intended to foster qualitative improvements and fulfill investment priorities. Additionally, these areas distinctly manifest characteristic morphotypes of planning and development [3].

The first category comprises cities with substantial potential for sustainable socio-economic development, including Minsk and regional centers. The second category encompasses cities with populations exceeding 80,000 and industrial centers within regions specializing in industrial and agro-industrial sectors. In these cities, the adoption of advanced information and communication technologies is being encouraged to elevate the quality of life. The third category consists of satellite cities, which are evolving into integral components of large urban agglomerations. The fourth category includes over thirty settlements confronting challenges related to intensifying the utilization of local resources, developing competencies, attracting investment in new industries grounded in the technological foundations of the green economy, and expanding the service sector, particularly agro-ecotourism. These settlements are characterized by negative population growth and demographic aging. Furthermore, eleven of these settlements were impacted by the Chernobyl disaster, which imposes constraints on their socio-economic development potential. To address pressing issues, most lagging regional centers implement "soft" urban planning measures focused on sustainable development, emphasizing the enhancement of environmental education.

2.2. Modeling

The ecological transformation of post-industrial urban areas was examined through case studies of three cities: Baranovichi, Soligorsk, and Zelva. Two distinct models were constructed grounded in current urban planning principles and landscape zoning frameworks. Model "A" delineates the configuration of the natural and ecological contact zone (Fig. 1a), whereas Model "B" identifies the morphotypes of development that constitute the urban ecological framework, differing in their levels of ecological transformation activity (Fig. 1b).

The examination of the spatial characteristics within the regional and urban contexts of the prototype cities facilitated the identification of zones exhibiting environmental stress as well as areas with potential for growth, particularly at their interfaces. The delineation of these contact zones corresponds to natural features and regulatory boundaries governing urban planning activities, including street setback lines, railway branches, and land use designations (Table 1). The insights derived from this analysis are instrumental in refining local spatial development strategies aimed at fostering a "high-tech" natural environment at the intersection with urban framework components.

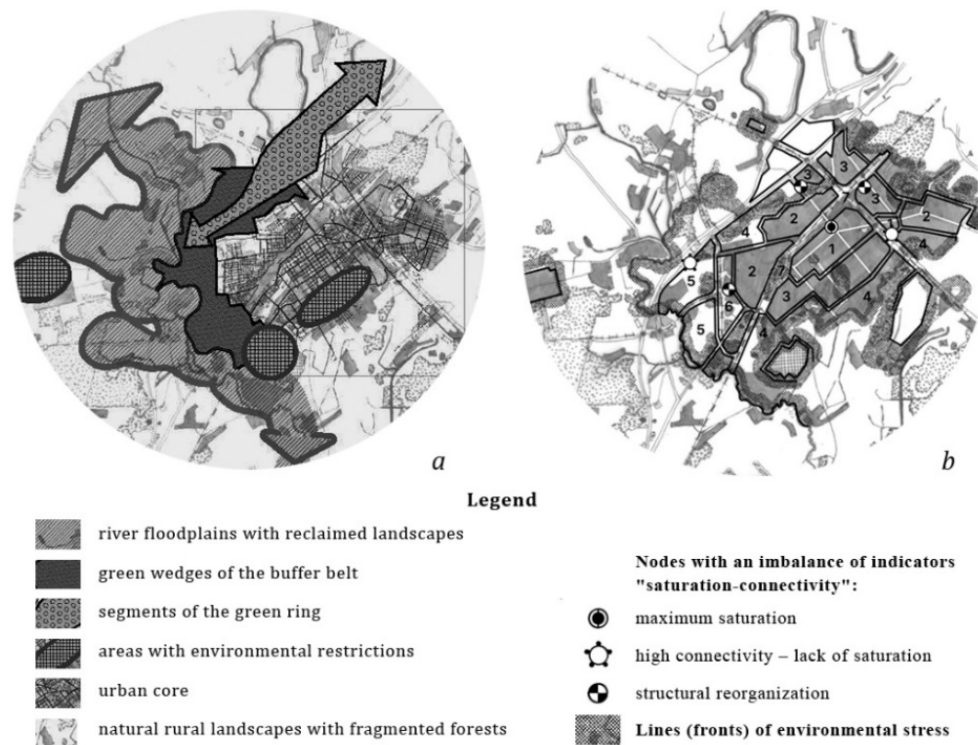


Fig. 1. Models of environmental transformation in the city of Baranovichi: a) Structural model of the natural and ecological contact zone, b) Configuration of urban fabric, nodes, and zones within the urban ecological framework

2.3. Features of the environmental transformation of industrial areas

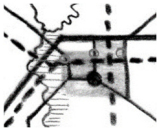
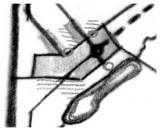
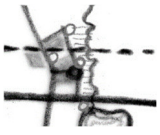
Industrial zones in Belarusian cities pose a significant challenge to urban environmental transformation due to their extensive spatial footprint and the ecological burdens they impose on the city. These factors contribute to broader urban-scale environmental issues. The environmental rehabilitation of industrial areas can be approached through two primary strategies: first, the modernization of technological processes and the upgrading of production engineering infrastructure – emphasizing principles such as the green circular economy, waste-free production, and efficient treatment facilities; second, the architectural and planning reconfiguration of the spatial structure and development patterns within these industrial zones. Within the framework of New Industrial Urbanism, these strategies correspond to the concepts of "reinventing" and the "formation of hybrid districts" [4]. In the context of Belarus, these objectives are pursued through specific architectural and planning interventions aimed at the ecological rehabilitation of existing industrial areas, including modifying the direction and density of pollutant emissions; reorganizing transport and pedestrian flows to minimize unnecessary harmful emissions from freight vehicles; implementing measures to increase development density; employing landscape architecture to mitigate production hazards and facilitate climatic adaptation (the use of shelterbelts, green spaces, water bodies, eco-friendly surface materials, and lawns); and altering functional zoning to relocate more environmentally detrimental facilities deeper within the territory, thereby reducing the extent of sanitary protection zones.

New developments within these areas should adhere to principles of multi-scalar design, modularity, and multifunctionality, offering diverse spatial configurations to accommodate various

forms of use and activities. This approach is exemplified by the Light-Industrial Innovation Cluster project located on the site of the track facilities in the Gromy district of Polotsk (Fig. 2).

Table 1

Lines (fronts) of environmental tension and points of potential growth within the contact zones of regional and urban frameworks in prototype cities

Urban case city	Structural and functional model of the city	Spatial features of the regional and urban frameworks
<p>Baranovichi serves as a model city upon which the rapid development of regional areas is contingent</p>		<p>An escalation of environmental stress is anticipated in areas where the urban fabric is integrated within the buffer zone of the regional framework. The primary urban center corresponds to nodes exhibiting extreme saturation; therefore, it necessitates a more complex spatial configuration and development. Structural reorganization and densification efforts will require the establishment of public spaces characterized by moderate saturation and cohesion, which serve as zones of active transformation.</p>
<p>Soligorsk represents a prototype of single-industry cities in Belarus that have initiated a transition towards a "green" economy, emphasizing the ecological restoration of degraded sites</p>		<p>Environmental pressures are projected to intensify in regions where sprawling suburban settlements intersect with networks of shallow watercourses and the natural core of the regional framework, namely forested areas. A central hub that, despite possessing comprehensive connectivity, suffers from insufficient functional and population density, requires reinforcement through the support of centers specializing in unique functions.</p>
<p>Zelva exemplifies an urban settlement confronted with the challenge of industrialization grounded in new technological foundations, alongside the advancement of the service sector, particularly agro-ecotourism</p>		<p>The zone of environmental tension extends across a broad strip of riparian territories. To restore ecological equilibrium within the mosaic structure of the urban fabric, the implementation of a multi-core system of public spaces is recommended.</p>

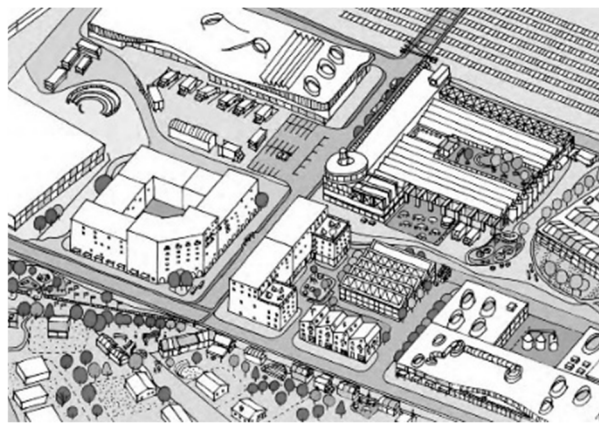


Fig. 2. The Light-Industrial Innovation Cluster project in the Gromy district of Polotsk (UNDP-Belarus Project "Green Cities")

An alternative strategy is necessary for the environmental transformation of industrial zones, some of which are characterized by abandoned, deteriorating facilities of defunct enterprises or extensive undeveloped land parcels. It is advisable to explore innovative "green" solutions by subdividing large plots; and implementing a phased removal of these areas from industrial zoning regulations, followed by targeted brownfield redevelopment.

The complexity associated with the development and reconstruction of many dormant industrial sites stems from their relative spatial isolation from external transportation and pedestrian networks. Frequently, new functions are introduced primarily along the periphery of these underutilized territories, which further constrains opportunities to mitigate their adverse environmental impacts. Consequently, it is imperative to identify strategies to actively integrate such areas into urban development and reconstruction initiatives, thereby addressing challenges related to the ecological revitalization of urban spaces.

Several architectural and planning methodologies are proposed for industrial area environmental rehabilitation, including:

- integration within the city's spatial structure and ecological framework,
- increasing the complexity of the planning layout by enhancing diversity, permeability, and functional efficiency through the introduction of new streets,
- establishing activity hubs and fostering connectivity among them,
- promoting a diversity of functional uses [5],
- achieving a balance between natural and built environments to create a distinctive and aesthetically coherent urban landscape.

The particular characteristics of industrial zones in the coastal areas of Belarusian cities present challenges not only from an ecological perspective but also in meeting stringent architectural requirements. Therefore, the ecological transformation of coastal industrial areas necessitates an integrated approach that encompasses architectural, planning, and spatial reorganization considerations. In response, proposed transformation models account for the unique features of the planning structure and industrial development patterns:

- "The linear model" entails the establishment of a green belt along the coastline. This approach facilitates the restoration of the beneficial sanitary effects of a green corridor within the urban environment and is particularly recommended for application in the city's transitional zones. Implementation requires the removal of dilapidated structures, including engineering facilities, garages, and warehouses, which should be relocated deeper into the industrial district. This relocation would enable the creation of a more architecturally and publicly appealing frontage for the industrial quarter. The linear model also integrates pedestrian green pathways into the broader pedestrian network of the city. This model is extensively applicable in Belarusian cities, where a "soft form" of connecting coastal areas to water bodies is prevalent. Such natural shoreline configurations support the preservation of high biodiversity levels and contribute to an aesthetically pleasing natural environment. Moreover, this model aids in the climatic adaptation of urban areas, as the green strip serves as a buffer against potential fluctuations in water levels.
- "The perpendicular model" involves the creation of green gaps within building structures that extend perpendicularly to the coastline. This model is particularly suitable for central urban areas where environmental concerns must be addressed while preserving historically significant industrial buildings. These green interruptions are designed as recreational spaces enriched with public amenities.
- "The nodal model" focuses on the development of planning nodes at locations of pedestrian and transport bridges. Its implementation can facilitate the creation of attractive urban centers, promote the emergence of functionally diverse complexes, and encourage active utilization of transit zones between coastal areas. In applying the nodal model, certain industrial and public facilities occupying unattractive buildings or situated far from transport and pedestrian routes may be relocated along the coastline. This strategy enhances both the spatial organization and environmental quality of the coastal zone. An example is presented in Figure 3, which depicts

a public area project. The proposal includes the construction of a multifunctional complex intended to serve as a focal planning and compositional node.

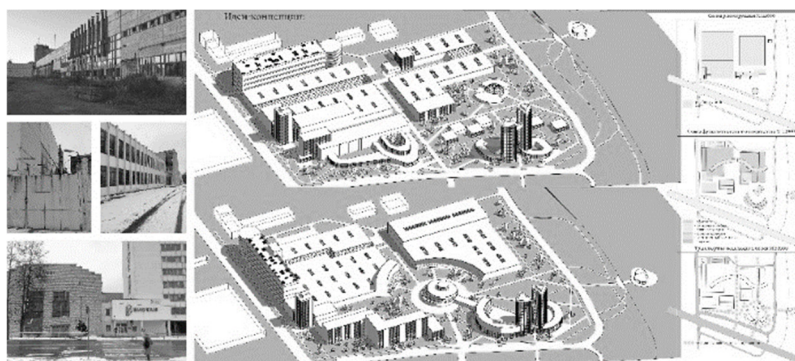


Fig. 3. Vistan Plant Reconstruction Project (Vitebsk)

3. Conclusions

The determination of strategic directions for the long-term development of post-industrial urban territories constitutes a complex and multifaceted process, wherein the environmental factor plays a pivotal role. It is posited that only through an integrated approach to developmental transformation, which comprehensively addresses urban planning, social, architectural, and spatial dimensions, can an optimal "green city" environment be achieved. The implementation of a comprehensive set of proposed environmental transformation measures, alongside diverse initiatives within the "green" economy sector in Belarusian regions, is expected to enhance the efficiency of natural resource utilization and alleviate ecological pressures, thereby contributing to improved living conditions and the overall environmental quality.

References

- [1] Fücks R., *Intelligent wachsen: Die grüne Revolution*, Carl Hanser Verlag GmbH & Co. KG, 2013.
- [2] *National Strategy for Sustainable Development of the Republic of Belarus until 2035*, Publication of Ministry of Economy of the Republic of Belarus, 2021.
- [3] Vashkevich V., Sysoyeva V., *Urban planning tools for the transformation of residential development in Minsk*, *Architecture and Construction* 2024, 6.
- [4] Hatuka T., Ben-Joseph E., *New Industrial Urbanism*, Routledge, New York 2022.
- [5] Rappaport N., *Hybrid Factory – Hybrid City*, *Built Environment* 2017, 1, 43.

Transformacja środowiskowa w kontekście miast przemysłowych: analiza modeli rozwoju urbanistycznego na Białorusi

STRESZCZENIE:

Dokonano analizy transformacji środowiskowej miast przemysłowych na Białorusi poprzez opracowanie i ocenę modeli przestrzennych, które integrują zasady ekologiczne z procesami planowania urbanistycznego. Badanie identyfikuje kluczowe wyzwania związane z tą transformacją na podstawie studiów przypadków Baranowicz, Soligorska i Żelwy. W artykule przedstawiono ramy diagnostyczne i modelowe przeznaczone do oceny ekosystemów miejskich, wyznaczenia stref kontaktowych oraz poprawy integracji między środowiskiem naturalnym a zbudowanym. Szczególny nacisk położono na rewitalizację terenów przemysłowych, zwłaszcza obszarów nadwodnych, z wykorzystaniem modeli planistycznych o układzie liniowym, prostopadłym i węzłowym, które wspierają wdrażanie zielonej infrastruktury, ochronę bioróżnorodności i adaptacyjne ponowne wykorzystanie terenów przemysłowych. Wyniki badań pokazują, że środowiskowo zorientowana restrukturyzacja przestrzenna może zwiększyć efektywność wykorzystania zasobów, ograniczyć

negatywny wpływ na środowisko oraz sprzyjać powstawaniu nowych tożsamości miejskich. Zaproponowane modele stanowią praktyczne narzędzie wspierające wdrażanie inicjatyw zrównoważonego rozwoju w kontekście miast przemysłowych.

SŁOWA KLUCZOWE:

transformacja środowiskowa; miasto przemysłowe; model urbanistyczny