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PRINCIPLES OF IMPROVEMENT OF VOLUME-SPATIAL SOLUTIONS OF INDUSTRIAL FACILITIES DURING RENOVATION FOR RESIDENTIAL BUILDINGS

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Annotation. The article analyzes the main scientific and practical methods for renovating industrial facilities for residential use, focusing on volumetric and spatial solutions. These methods are examined through classical and innovative approaches to address outdated infrastructure and spatial compositions that no longer meet contemporary ergonomic and functional standards. The study emphasizes adapting former industrial facilities to modern residential requirements while improving energy efficiency and environmental sustainability. Special attention is given to optimal transformation techniques that ensure effective renovation while enhancing urban quality. The integration of these renovated structures into the urban fabric supports sustainable development, considering socio-economic factors and preserving architectural heritage. A key aspect of these projects is resolving architectural deficiencies that characterize obsolete structures. The primary objective is to create a more harmonious environment by modernizing industrial facilities and incorporating new functions aligned with contemporary urban demands. Refunctionalization involves reconfiguring volumetric and spatial solutions and introducing modernized floor plans to improve compliance with living standards and increase functionality. This process maintains urban identity while addressing the growing demand for real estate in central and near-central areas. The principles of transformation preserving original structures, implementing strategic minimal interventions, and undertaking complete redevelopment where necessary are examined for their effectiveness in creating functional, energy-efficient, and aesthetically cohesive residential environments. Ultimately, the research highlights how applying these methods ensures the sustainable integration of renovated industrial facilities into modern urban landscapes. This allows them to retain historical significance while aligning with contemporary architectural, social, and environmental standards. The study confirms the importance of an interdisciplinary approach, combining architecture, urban planning, and sustainable design principles to optimize the use of former industrial spaces for residential purposes.

Keywords: industrial facility, volumetric and spatial solutions, residential facility, renovation, adaptation.

Relevance of the study. Renovation and technical re-equipment of certain industrial facilities is a serious problem not only from the point of view of economics, but also of architecture. Industrial development, performing a structure-forming function, actively influences the formation of the architectural appearance of cities. The physical condition of buildings and structures, architectural and aesthetic qualities of industrial facilities, the negative impact of obsolete equipment and technologies on the environment leads to certain contradictions between production and the modern city. Often such problems are proposed to be solved by liquidating industrial production facilities or simply abandoning them. At the same time, social and economic advantages of such territories are lost due to their location in the city structure. Industrial facilities are always interconnected with residential areas. In their absence, the uniqueness of the existing architectural environment is disturbed. Industrial suburbs, infrastructure and buildings in a state of decommissioning should no longer be considered waste, but a resource with which to open up new social and economic scenarios.

[1] By carrying out renovation, it is possible to achieve economic efficiency of former production, to solve environmental and transport problems, not only to restore the original appearance of objects of historical and cultural value, but also to preserve the architectural diversity of urban space, returning it to the urban fabric, adapting it to modern life.

The problem stated in general terms. In modern conditions, when there is a huge demand for real estate, when modern cities are becoming denser, when residents want to live in central or near-central areas, there is practically no free land left for development. One of the options for solving this problem is renovation, in particular, the renovation of former industrial facilities for residential purposes. In the context of historical development, modern cities have huge industrial areas that have lost their original function. Renovation and repurposing of such facilities and territories plays an important role in solving economic and social problems. Moreover, it not only brings abandoned and decayed industrial sites back to life, but also makes these areas important economic and business centers again.

Analysis of recent research and publications. Recent research emphasizes the importance of working with volumetric and spatial solutions in ensuring the functionality, habitability and architectural integration of repurposed industrial sites into the urban fabric. Studies by contemporary scholars emphasize various aspects of industrial redevelopment, including sustainable building techniques, volumetric extensions and spatial reconfigurations. By examining these sources, we can identify the prevailing trends, innovative approaches and challenges that influence contemporary design decisions in this area.

Dissertation “Principles of architectural and planning organization of multifunctional complexes based on the renovation of industrial facilities” by author N.O. Dmytryk. [2] In one of the subsections of which the author examines architectural and planning methods for the renovation of industrial buildings into multifunctional complexes. The study categorizes buildings based on their structural flexibility and suggests adaptive reuse strategies such as adding floors, extending spans, integrating atriums and modifying interior layouts to improve spatial efficiency and functionality. The study emphasizes the importance of balancing historic preservation with contemporary design needs while taking into account economic and regulatory constraints.

Dissertation “Principles of loft formation in the conditions of restructuring of non-functioning industrial objects” by O.A. Popova. [3] In which the author analyzes architectural and planning techniques aimed at adapting industrial buildings for modern residential needs, taking into account the preservation of their historical and cultural value. Particular attention is paid to the principles of formation of volumetric and spatial solutions that provide comfort and functionality of living spaces in former industrial facilities.

The research article “Identifying industrial buildings as a spatial resource for sustainable urban regeneration in densely populated post-industrial Asian megacities” by authors Miao Sun and Tan Qin. [4] The study emphasizes that the process of smart redevelopment of industrial facilities improves project balance, prevents competition for limited land urban resources, and promotes social equity by integrating community-oriented functions such as commerce, public spaces, and social welfare facilities.

Dissertation “Methodological Basis for Renovation of Industrial Facilities for Hotels (China Case Study)” by Gongzehong. [5] In which the author investigates the principles, techniques, structural and physical conditions for improving and ensuring energy efficiency in the renovation of industrial facilities for hotels.

Scientific article “Basic principles and techniques of reconstruction of industrial facilities for civilian buildings” by O. V. Semko. and E. P. Voskobiynyk. [6] In which the authors consider the basic principles and techniques of reconstruction of industrial facilities on the basis of their renovation for civilian buildings and offer a classification of the main factors analyzed in the design of reconstruction on the basis of renovation of an industrial building into a civilian one.

Purpose. The aim of the work is to determine the principles of improving volumetric and spatial

solutions during the renovation of industrial facilities for residential objects, taking into account modern architectural, functional, social and environmental requirements. The research is aimed at identifying optimal transformation techniques to improve the quality of the residential environment, integrate the renovated objects into the urban fabric and ensure their sustainable development, taking into account socio-economic factors and the preservation of architectural heritage.

Presentation of the main material. Creation of public buildings on the basis of industrial facilities renovation allows to effectively utilize the existing industrial development with simultaneous solution of urgent problems of the city development. This is especially relevant for non-functioning industrial facilities, which are located in the zone of influence of important urban highways and interchange hubs in the structure of a modern developing city. [6, p.7] Industrial buildings complement the urban identity of cities and present an opportunity to act on pre-existing conditions, providing an opportunity to reflect on criteria for restoration, conservation, intervention and rehabilitation. Given the foresight and vision, the transformation of these spaces can benefit the urban habitat in the short, medium and long term, as well as comprehensively improving the quality of life of communities. The basic requirements for organizing this type of housing can include the availability of convenient transport accessibility, minimal financial costs for the reconstruction of facilities into housing. The formation of affordable and social lofts is aimed at creating favorable living conditions and its accessibility for the low-income category of the population. [3, p.144] The process of adapting industrial facilities to new needs is complex and multifaceted. It includes creation of functional hierarchy of premises, technical reconstruction of obsolete elements, prioritization of new energy saving systems, consideration of scenarios of human stay in architectural space in the future, its ability to transform, etc. [7] At the volumetric level the issues of renovation are solved - in the planning, architectural, structural and engineering structure of individual buildings. At the functional level, as an integral part of the volumetric and urban planning - the issue of activation of the historic center through its functional filling, finding actual functions for the existing and new buildings and open spaces of the center. [8]

The main decisive factors in the conversion of industrial buildings into public buildings are compliance with the regulatory requirements for four groups of main factors: urban planning, space planning, structural, and aesthetic. The space-planning requirements for public buildings include the presence (or the constructive possibility of additional arrangement) of the main entrances, which should have convenient approaches and optimal dimensions, taking into account the physical capabilities of all estimated categories of visitors. The number of entrances (exits) should correspond to the calculation, taking into account the building's capacity and operational requirements. In addition, it is necessary to investigate the possibility of installing elevators, the height of the premises and the degree of fire resistance, etc. A comparative analysis of the space-planning factors shows that if the floor height of an existing industrial building is not compliant with the relevant requirements for public facilities, its further reconstruction (with a change of use) is practically impossible or requires partial dismantling of existing structures, which requires significant investment. [6, p.5].

The renovation process is usually associated with the transformation of volumetric and spatial organization and full or partial internal redevelopment due to new requirements for the organization of space, the need to ensure the required size of areas, fire or hygienic characteristics.

The following compositional methods of adaptation of industrial buildings in the city structure are distinguished:

- modification - change of proportions, shape, configuration and position of parts of the object;
- replacement - use of new individual forms, designs, projections, functions;
- exclusion or introduction of the number of functions, forms, designs of the object;
- combination - combinatorics of properties, functions, ideas, elements in one;
- inversion - opposition, consideration of the set tasks according to the principle from the opposite principle [9].

Based on the work with volume-planning solutions in the renovation of industrial facilities, the following principles can be emphasized:

1. The principle of maximum preservation of objects implies preservation of the structural, volume-planning scheme, the general image of the building. This principle is appropriate if the status of the architectural monument of this complex; buildings have a structural or planning scheme, the change of which is impossible for technical reasons; spatial development of building volumes is impossible.

2. The principle of minimal intervention implies only necessary structural and volume-planning transformations of buildings, provided that it is possible to partially change the structural scheme of the building, partially transform the existing interior or exterior space by installing or demolishing walls and partitions, floors, additions and superstructures.

3. The principle of free reconstruction of objects implies expedient intervention in the structural and volume-planning scheme of industrial buildings in the absence of the status of a cultural monument, technical possibility of complete change of the structural scheme and introduction of new construction solutions. While preserving the industrial function, the reconfiguration of volume-planning solutions of the reconstructed buildings should ensure clear ergonomic functional zoning.

When adapting a building for a new use, it is necessary to create conditions for new functions. Transforming an industrial building it is necessary to identify new typological characteristics of the object. It is necessary to take into account the peculiarities of planning, spatial, architectural and artistic characteristics of the reconstructed industrial object, to thoroughly investigate the load-bearing capacity of the structures that have been preserved.

The reconstruction of industrial buildings usually involves the following series of architectural and construction measures to optimize their planning and spatial structures:

– increasing or decreasing the height of buildings or their number of stores;
– increase of span parameters by method of column grid rarefaction
– introduction of new building structures to accommodate new functions;
– remodeling of walls and coverings to improve aeration and natural light conditions;
– room expansion or consolidation;
– combining several rooms into one with their height alignment and internal reorganization;
– incorporation of new volumetric and spatial elements. [2, p.185-187]

For this purpose, in practice, in architectural design, the following techniques are used in the work with volumetric and spatial composition:

– new additions to existing buildings or additions between them, which may be designed with offset axes;

– the superstructure of individual parts or the whole building, which, in case of insufficient load-bearing capacity of the frame, is carried out on independent load-bearing structures and supports;

– organization of additional levels in the internal space of the existing building in the form of built-in floors, mezzanines and separate platforms.

The choice of the method of space enlargement depends to a large extent on the type of building being reconstructed. As a rule, the expansion of areas of span-type buildings occurs by increasing the number of steps of existing spans, i.e., by increasing the length of the building, or by adding new spans, i.e., by increasing its width. Cell type buildings are characterized by planned development with additional cells. The possibility of flexible placement of new cells in the planning structure allows to obtain not only additional areas, but also to diversify the volumetric and spatial solution of the building (Fig. 1).

Industrial buildings of the hall type are usually unique and were originally designed as the dominant feature of the enterprise, so it is desirable to preserve their uniqueness during the reconstruction. In this case, the following techniques are advisable: revealing the main hall by means

of lower-height extensions, developing the building as an enfilade of halls, changing the interior space with the help of extensions and additional levels.

Depending on the volume-planning solution adopted, partial or complete superstructures can be carried out. The following variants of constructional design of the superstructure are possible:

- with reinforcement of existing vertical structures; duplication of bearing supports of the building;
- use of additional supports for the superstructure; suspended superstructure on frames.

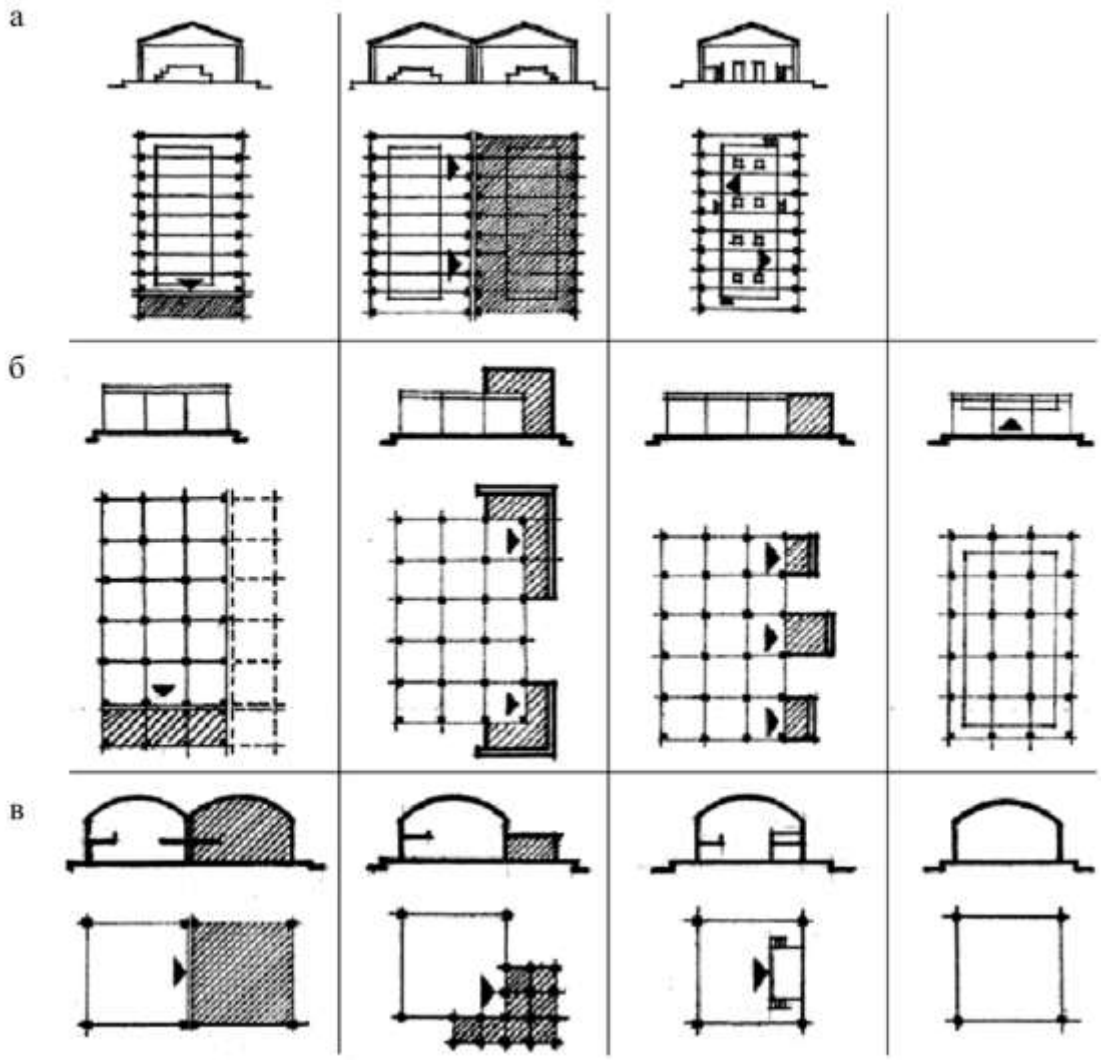

Fig. 1. Methods of expanding production areas during the reconstruction of industrial buildings of various types: a - span buildings; b - cellular buildings; c - hall buildings

Let's consider some specific examples of renovation of industrial areas and their facilities for residential buildings, where we can trace examples of works with volumetric and spatial composition. Ostenburg is a large-scale renovation project of a former industrial island in the center of Amsterdam. The new island combines industrial heritage with Amsterdam's new urban density, quality public spaces for living and community growth (Fig. 2). Studioninedots investigated how this diversity could be preserved in the building envelope in combination with an architectural quality plan (Fig. 3). Studioninedots investigated how this diversity could be preserved in the building envelope in

combination with an architectural quality plan. This approach combined the directional diversity of the Cityplot concept with a vision of a spontaneously evolving city. All residential buildings are designed with vertical volumes, providing a bold contrast to both the old and new elongated working buildings. By combining this with smaller and larger buildings on different lot sizes, we have achieved a very high density for Amsterdam, while maintaining a human scale that contributes to a sense of community. By leaving many entrances and stairwells open, we created numerous informal connections between courtyards and public streets, complementing formal passageways. Along with the nearly car-free neighborhood layout, this design promotes social interaction between residents, businesses, and visitors, creating a vibrant neighborhood in the new Ostenburg. [10]

Fig. 2. Ostenburg in Amsterdam, 2015

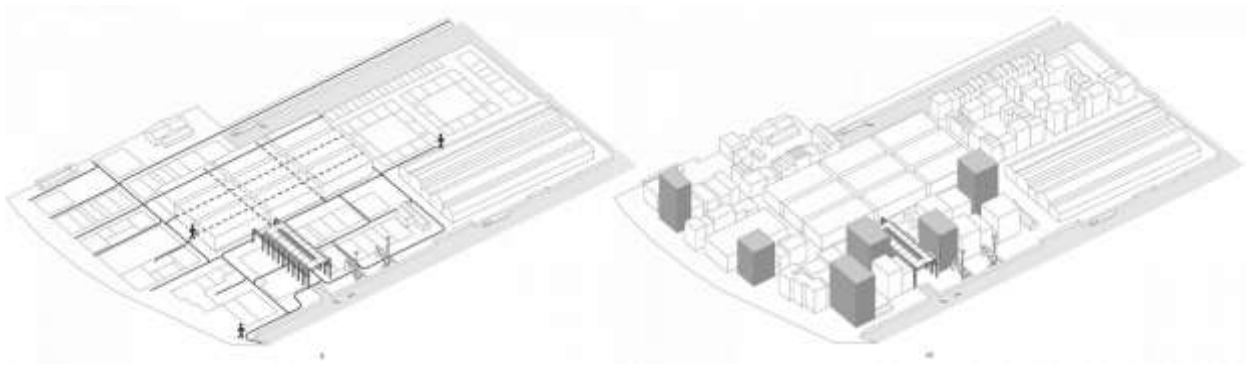

Fig. 3. Volumetric-spatial work with Ostenburg area, 3D schemes

Pumphouse commercial and residential building in Winnipeg, Canada. Renovation project of a former pumping station surrounded by railroad tracks and its workshops (Fig. 4). The site integrates offices and a restaurant while surrounded by two residential units that unlock the potential of multi-family housing. Each of the residential buildings is offset relative to the existing building, creating new pedestrian walkways that respect the original contour of the pumping station, reference the human scale, and extend the first-floor commercial facades. The massive plan emphasizes the connections between old and new (Fig. 5). Barrier-free access points are located along pathways between the historic façade and the new residential entrances, and internally, two outdoor amphitheaters, public areas, and bridges are designed to move residents between the residential neighborhoods and the historic portion of the building.

Fig. 4. Pumphouse commercial and residential building in Winnipeg, 2015

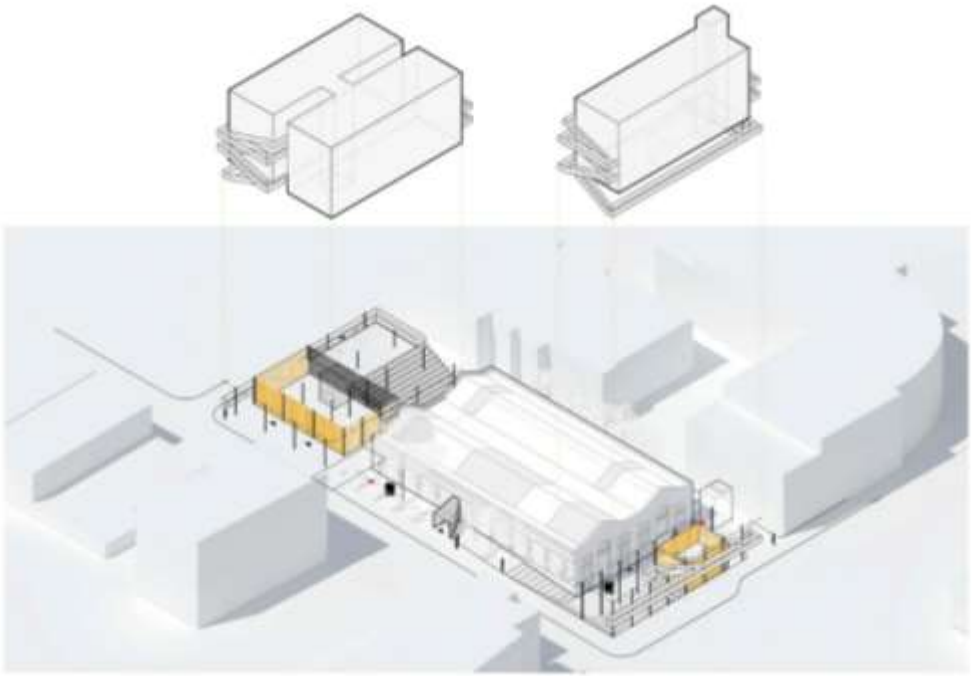

Fig. 5. Pumphouse volumetric-spatial composition

The intertwining nature of these passageways extends the winding streets that define the neighborhood and integrates various forms of public space as an important component of the project's layout scheme. The apartments fundamentally redefine the developer's multi-family housing efficiency goals by turning the typical Winnipeg apartment building inside out. Outdoor access transforms unassuming interior corridors into vibrant exterior passageways. Passageways weave in and around new and existing buildings and become extensions of the apartments, creating a shared space for neighborhood interaction. The north and south facades are defined by open stairwells, providing a sequence of unexpected experiences with unobstructed views of the city, adjacent river and park. Both buildings utilize a skip-stop configuration where access to the apartments on each

second floor is provided within the unit itself, greatly increasing efficiency and embodied energy, essentially halving the corridor footprint, and providing through-air apartments with ventilation and natural light on both sides. [11]

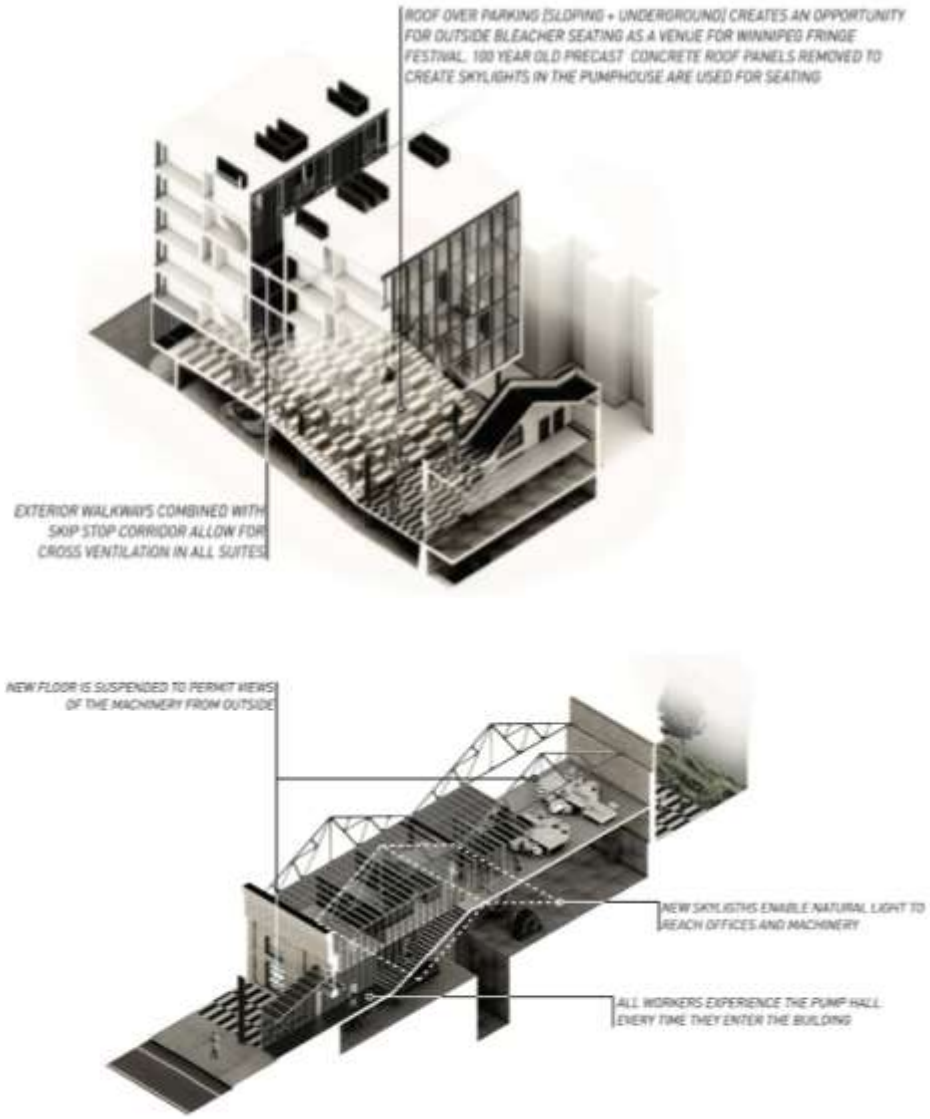

Fig. 6. Pumphouse volumetric-spatial composition

St William Homes, a developer specializing in urban regeneration, has undertaken ambitious projects to convert disused gasworks into residential areas in the UK, the conversion of Victorian gas holders in Bethnal Green and Bromley-by-Bow into modern apartments, (Fig. 7) illustrates the potential of industrial structures to be converted into desirable living spaces. [12] The cylindrical architectural 'fabric' was neatly incorporated into the architectural 'fabric' of the three residential buildings, the main ornamentation of which were stunningly beautiful atriums with circular staircases. The cylindrical configuration of the buildings made it possible to create open-plan apartments, where bedrooms and living rooms are located on the outer perimeter, which ensures their natural insolation. [13]

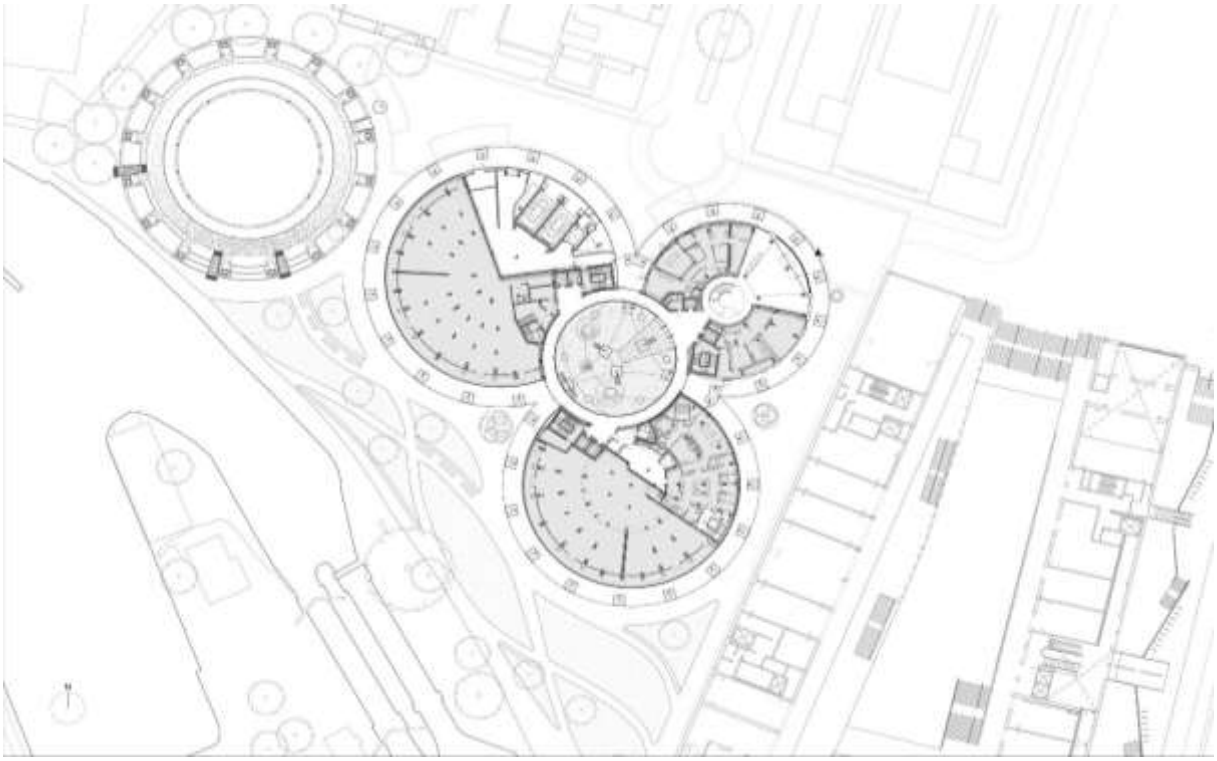

Fig. 7. Redevelopment plan for the three gas holders. The fourth remaining gas holder has been converted into a green park, Gasholder Park, designed by Bell Phillips Architects

A project to renovate the entire historical and industrial quarter of Rotermanni in Estonia. The approved detailed plan called for the reuse of existing buildings, as well as the addition of new volumes between them to create a living and working and pedestrian-friendly environment in the heart of the city, as well as 400 underground parking spaces (Fig. 8). The new flour warehouse was designed to shape the plaza as the new focal point of the neighborhood. The project consists of three volumes: the old flour warehouse with two additional floors, the new flour warehouse and the atrium connecting them. The first floor is dedicated to retail and all upper floors are dedicated to offices. Three massive, techno-futuristic towers made of graphite glass and metal were built over the old light beige sandstone building.

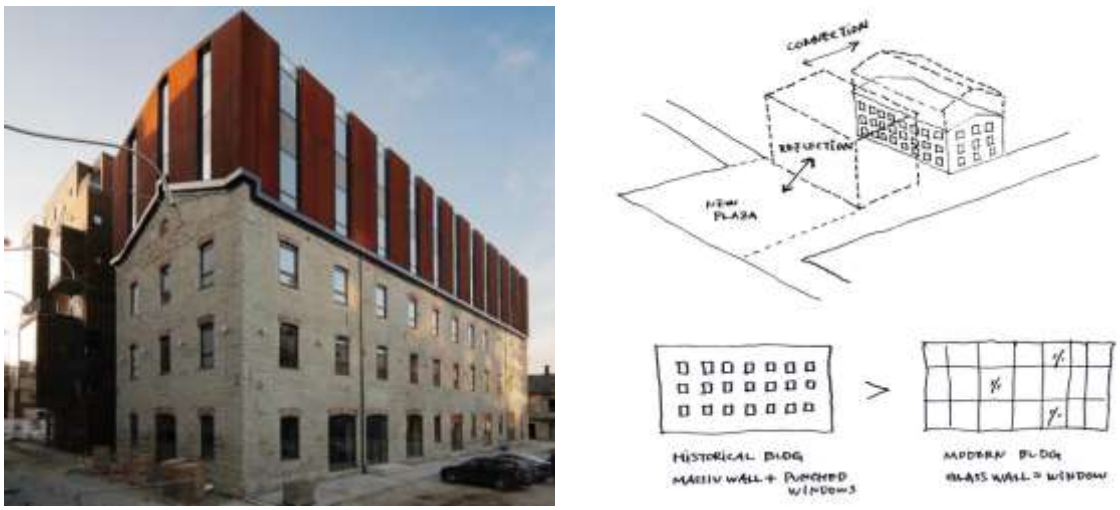

Fig. 8. Rotermann's Old and New Flour Storage / HGA, Hayashi – Grossschmidt Arhitektuur

Visually, the towers completely modernize the building, yet it is also a reference to the historic industrial architecture of the last century: stark, large-scale, impressive. The two lower floors of the renovated historic building are dedicated to the service sector (cafes, restaurants and pastry shops). The most elevated towers house office space, which the city successfully rents out. At night, the towers are illuminated with different colors, which are clearly visible even outside the block, making them a symbol of the new life of this place. [14].

The transformation project of the warehouse building of the old industrial complex of Fabra & Coats in Barcelona, Spain is included in the process of reconversion of this textile complex of the XIX and XX centuries to incorporate it to the "BCN creation factories" network. The project will bring to the Sant Andreu district more than 28,000 m2 of facilities and, as a first time in an industrial heritage transformation, social housing is included. The project includes 46 housing units of two bedrooms: 41 units for young people and 5 units as a temporal residence for artists in relation with the complex. Facades and roof of the building as a thermic buffer for the housing units.

The original building is 100m long, where the first decision was to bring the value of its maximum dimension, which is the length. We access through the center creating an interior square where the promenade of the interior stairs begins in diagonal double ascending. The original building is communicated physically and visually from the ground level until the roof structure. This vestibule also connects the building to Parellada Street and the Fabra & Coats complex square. This new communal space is the new structural contribution to the original building (Fig. 9).

This industrial constructive logic, where the building can be summarized as a repetition of a single transversal section, is transformed once you are in the interior, because the vision of the whole length of the building is stronger than the repetition of the module. The intervention in the building activates all the elements of the original building creating the new program, and reuses its physical, spatial and historical qualities to make the new construction more efficient and to reinforce the character of the original building (Fig. 10).

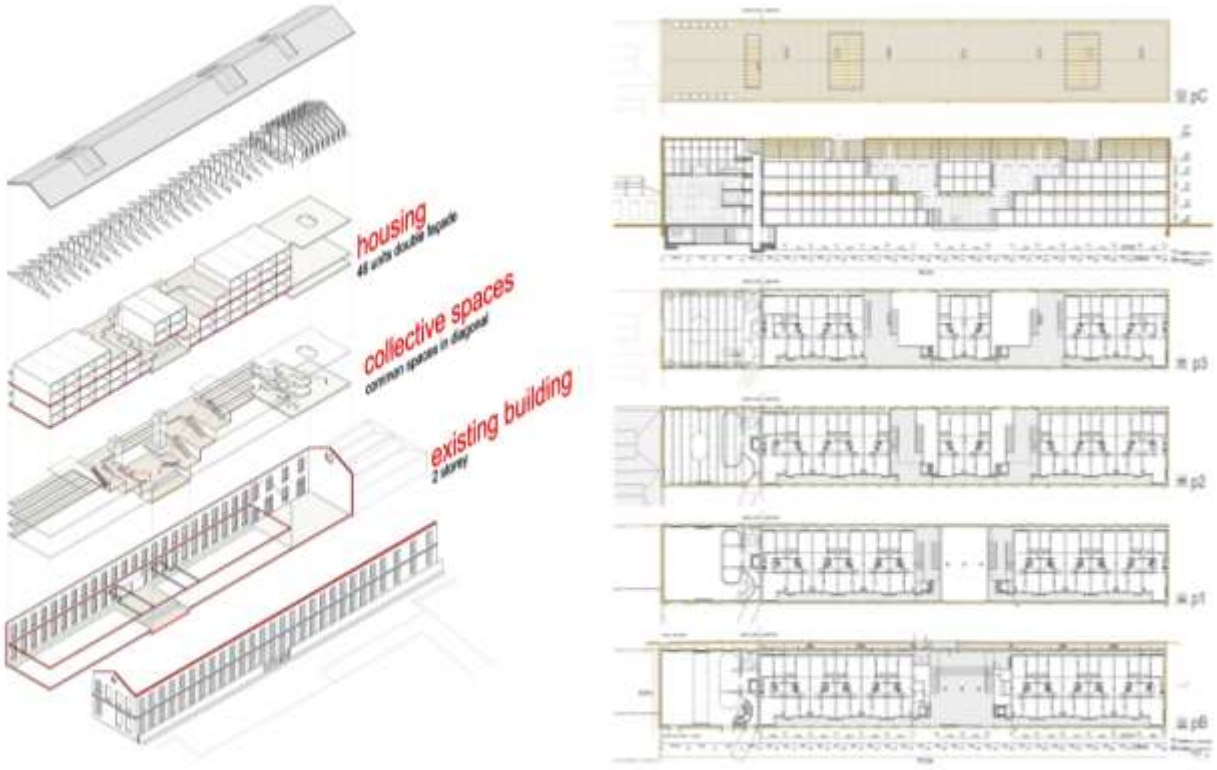

Fig. 9. Structural and spatial schemes of the Fabra & Coats in Barcelona, Spain

Structural reuse of the two inner floors of the building, using them without any reinforcement (load capacity of 1,100kg/m2) to support on both floors the two new levels of housing. We convert two floors into four, to reach this we use a wooden structure, because it is 5 times lighter than a steel structure. The wooden frame structure is a translation of the old steel structures used as shelves for the storage of the threads. [15]

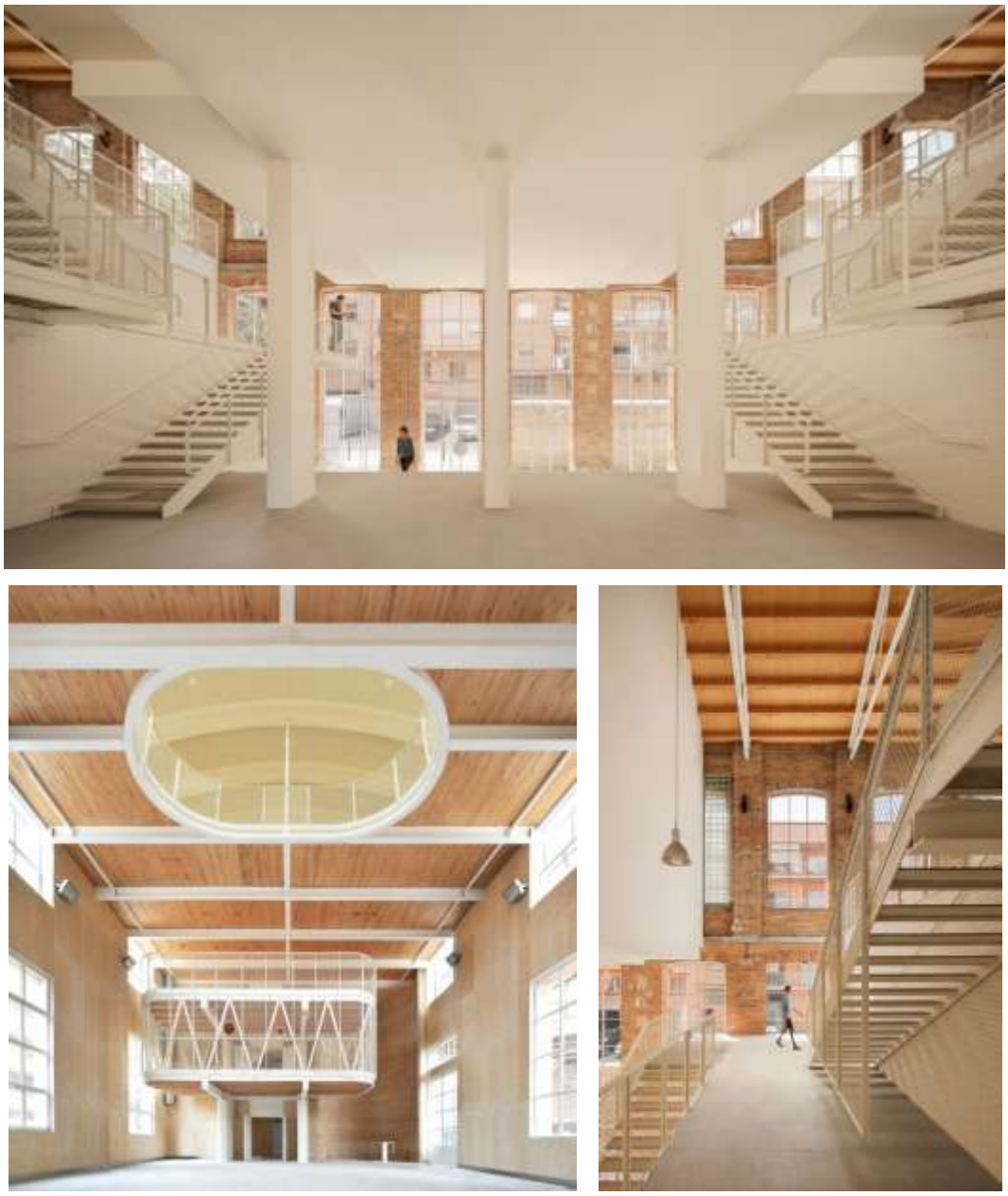

Fig. 10. Interior solutions introduced during the renovation of the Fabra & Coats building

Conclusions. As a result of the study, it has been established that the renovation of industrial facilities for residential buildings is a complex process that includes architectural and planning, structural, environmental and socio-economic aspects. The analysis of classical and innovative approaches allowed us to identify the main methods of volumetric and spatial solutions and the possibilities of their application and adaptation, ensuring harmonious integration of renovated objects into the urban environment and compliance with modern comfort requirements.

The application of the principles of minimal intervention, preservation of architectural heritage and free redevelopment allows to achieve a balanced approach to the transformation of industrial buildings, ensuring their functional suitability for residential use. It is important to take into account the structural flexibility of buildings, the possibility of changing internal layouts and the introduction of energy-saving technologies to improve their performance.

Renovation of industrial buildings, in addition to its architectural and urban planning significance, contributes to solving environmental and economic problems, helps to preserve historical heritage and form a sustainable urban environment. This approach allows not only to optimize the use of the urban area, but also to create favorable conditions for living, working and leisure of citizens.

Thus, the results of the study confirm the importance of an integrated approach to the renovation of industrial facilities based on the principles of sustainable development, adaptability and functional transformation. The future of such projects lies in their integration into modern urban structures, taking into account the current architectural, social and environmental standards.

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ПРИНЦИПИ ВДОСКОНАЛЕННЯ ОБ'ЄМНО-ПРОСТОРОВИХ РІШЕНЬ ПРОМИСЛОВИХ ОБ'ЄКТІВ ПРИ РЕНОВАЦІЇ ПІД ЖИТЛОВІ БУДИНКИ.

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Анотація. У статті аналізуються основні науково-практичні методи реновації промислових об'єктів під житлові будинки з акцентом на об'ємно-просторові рішення. Ці методи розглядаються на прикладах, класичних та інноваційних підходів, які використовуються для вирішення проблем інфраструктури та застарілих об'ємно-просторових композицій, що втратили не лише свою актуальність, а й не відповідають сучасним ергономічним вимогам. Важливий акцент зроблено на адаптації колишніх промислових об'єктів до поняття сучасного житлового об'єкта, а також на підвищення їх енергоефективності та екологічної стійкості. Мета вивчення цих принципів трансформації є виявлення оптимальних методик трансформації, що дозволяють грамотно провести реновацію під житловий об'єкт і підвищити якість житлового середовища, інтегрувати об'єкти, що реновуються, в міську тканину і забезпечити їх сталий розвиток з урахуванням соціально-економічних факторів, з урахуванням збереження архітектурної спадщини. У таких проектах пріоритетом є усунення архітектурних недоліків, що визначають застарілі структури у їхньому існуючому контексті. Основна мета таких ремонтних робіт – створити гармонійніше середовище шляхом модернізації промислових об'єктів з додаванням нових функцій. Рефункціоналізація певних фрагментів цих промислових об'єктів та реконфігурація об'ємно-просторових рішень, де запроваджуються модернізовані плани поверхів, з метою покращення відповідності стандартам життя та підвищення просторової функціональності. Такий підхід не лише модернізує об'єкт та прилеглу інфраструктуру, а й відображає зобов'язання щодо збереження культурної та архітектурної спадщини, гарантуючи, що вони відповідають вимогам майбутнього, не втрачаючи свого історичного значення.

Ключові слова: промисловий об'єкт, об'ємно-просторові рішення, житловий об'єкт, реновація, адаптація.