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INNOVATIVE METHODS USED IN THE RENOVATION OF INDUSTRIAL BUILDINGS IN MODERN CITIES

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Abstract. The article explores innovative methods used in the renovation of industrial buildings and areas in modern cities, addressing the challenges posed by rapid urbanization. The author found that the modern renovation of industrial buildings in cities is a key factor in sustainable development, aimed at integrating historical architectural heritage into the new urban structure. It has been established that the use of innovative methods and technologies, such as building information modelling (BIM), adaptive reuse, artificial intelligence and green technologies, contributes to the formation of multifunctional and environmentally balanced urban environments. Scientific research confirms the advisability of combining interdisciplinary architectural, urban, social, and technological approaches in the reconstruction of industrial facilities. A SWOT analysis of two industrial zone renovation projects in Odessa was conducted, which revealed the advantages and risks of transforming industrial areas into residential and public-business functions. The author have proven that intelligent technologies increase the accuracy of analytical assessments, reduce research time and strengthen the validity of design decisions. The use of AI in comparative analysis has demonstrated its effectiveness in assessing the environmental, architectural, artistic and social aspects of projects. It has been established that innovative renovation methods provide a harmonious combination of cultural, economic and environmental components, contributing to the formation of adaptive, inclusive and sustainable urban spaces. International examples illustrate successful transformations, demonstrating the potential of industrial reconstruction to enhance economic growth, social integration and environmental sustainability. The results of the study confirm that the renovation of industrial areas using modern technologies is not only an architectural but also a socio-cultural process that defines a new paradigm for urban development in the post-industrial era.

Keywords: active house, city, industrial area, industrial building, innovative methods, reconstruction, renovation.

Introduction. Rapid urbanization is forcing cities to adapt old industrial areas, integrating them into the modern urban environment for sustainable development. Studies show the positive impact of renovation on the economy, social environment and ecology of cities. In Ukraine, many cities shaped by industrial development face unique challenges in their transition to a post-industrial society. As industrial facilities become obsolete, these areas often turn into isolated, economically depressed zones, negatively affecting the image and economic attractiveness of the city.

The decline of industry has also led to the emergence of neglected architectural spaces that are out of harmony with residential areas, highlighting the urgent need for renovation. Adaptive reuse, BIM technologies and the use of artificial intelligence can help to analyze in detail, the actual condition of architectural objects, identify strengths and weaknesses, and subsequently modernize buildings and infrastructure, increase their energy efficiency, improve living comfort and reduce environmental impact. In addition, smart technologies and green solutions ensure efficient use of resources and reduce the carbon footprint. The use of sustainability certifications and innovative

technologies promotes an integrated approach that transforms industrial areas into functionally modern, environmentally responsible and socially beneficial spaces.

Analysis of recent studies and publications. Many contemporary scientists and architects are engaged in researching innovative methods for renovating industrial buildings. Among Ukrainian specialists who are making a significant contribution to the development of the theory and practice of industrial building renovation, offering innovative solutions for integrating historical objects into the modern urban context, we can mention such figures as Y. Senkovska, Y. Haiko, O. Popova and others. Research by Ukrainian architects and scientists examines the features of the development of industrial architecture in Odesa [1]. In addition, the studies by Urenev V.P. and Dmytryk N.O. on the architectural transformation of industrial heritage for new functions [2] and the assessment of factors influencing on the formation of multifunctional complexes under conditions of renovation of industrial facilities [3] are of great importance. Kharytonova A.A., Goldina M.V. and Belova O.V. researched the current trend in contemporary architecture regarding the reindustrialization and gentrification industrial territories of the cities [4].

German architects who have contributed to research in this field should also be noted, in particular Jan R. Krause, professor at the Department of Architectural Media Management (AMM) at the Bochum University of Applied Sciences. Krause, who focuses on contemporary formats of architectural communication, the use of artificial intelligence and modern technologies in architecture [5] in his teaching and research work, and German architects Dietmar Danner and Friedrich H. Dassler, who emphasize the importance of integrating active facades and green technologies. Cornelia Ninaus, a researcher on the implementation of research projects in the field of innovative and sustainable building renovation, digitalization, zero-energy and plus-energy construction, and scientist Christian Hofstadler in their article ‘Methods and Tools to Support On-Site Knowledge Management in Infrastructure Projects’ (2020) explore what is important for contemporary architectural and urban planning research, including in renovation processes. In this paper, the authors consider methods of digital knowledge management at construction sites based on the integration of BIM technologies, intelligent databases, and communication systems between designers, contractors, and operators [6].

However, most studies are conducted within a single discipline, which limits their applicability. As P. Dubrovsky notes, an interdisciplinary approach allows for more comprehensive solutions for the renovation of industrial areas [7]. According to a 2020 report by the German Association of Urbanists, social inclusion is crucial for successful urban renovation, but is often underestimated in academic circles. Recent architectural research in the field of industrial area renovation has significant potential, but also needs improvement to become more comprehensive, socially sensitive and technologically adaptive. The active use of innovative technologies will enable more effective and sustainable renovation projects.

Problem statement.

In 2022, with the emergence and spread of artificial intelligence technologies in the professional architectural world, search and analysis methods were forever changed, accelerating and optimizing the design process. This phenomenon at the current stage of scientific development is the subject of much debate and special study. And although most scientists and researchers believe that ‘academic circles face some very serious problems,’ the practical significance of this phenomenon for the professional community is indisputable proof that modern technologies and innovations not only play an important role but also have undeniable practical value.

The goal is to justify the importance of using innovative methods in the renovation of industrial buildings, based on research into the causes and comparison of means and results, clarifying their place and role in modern design.

Materials and methods. This study is based on a comprehensive approach that allows for a more thorough analysis of innovative methods for restoring industrial buildings. The following methods were used in the study:

- Method of analyzing scientific literature and recent research to determine the stages of development and evolution of industrial facility reconstruction technologies.

- Visual observation and field survey of research objects for more detailed identification of key trends in the reconstruction of industrial facilities.
- A comparative analysis method for comparing architectural solutions of different objects, identifying common features, differences and innovative techniques that help take restoration practice to a new level.

Visual observation and preparation of photo documentation. Analysis of literature and Internet resources helped to determine the location of the research objects. Several objects were selected for this study, the study of which helped to identify the main methods of modern renovation and deepen the range of innovative technologies used in the renovation of industrial buildings. Field surveys and photographic documentation of the objects allowed us to clearly see the detailed technologies, legal frameworks, and differences in approaches to renovation. Photographs of the objects are attached to the article.

Descriptive and comparative analysis of objects. Comparative analysis of architectural and design documentation (master plans and planning decisions) and photographs of objects made it possible to compare renovation techniques and methods in order to identify patterns in selected innovative solutions for further sustainable development and adaptation of buildings to modern needs. This will contribute to the development of industrial areas and make them economically attractive for investment and the introduction of energy-efficient technologies.

Results and discussion.

Renovation of industrial facilities in the context of sustainable urban development.

The world is urbanizing at an unprecedented rate, with more than half of the world's population living in cities. Although urbanization opens up many opportunities, rapidly expanding cities face many challenges. The current state of Ukraine's industrial cities is characterized by problems associated with society's transition to the post-industrial period. Many industrial facilities are ceasing to exist, resulting in their transformation into depressed areas isolated from the social environment of the city. The decline of city-forming enterprises, neglected industrial sites, and the lack of architectural and aesthetic connection with residential areas negatively affect both the image and competitiveness of the city. Renovation involves giving industrial facilities a new non-productive function and ensuring their adaptation to the modern urban environment. In addition to the economic efficiency of using existing industrial buildings, renovation is a means of preserving the historical fabric of the city and solving the aesthetic and ethical problems of old industrial facilities [8]. Innovative approaches to industrial development are extremely relevant in the context of contemporary urban development. They not only contribute to economic growth and social development, but also ensure environmental sustainability and the preservation of cultural heritage. These aspects make renovation an essential part of strategic planning in modern cities striving for sustainable development. Cities must take advantage of opportunities to increase sustainability. Given population growth, rapid urbanization and the effects of climate change, it is clear that cities will need to adopt innovative approaches in the future to meet the growing needs of their residents. Cities can and must become hubs of innovation and drivers of economic growth, where jobs are created, economies develop and resources are used efficiently. Our decisions on how to build, populate and maintain cities will have long-term global consequences [9].

New approaches to the renovation of industrial zones.

One of the key aspects of renovation is the creation of infrastructure that meets modern environmental standards and the needs of the city. This may include modernizing the water supply system, improving the energy efficiency of buildings, using renewable energy sources and introducing environmentally friendly technologies [10]. In general, the renovation of industrial areas and their adaptation to the modern urban environment are complex tasks that require a comprehensive approach and cooperation between government agencies, NGOs, businesses, and local residents. The results of such projects can be significant in terms of sustainable urban development and improving the quality of life of their residents [11]. Many facilities no longer meet the needs of modern lifestyles or the requirements of technological progress and environmental sustainability [12]. Recent studies emphasize the importance of stimulating innovation and

technological development in the process of industrial area renovation. The introduction of new technologies, environmental solutions and the creation of innovation clusters contributes to the creation of competitive and sustainable industrial areas. Innovative methods for renovating industrial buildings in modern cities include a range of approaches, practices and technologies that not only contribute to the restoration and transformation of industrial areas, but also facilitate their proper adaptation into functional, modern and attractive spaces. The latest technologies, which are becoming an increasingly integral part of architectural reality, offer architects and scientists new technological methods that need to be implemented in their research and design practice. In 1987, Norwegian Prime Minister Gro Harlem Brundtland delivered a report entitled 'Our Common Future' to the UN Assembly, in which she expressed the view that the sustainable use of natural resources should meet the needs of the present generation 'without compromising the ability of future generations to meet their own needs' [13]. Since then, the term 'sustainability' has become part of everyday language. This concept plays an important role in the field of architecture and construction. How exactly can we mitigate the impact of construction during the life cycle and demolition of buildings? A sustainable building, in its design, construction and operation, should reduce or eliminate negative impacts overall and may even have a positive impact on the climate and the environment, while conserving resources and improving quality of life. It is easy and even tempting to say that a house is sustainable. But how can sustainable construction be achieved? The first step is to turn to innovative methods which will be discussed below.

Transformation of industrial zones: urban development technologies.

One of the key modern methods in architecture in general, and in the reconstruction of industrial areas in particular, is the use of intelligent technologies. Today, no project can be developed without involving BIM technology in the design process. Building information modelling technology is the construction of a three-dimensional virtual model of a building in digital form which contains complete information about the future object. The use of BIM technology in building design involves the collection and comprehensive processing of technological, architectural, design and economic information about the building so that the building and everything related to it is considered as a single entity. BIM is a common knowledge resource for obtaining information about an object, which serves as the basis for decision-making throughout its life cycle, from the very first concept to demolition. The effects of using this technology include: a 40% reduction in the likelihood of errors and inaccuracies in project documentation compared to traditional design methods, a 20-50% acceleration of the design process, a sixfold acceleration of project verification, a 90% reduction in project coordination and approval time, a fourfold reduction in budget errors during planning, savings of up to 50% in the investment phase of the project, a 20-50% reduction in construction time, and a 30% reduction in construction and operating costs [14]. The integration of other smart technologies into renovation, such as IoT (Internet of Things) and automated building management systems (BMS), can increase the efficiency of industrial facilities. These technologies can optimize energy consumption, improve safety and create comfortable conditions for users.

In addition, artificial intelligence (AI) is used on a daily basis in architectural projects for the renovation of industrial areas. The architecture and construction sectors face strict regulation which slows down their digitalization compared to other industries. Most often in architecture, and in particular in projects for the renovation of industrial buildings and territories, Artificial Intelligence is used for SWOT-analysis of projects, performing initial economic calculations to justify the feasibility of projects, creating sketches, searching for forms, analyzing plans, working on visualizations, printing volumetric models, etc.

Let us verify the assumption by conducting an AI SWOT analysis where the objects of study were two options for renovating the industrial zone: the first is a residential complex with services (Fig. 1), and the second is a multifunctional business center (Fig. 2). This approach allowed us to identify key aspects of architectural and planning solutions, environmental feasibility, aesthetic and functional characteristics, as well as the potential for development of the territory.

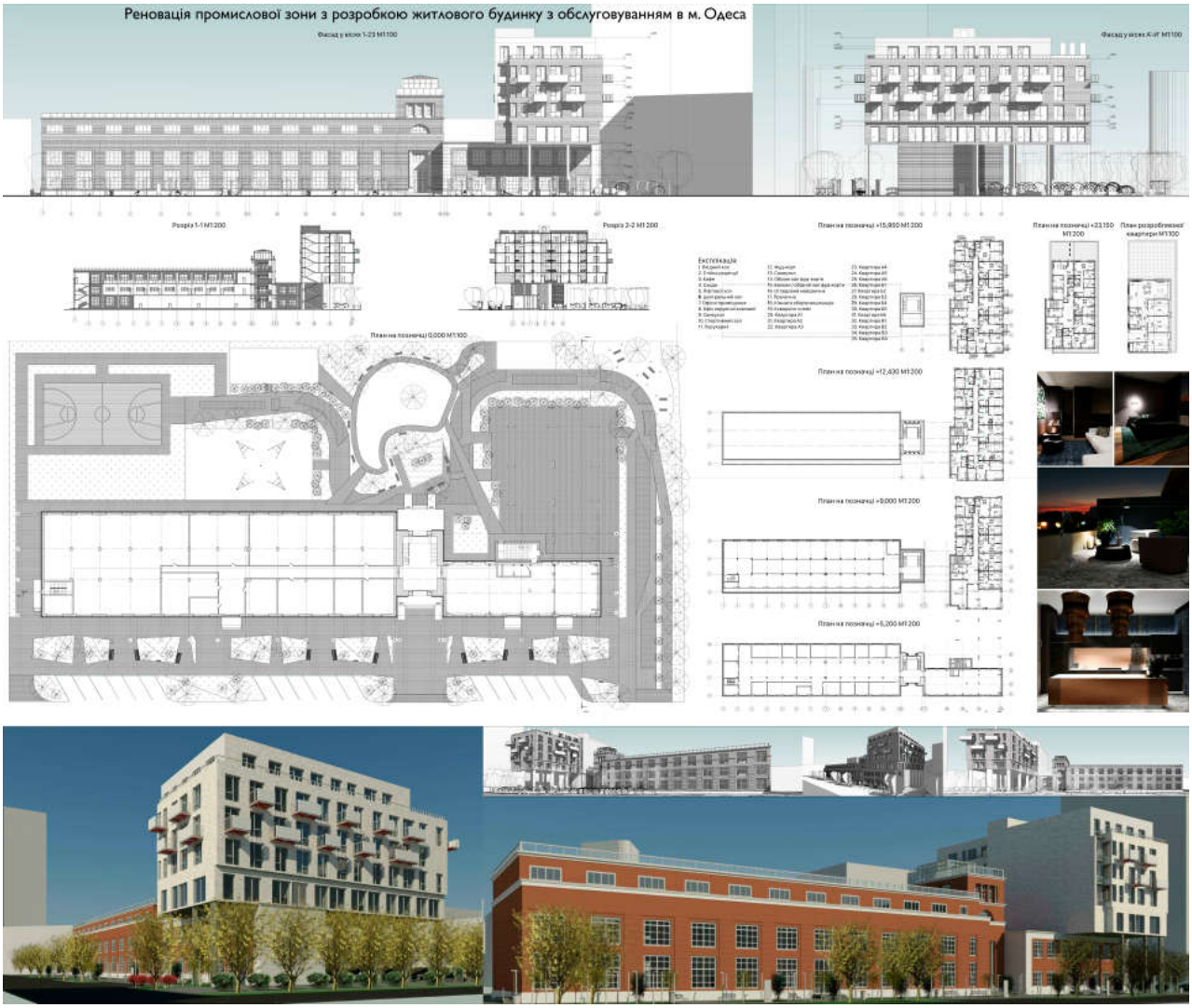

Fig. 1. Renovation project for an industrial zone with the development of a serviced residential building in Odesa. [Author: Shapovalov M., 2020]

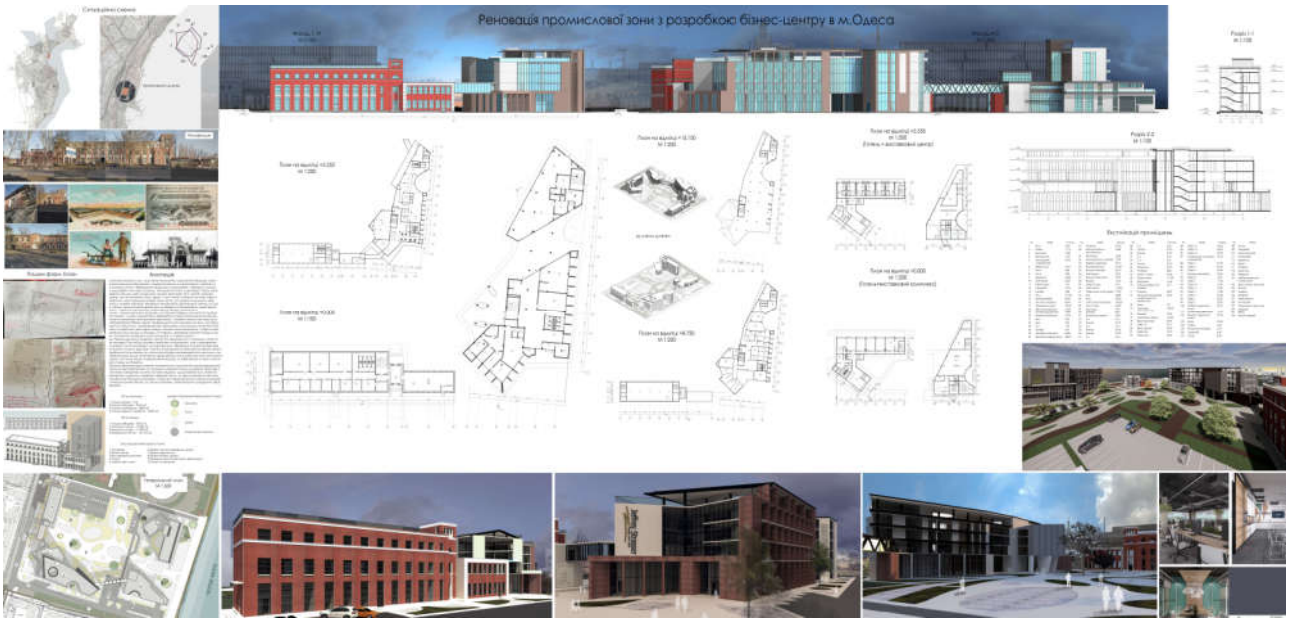

Fig. 2. Renovation project for an industrial zone with the development of a business center in Odesa. [Author: Shapovalov M., 2022]

SWOT-analysis provides an opportunity to assess the current situation and strategic prospects. This method is effective when conducting an initial assessment of the current situation and allows for a detailed study of the external and internal environment. SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats, which can be represented visually [15].

Accordingly, the most common type of artificial intelligence today, ChatGPT, was used to conduct this analysis. It was given specific parameters to assess the feasibility of projects, their functional stability, environmental friendliness, social integration, and the preservation of architectural heritage.

The collected and analyzed factual material allows us to illustrate and conclude that residential renovation has strengths in creating a comfortable living environment, integrating the natural landscape, implementing the principles of biophilic design, and using energy-efficient technologies. (Fig. 3). The main challenges remain the adaptation of existing structures to residential functions, ensuring regulatory levels of sunlight and sound insulation, and optimizing space for the modern needs of residents. In the context of public-business renovation, the advantages are identified in increasing the investment attractiveness of the territory, preserving the historical appearance of the facades, and creating points of urban activity, cultural, educational, and business clusters. Among the threats, the possible loss of local identity due to excessive commercialization and the risks of disrupting the architectural balance between old and new buildings have been identified.

A comparative analysis showed that effective renovation is only possible if environmental, architectural, artistic, and socio-economic aspects are harmoniously combined. Innovative methods identified in the study include adaptive reuse of structures, digital modelling of the environment (BIM technologies), integration of renewable energy sources, modular planning, use of local environmentally friendly materials and creation of open public spaces as elements of “soft” renovation.

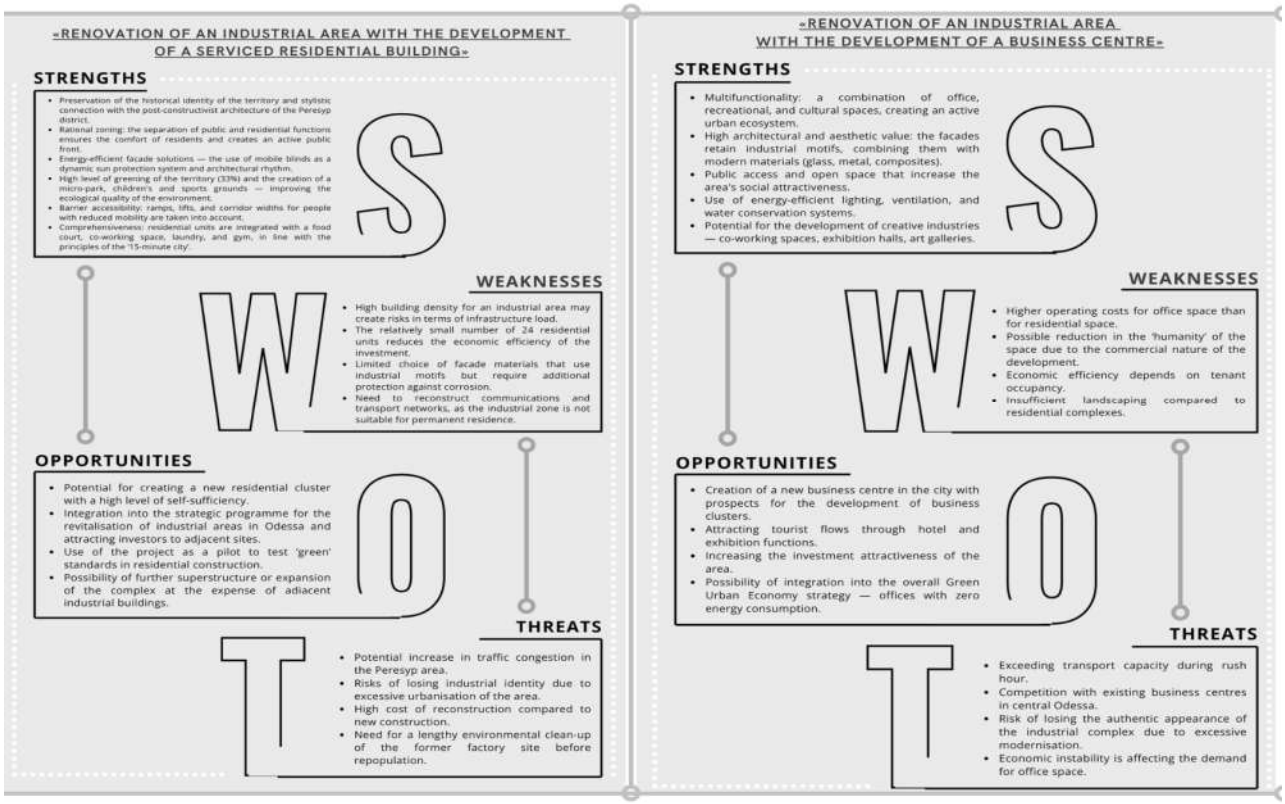

Fig. 3. Comparative analytical conclusion: analysis of renovation projects in the industrial zone. [Author: Shapovalov M., 2025]

The use of artificial intelligence (AI) technologies, in particular GPT-type analytical algorithms, played a special role in conducting this analysis. These algorithms allow for the systematization and interpretation of large amounts of information, optimization of the comparative analysis process, and identification of interrelationships between the environmental, structural, and aesthetic parameters of projects. The use of such tools increases the accuracy of assessment, reduces the time spent on analytical stages, and contributes to the adoption of scientifically sound design decisions. In the context of architectural design, this creates the conditions for the formation of a new research culture, where AI technologies become not only an auxiliary tool but also a full-fledged element of analytical methodology.Among other things, according to the Bundes Architekten Kammer, there are a number of plugins and software solutions that can already be used in architecture and are applied to specific planning tasks [16]. The following applications of artificial intelligence technologies in planning already exist or are under development:

- Text generators for research, tenders, public relations, etc.;
- Image generators for finding ideas, designing, visualizing, etc.;
- AI for modelling and optimization (analysis of climate, lighting, wind, transport, energy balance, etc.);
- AI for creating options (facades, floor plans, etc.) and technical and economic justifications (analysis of space potential, cost estimates, etc.);
- AI for inventory and model creation;
- AI for loss assessment and risk prediction;
- AI for monitoring and documentation during construction;
- AI in construction robotics (production, assembly, measurement, etc.);
- AI in reviewing plans and obtaining building permits;
- AI in building automation for optimizing operations.

In addition to general image generation tools such as Midjourney, Dall-E, Dreamstudio, and Invoke, there are interesting developments focused on architecture, such as Archivinci, Corbu, LookX, and Vitruvius. Wherever data serves as the basis for architectural planning, there are incredibly powerful artificial intelligence tools. For example, Giraffe for urban planning, Plan4Better for site analysis, Syte for property valuation, Urbanistic, Spacio and Snaptrude for designing architectural ensembles, notes architect and professor Jan R. Krause [17]. Another architect, urbanist and associate professor at the Free University of Bolzano, Mustapha El Moussaoui, in his research article on the use of AI in architectural practice, gives examples of several interesting AI programs that are directly applicable to the renovation of industrial facilities. For example, the Maket application uses advanced artificial intelligence algorithms to understand project constraints at the pre-design stage, allowing users to specify the size of the land, the building and the desired distance between rooms, and quickly switch between 2D and 3D models. During the architectural design analysis stage, tools such as Digital Blue Foam facilitate sun and wind studies, allowing designers to create and download reports containing critical information for the project [18]. This flexibility allows you to create floor plans that meet the requirements of the project. The generative capabilities of artificial intelligence allow users to quickly test concepts, creating thousands of design options in the early stages within minutes. This feature is especially valuable for exploring different architectural solutions and selecting the best option for the project vision.

Among other practical methods, green technologies should also be mentioned – the introduction of energy-efficient systems, the use of solar panels and green roofs, which help to reduce energy costs and optimize energy consumption. In 2016, the Active House standardization and labelling system was launched, and project verifiers were trained to educate and advise planners, architects and designers on creating buildings that are healthy for people and the planet. The Active House standard is an architectural unit that provides a healthier and more comfortable microclimate for residents without negatively impacting the climate, as measured by energy consumption, fresh water use, and the use of environmentally friendly materials. It is a holistic approach to building design that has been adopted by the construction industry, architects and

designers. The principles and specifications have been applied to many types of buildings: single-family and multi-family residential buildings, social housing, offices, schools, stadiums, etc. The results and feedback have shown many positive effects from following these principles, creating buildings that are reliably efficient and very comfortable in all seasons and can be used for many generations. The projects were implemented in different climate zones and covered both new construction and renovation – the RenovActive project was introduced to confirm the financial viability of renovation. The renovation concept is based on the principles of the seven most applicable and cost-effective renovation solutions. Each part consists of a building element designed to enable existing buildings to function at the same level as new buildings. Depending on the existing building structure and the renovation budget, various elements can be implemented to increase daylight levels, improve ventilation, strengthen the building envelope and expand living space through sealing or extension. The modularity of the concept allows it to be adapted to any type of building (Fig. 4). An interesting project is an international school in the port area, whose building is covered with 12,000 solar panels, each of which is positioned separately to create a sparkling effect, providing more than half of the school's annual electricity consumption. The solar panels cover a total area of 6,048 square meters, making it one of the largest integrated solar power plants in Denmark, estimated to produce over 200 MWh per year.

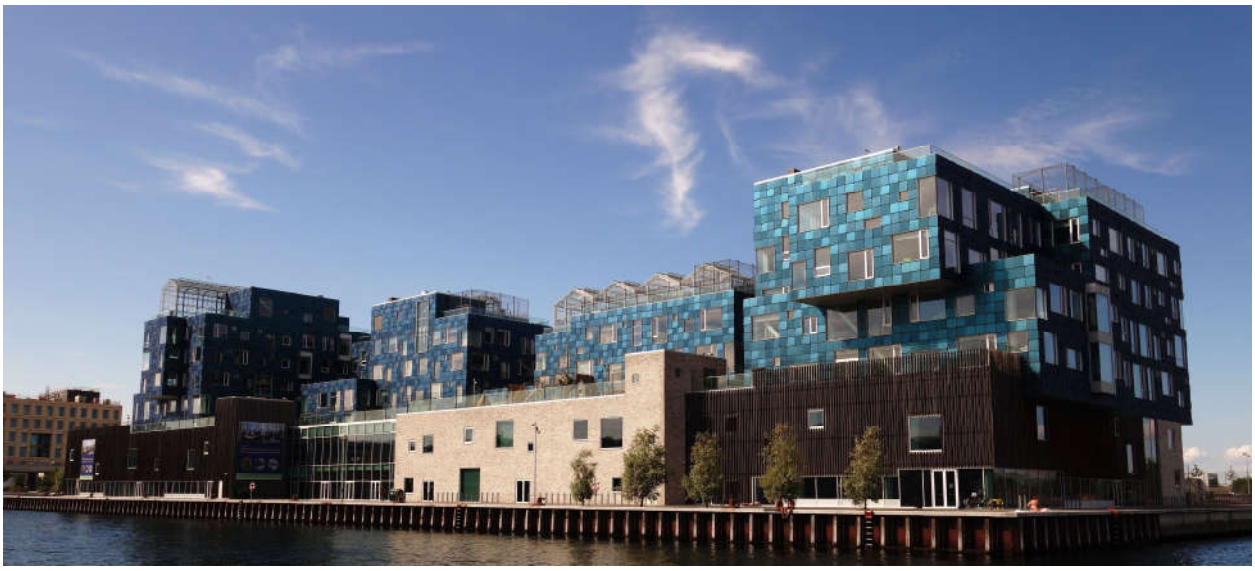

Fig. 4. Unique facade of the school building. International school, Copenhagen, Denmark. [Source: photo by Jens Cederskjold, 2022]

The next key method is adaptive reuse. This method applies to architectural and organizational solutions as well as methods of working with building materials. Adaptive reuse preserves the authentic architectural forms and structures of objects, integrating them into new functional applications. This enhances the cultural and social value of such objects, contributing to both their revitalization and the improvement of the urban environment. It involves changes in functional purpose, typology and aesthetic appearance, but preserves the basic structural elements, reducing costs and environmental impact by minimizing new construction work. The basic concept of reuse involves preserving the authentic structural elements of the building. These include original load-bearing structures such as frames, beams, columns and other structural elements, often made of metal or concrete, typical of industrial architecture. Preserving these elements not only reduces demolition and restoration costs, but also preserves the ‘historical memory’ of the building. Structures usually undergo a process of modernization, i.e., upgrading elements to meet current safety and durability requirements, for example by strengthening structures or adding modern engineering systems.

In adaptive reuse, the ability to change the interior space to suit new functions is particularly important. The large open plans of old factory buildings give architects and designers a high degree of freedom when designing new interior spaces. They can be easily adapted for office space, creative clusters, exhibition areas or even housing. Modular partitions are commonly used, allowing the configuration of the space to be changed without significant structural alterations. Facade renovations may include cleaning or restoring materials such as brick, emphasizing the authenticity of the building. In some cases, facades are combined with new architectural solutions, creating a contrast between the historical structure and modern additions. An example of the most popular and successful adaptive use in the reconstruction of an industrial area is the Vienna Gasometer — old gas tanks integrated into a new residential and office complex in the late 1990s. Each of the four gas tanks not only received a unique architectural image but also functional content, while retaining their original shape and partial structure. In terms of functional equipment, they were divided into three functions: residential, office, and entertainment and retail (Fig. 5, Fig. 6).

Fig. 5. North-east facade of the Gasometer, Vienna, Austria. [Source: photo by M. Shapovalov, 2024]

Fig. 6. Southwest facade of the Gasometer, Vienna, Austria. [Source: photo by M. Shapovalov, 2024]

According to the data, innovative methods of industrial facility reconstruction are now not only theoretically and scientifically sound requirements for sustainable design, but also part of the certification requirements. Over the past 30 years, several building sustainability certificates have been created. Using independent and objective assessments from various sources, they seek to verify the sustainable aspects of any building. Each of them relates to specific elements of the building and, as a rule, focuses on specific regions of the world. Some certificates confirm whether a building meets certain performance criteria, while others create different classifications by assigning points based on these assessments. It is known that buildings consume about 40% of the world's energy, emit 40% of global carbon emissions and use about 20% of the world's available drinking water. Transforming civil construction into an industry with less environmental impact through higher efficiency, better materials and more conscious choices is an extremely important task worldwide.

Conclusions. Thus, the goal of innovation is to promote positive change and progress in various aspects of design, architecture, and construction. This involves the creation, development, and implementation of new ideas and technologies, methods, products, or processes that improve existing ones or introduce entirely new concepts. Innovative methods of industrial site renovation involve rethinking and integrating industrial facilities and their territories while preserving architectural authenticity and properly returning these facilities and their territories to the history of the modern city. They require the integration of knowledge from various disciplines: architecture, urban planning, sociology, computer technology, ecology and economics.

It should be noted that innovative methods have significant potential, but also need to be improved to become more comprehensive, socially sensitive and technologically adaptive. This will enable more effective and sustainable industrial area renovation projects in modern cities. Ultimately, innovation in this context is not limited to technological progress, but encompasses broader cultural and urban transformation. This requires a rethinking of values, openness to experimentation, and a willingness to challenge traditional planning models. It is important to involve local communities in the reconstruction, to respect the multi-layered history of the place and to be able to anticipate the future needs of a diverse and changing urban population. When applied thoughtfully, innovative approaches can transform neglected industrial areas into vibrant, multifunctional urban environments that serve as models of sustainability and inclusiveness. In this way, innovation becomes not just a tool for development, but a vital means of shaping more humane, adaptive and forward-looking cities.

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ІННОВАЦІЙНІ МЕТОДИ, ЯКІ ВИКОРИСТОВУЮТЬСЯ ПРИ РЕНОВАЦІЇ ПРОМИСЛОВИХ БУДІВЕЛЬ У СУЧАСНИХ МІСТАХ

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[1] Одеська державна академія будівництва та архітектури

Анотація. У статті досліджуються інноваційні методи, які використовуються при реновації промислових будівель та районів у сучасних містах, що дозволяють вирішити проблеми, пов'язані зі швидкою урбанізацією.

Автором виявлено, що сучасна реновація промислових будівель у містах є ключовим чинником сталого розвитку, спрямованим на інтеграцію історичної архітектурної спадщини у нову міську структуру. Встановлено, що використання інноваційних методів і технологій, таких як інформаційне моделювання будівель (BIM), адаптивне повторне використання, штучний інтелект і «зелені» технології, сприяє формуванню багатофункціональних і екологічно збалансованих міських середовищ. Наукові дослідження підтверджують доцільність поєднання міждисциплінарних архітектурних, урбаністичних, соціальних та технологічних підходів у реконструкції промислових об'єктів.

Автором здійснено SWOT-аналіз двох проектів реновації промислових зон м. Одеси, що дозволив виявити переваги та ризики трансформацій промислових територій під житлову і громадсько-ділову функції. Доведено, що інтелектуальні технології підвищують точність аналітичних оцінок, скорочують час дослідження і підсилюють обґрунтованість проектних рішень. Використання ШІ у порівняльному аналізі продемонструвало його ефективність для оцінки екологічних, архітектурно-художніх і соціальних аспектів проектів. Установлено, що інноваційні методи реновації забезпечують гармонійне поєднання культурних, економічних та екологічних складових, сприяючи формуванню адаптивних, інклюзивних і сталих міських просторів. Міжнародні приклади ілюструють успішні перетворення, демонструючи потенціал промислової реконструкції для посилення економічного зростання, соціальної інтеграції та екологічної стійкості.

Результати дослідження підтверджують, що реновація промислових територій із застосуванням сучасних технологій є не лише архітектурним, а й соціокультурним процесом, який визначає нову парадигму розвитку міст у постіндустріальну епоху.

Ключові слова: активний будинок, місто, промислова зона, промислова будівля, інноваційні методи, реконструкція, реновація.

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