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Renovation of Residential Buildings of the First Mass Series from A Sustainable Development Point of View

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Abstract Problems related to the renovation of residential buildings in the first series of mass are considered. It was established that two-thirds of housing in Post-Soviet countries needed renovation and reconstruction. The use of modern technological solutions in renovation can guarantee an increase in energy efficiency in the construction industry. The houses of the first mass series were studied. It was established that this housing, which to this day makes up 30 to 50% of the existing housing stock, morally dilapidated and ultimately does not meet urban planning and sanitary-hygienic standards. Its volume planning solution requires reconstruction and renovation with complete replanning of internal premises. The study used a systematic and comparative analysis of a series of panel houses, in the context of sustainable development of cities, on the one hand, and the other - from the point of view of improving the social, economic, and ecological conditions of living. The optimal approach to renovation can be considered the option when the modernization of a typical building is put on a typical basis, considering specific conditions. This approach will enable the production of a series of building structures for specific typical reconstruction projects. A holistic renovation of several buildings or a block built in the 1950s-60s, including partial demolition, replacing main utility networks, developing additional infrastructure, and adding new modern residential buildings, is promising. Methods of reconstruction of housing may include changing the structural scheme or not, changing the volume of the building due to an extension, changing the size of the house, and changing the appearance. The authors recommend building reconstruction using prefabricated modular panels to ensure energy efficiency and comfort for existing multi-apartment buildings. In terms of economics, the proposed renovation methods effectively increase energy efficiency. Socially and architecturally, renovation principles make it possible to improve living conditions, increase the appeal of affordable housing, and rationally design its structure in line with UN goals.

Keywords Renovation of Residential Buildings, Affordable Housing, Energy Efficiency, Reconstruction, Architectural Renovation of the First Mass Series, Prefabricated Modular Panels

1. Introduction

There is a problem of reconstruction and modernization of typical buildings of mass series due to their noncompliance with today's requirements in almost all countries of the former USSR, where at one time, large areas were built with such housing.

Nowadays, housing reconstruction is seen as part of sustainable urban development, which limits territorial growth, improves comfort, and creates public spaces. In this regard, the reconstruction of the outdated housing stock is of primary importance [1].

A sustainable transformation is highlighted in Goal 11 of the 2030 Agenda for Sustainable Development [2], which is dedicated to ensuring inclusiveness, security, sustainability, and sustainable development cities, which confirms the New Urban Development Program and the "Green Deal" of the European Union [3,4]. New Leipzig Charter (2020) establishes a framework for developing and implementing these European and global agreements [5-7].

The European Union Economic Commission considers the housing sector one of the priority areas for energy efficiency, first because it consumes a large amount of energy and, second, is very wasteful [7]. In this industry, it still maintains outdated, inefficient practices, and the high energy consumption problem of energy savings through the reconstruction of existing buildings was considered in recent debates on the adoption of a climate and energy package by 2030 [9]. In particular, the heads of the construction industry appealed to EU countries with a call to approve a mandatory energy efficiency target of 40% [10,11]. In fact, modern technological solutions in the construction industry can ensure that the goal is achieved by 2030 [12-14].

S.Tsenkova, N. Foster, K. Young, A. Chegut, P. Eichholtz, and others acted as ideologues in the construction of energy-independent buildings [8-10]. Researchers I. Gabriel, H. Ladener, A.Afanasiev, M. Diomin, and M. Zimmermann significantly contributed to the development of reconstruction methods of buildings based on the principles of energy efficiency. These authors also emphasize improving living conditions and forming public spaces [11-14]. M. Diomin and M. Zimmermann also show the need for an integrated approach to reconstruction with social infrastructure development.

Thus, architectural and energy efficiency aspects of the sustainable renovation of residential buildings are shown in the works of G. Malacarne, G. Pasetti Monizza [15], K. Sandberg [16], R.G. Martinez, and J.B. Ayucar [17]. They consider the effectiveness of different hinged facades using materials such as plaster, wood, metal, glass, and even slate [18].

The accumulated experience of the experimental construction of energy efficient buildings with energy supply based on renewable energy in the current stage also provides the possibility of developing specific design solutions for energy-efficient reconstruction of buildings [19,20].

2. Materials and Methodology

The methodology for solving the problem of renovating residential buildings of the first mass series is based on careful and detailed consideration. In this study, the types of panel houses of the first Soviet series were systematically and comparatively analyzed for energy savings on the one hand and for improving social, economic, and ecological living conditions on the other.

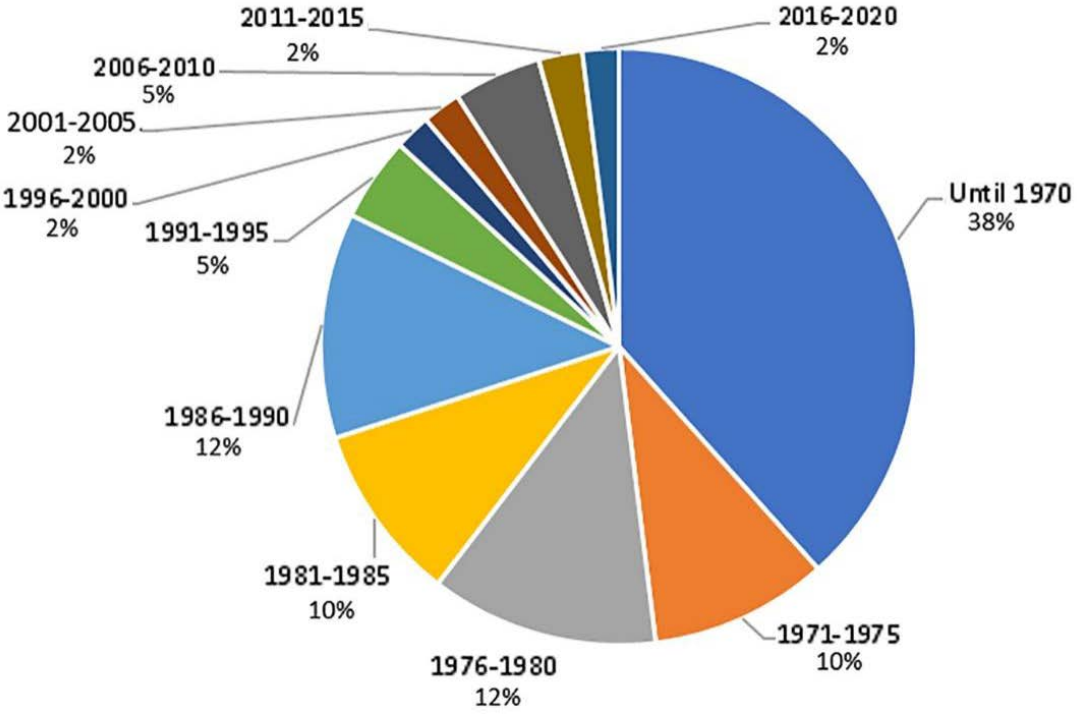
When researching the existing housing stock, we used a systematic approach, manifested in analyzing and synthesizing renovation methods of panel houses and their types, which correlate with energy-saving problems; this is on the one hand. Furthermore, on the other - with the problems of improving living conditions, as scientifically justified, a human-centered approach that explores the relationships between spatial planning and whole, alongside social, economic, and environmental phenomena.

The systematic and comparative analysis included additional analytical methods (statistical and selective), expert and probabilistic prediction methods, and statistical data analysis from the National Statistical Office of Kazakhstan. The research analyzed archival data on residential buildings of the first mass series in the last soviet period on the territory of the Republic of Kazakhstan, Ukraine, Estonia, and Germany.

With the help of comparative analysis, the plan-spatial structures of panel houses of the first Soviet series were investigated. It was found that one-third of the housing stock is already unsuitable for further use. Two-thirds need modernization and reconstruction from the point of view of energy saving.

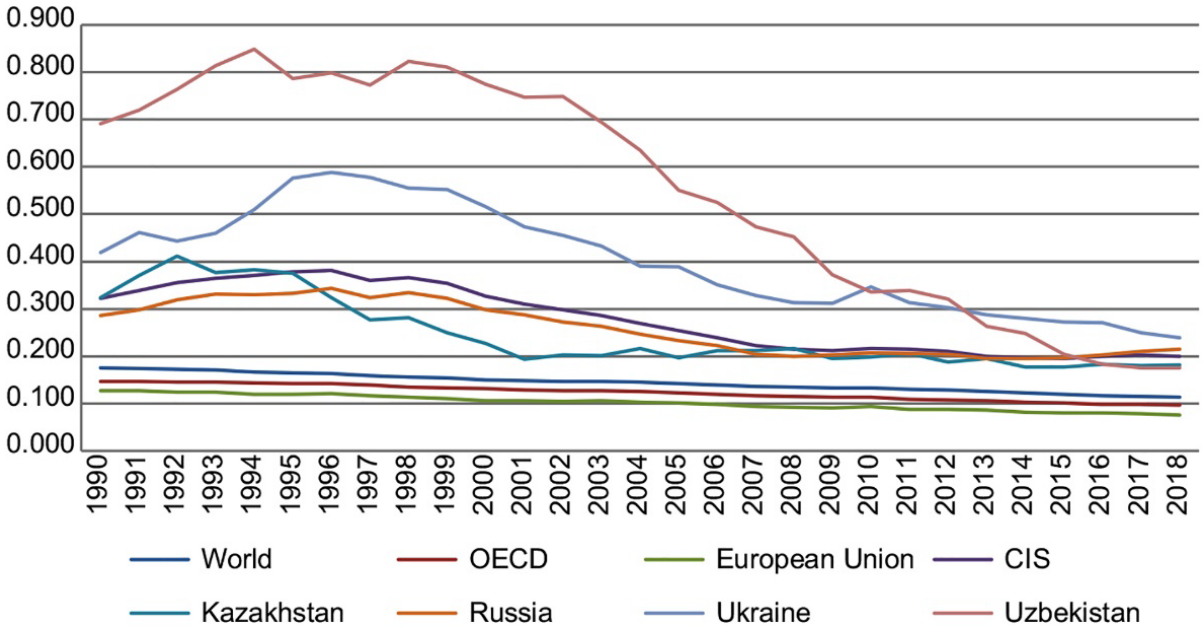
3. Results

According to the data from the Bureau of National Statistics of Kazakhstan [21], for 2020, the number of houses built before 1970 is 38% of the housing stock, and the share of residential buildings built before 1990 is 82% (see Figure 1). However, all residential buildings built before 2005 require increased attention from the point of view of energy consumption, and most of them - 91%.



Source: [22]

Figure 1. Share (%) of apartment buildings by year of commissioning



Source: [24]

Figure 2. Energy intensity per unit of GDP in different countries

Therefore, more than a third of the housing stock is no longer suitable for further use. These houses do not meet modern requirements and standards, are unnecessarily energy-consuming, and are extremely expensive. Furthermore, the remaining two-thirds of the existing housing needs modernization and reconstruction from the point of view of energy savings.

The economies of the CIS countries are considered very energy intensive [30]. Most post-soviet countries use several times more energy per production unit than in more developed regions. In Kazakhstan, thermal energy consumption in buildings is approximately 240 kWh/m^2 per year (for comparison, this figure in Sweden is 82 kWh/m^2 per year, in Germany - 120, in France - 126, in

England – 130, in Ukraine – 300). Residential buildings consume approximately 13.6% of electricity and 40% of heat energy [23]. Moreover, until now, the problem of reducing energy consumption is one of the most urgent in the world (see fig. 2).

Thus, the construction sector and mainly housing are the most energy intensive, but modern construction methods can guarantee improvements in energy efficiency [25].

Therefore, the problem of reconstructing the outdated housing stock is urgent, both in Kazakhstan and in other post-Soviet countries. At the same time, special attention should be paid to energy savings and efficiency [26].

The analysis of the structure of the housing fund

Block buildings (Plattenbau) built in Berlin and Dresden since the 1920s became the prototype for the first Soviet "Khrushchev" [27]. These buildings were well equipped - large kitchens, separate bathrooms, elevators, and garbage disposals. Nevertheless, under the influence of Soviet ideology, the comfortable requirements for planning apartments were lowered (standard pass-through rooms), the size of auxiliary premises - hallways, kitchens, corridors (the area of kitchens - up to 6 square meters) was reduced; combined bathrooms and small-sized sanitary-technical devices have been introduced, the sound and heat-insulating qualities of fence-chewing structures have been underestimated. The height of the floors was also reduced to 2.5–2.4 m, and the height of the building was limited to five floors to avoid installing elevators and garbage chutes. As a result, entire housing estates were built with inferior (even for that time) houses. Even during the construction of these buildings, their low thermal insulation characteristics were noted [27].

From 1956-1965, more than 13,000 residential buildings were built in the USSR. In the III construction-climatic zones, which covered a significant territory of the Soviet Union (this included Ukraine, Moldova, the southern part of the European part of Russia, and Central and southern Kazakhstan), houses of series 1-464, 1-438, 1-480, 1-463 with partially limited orientation, with three or four apartments on the staircase, were used [28].

Series of houses of the 1950s-60s, the so-called "Khrushchevs": 1-464; 1-335; 1-434; 1-434C, - are recognized as unfit for habitation. Therefore, the houses of these series are mainly demolished in all post-Soviet countries.

Series of typical houses 1966-1977: 1-464A; 1-335A; MK-5; 1-OPB already have specific differences. They have an increased ceiling height of up to 2.7 meters; more spacious kitchens and living rooms; built-in furniture: wardrobes, mezzanines, balconies, or loggias.

Since the end of the 1970s, mainly 9-story buildings have been built from prefabricated panels and bricks.

The toilets and bathrooms are separated from now on, and the entrances are equipped with a passenger elevator and a garbage chute [29].

Houses of the 1-464 series

The most common prefabricated houses of the first generation are residential buildings of the series of typical projects 1-464.

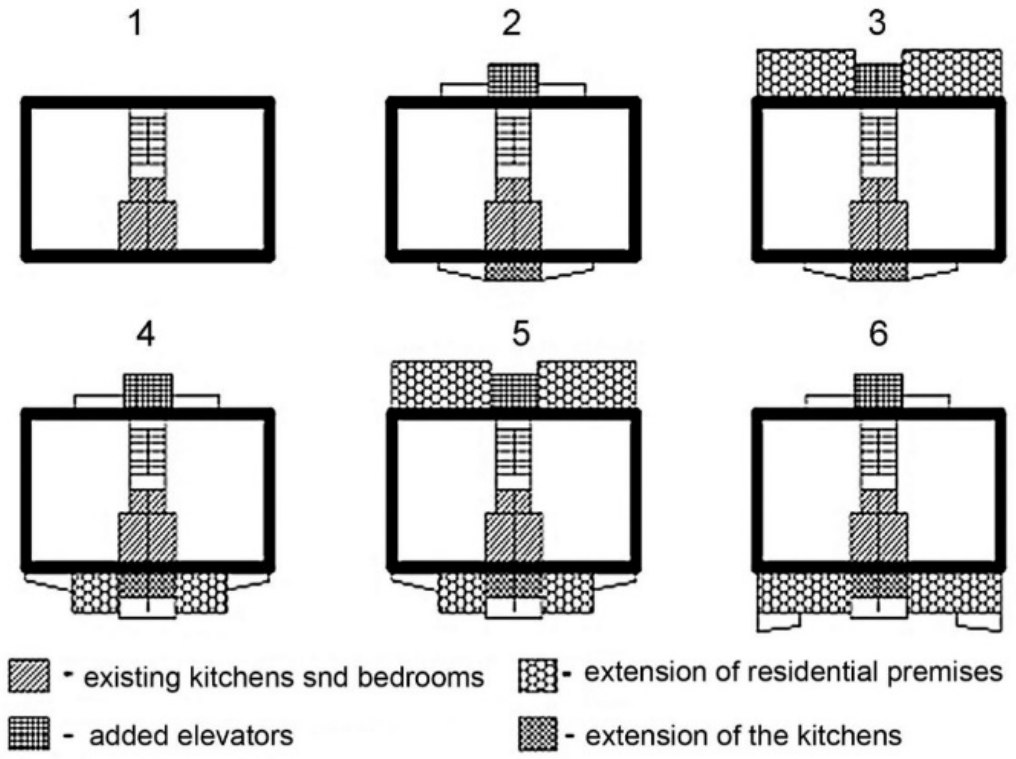
The main supporting walls in this series were transverse reinforced concrete walls, with a step of 3.2 and 2.6 m, due to which all internal walls carried the load from the ceiling. This made it impossible to move these walls and, therefore, to change the room's dimensions. For this reason, the removal of external walls is also excluded.

When remodeling houses in the 1-464 series, there is a need to arrange new or expand existing openings in the transverse walls. Within narrow limits, this is possible but requires confirmation by calculations [28].

Five-story panel houses of the 1-468 series

The bases of the houses of this series are supported by the transverse walls with a step of 3 and 6 m. Therefore, the houses of this structural system were called houses with a "mixed" step of the transverse bearing walls, unlike the houses of the 1-464 series.

The main advantage of these houses is that floor panels do not rest on the longitudinal walls of a building. Therefore, these walls can be dismantled in some places. This circumstance opens up great opportunities for the modernization of such buildings to eliminate the shortcomings of the redevelopment of existing buildings by completing additional volumes [28] (Fig. 3, 3-6).



Source: [28].

Figure 3. Options for adding additional volumes to a typical block section: 1 – existing section; 2-6 – options for adding additional volumes

Five-story panel houses of the 1-335 series

Residential buildings of the series 1-335 are classic 5-story "Khrushchevka" buildings with an incomplete frame and longitudinal load-bearing walls. Due to the incomplete frame, the "free planning" principle can be fully realized in the houses of this series.

Five-story brick houses of the 1-447 series

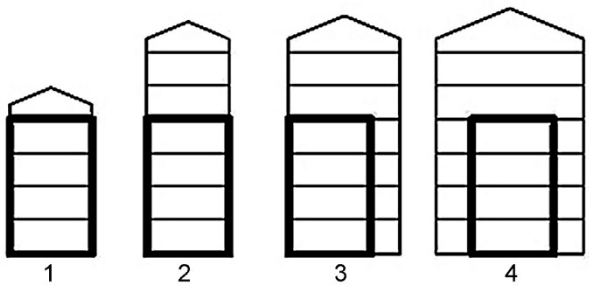
The 4-5-story brick residential buildings of the 1-447 series include typical projects with three longitudinal load-bearing walls and transverse brick ones - external and internal, between which stairwells are located. Transverse brick walls work as stiffening diaphragms. All other walls (internal and inter-apartment) are non-bearing. The openings can be placed on the end walls during reconstruction [28].

Methods of reconstruction

Therefore, the main goal of reconstructing the houses of the first mass series can be to improve the energy efficiency and planning characteristics.

In many European countries, even in the 1970s and 1980s, measures were taken to insulate buildings in a complex with rehabilitation works, which included increasing the comfort of living and improving maintenance and operation processes, modernizing engineering equipment and networks, replacing the filling of window and door openings [7,12,28].

The main options for reconstruction in order to improve planning characteristics are the addition of an attic, one or several floors, and the addition of additional volumes [11] (Fig. 4). The arrangement of mansards allows one to increase the total area of the house by up to 40%, reduce heat loss only through the covering by 10%, and change the architectural expressiveness of the house. It should be noted that the suitability of the building for reconstruction largely depends on a series of typical projects, its structural scheme and material, and the technical condition of the load-bearing structures (Table 1).



1-2 – Superstructure of additional volumes.

3-4 – Completion and superstructure of additional volumes.

Source: authors

Figure 4. Options for extensions and superstructures of additional volumes

Table 1. Type of reconstruction for different structural systems of housing

Type of reconstruction and composition of works	The structural system of the house						
	with longitudinal bearing walls		with a cross-wall bearing system	with transverse load-bearing walls			Frame and panel scheme
	Series of typical projects						
	1-438	1-447	1-480	1-464	1-467	1-468	1-335
Replanning of apartments in the existing dimensions of the building							
dismantling and installation of partitions	++	++	+	+	+	+	+++
transfer of bathrooms	++	++	+	+	++	++	+
arrangement of openings in the internal walls	++	+	+	+	+	+	++
Redevelopment with arrangement in the extension of bay windows, loggias.							
arrangement of openings in external walls	+	+	+	++	++	++	+
arrangement of new slabs of loggias, bay windows	+	+	+	+	++	++	+
Mansard Structure and Superstructure							
arrangement of slots in the ceiling of the upper floor	+	+	+	+	+	+	+
dismantling of the ceiling of the upper floor	+	+	-	-	+	+	-
use of the existing ceiling of the upper floor for housing	+	+	+	+	+	+	+
strengthening of the existing ceiling of the upper floor	-	-	+	+	-	-	+
Installation of a new ceiling on the upper floor	+	+	+	+	+	+	+
arrangement of the monolithic belt of the floor of the building	++	++	+	+	++	++	-
arrangement of the frame of the superstructure	+	+	++	++	+	+	++
arrangement of the cross-wall superstructure system	-	-	++	++	-	-	-

Notation:

+++ - significant reconstruction is possible; ++ - reconstruction is possible;

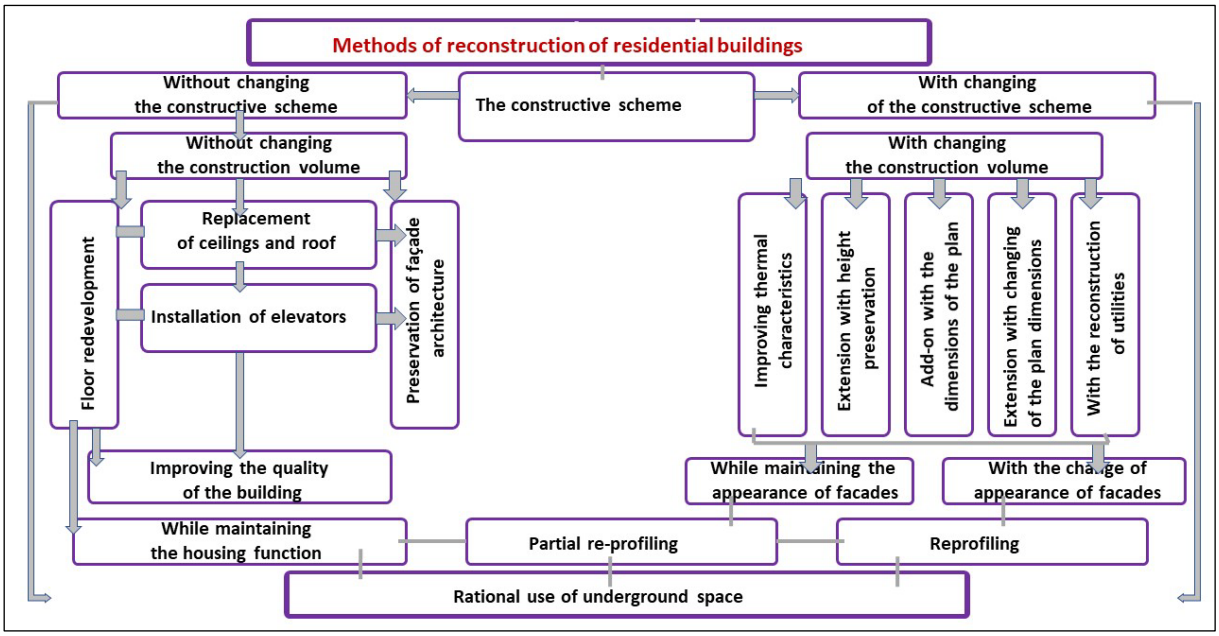
\+ - limited reconstruction is possible - - reconstruction is impossible

Possible options for adding additional volumes are shown in Fig. 3, and extensions and superstructures of additional volumes are shown in Fig. 4.

So, reconstruction methods of residential buildings may include: changing the structural scheme or not, changing the volume of the building due to an extension, changing the dimensions in layout, and changing the appearance of the facades of balconies or facade systems (Fig.5).

Most renovations in current construction affect individual parts of the house, such as roofs, facades, or heating systems. This often leads to expensive and inefficient solutions but does not guarantee a long-term reduction in energy consumption. Therefore, the reconstruction problems must be solved comprehensively, together with the problems of energy efficiency.

A comprehensive approach to the simultaneous reconstruction of several buildings, a quarter or a microdistrict built in the 1950s and 1960s, including the demolition of part of the buildings, the replacement of traditional and main utility networks, the development of additional infrastructure, and the construction of new modern residential buildings is promising. Calculations show that the cost of complex reconstruction of a block of 10-15 buildings is more than $ 1 million, but this approach is the most attractive for attracting investments.



Source: [30].

Figure 5. Methods of reconstruction of residential buildings

The optimal approach to reconstruction can be considered the option when the modernization of a typical building is put on a typical basis, taking into account individual characteristics and specific conditions.

This approach will make it possible to produce a series of typical building structures for specific typical projects of reconstruction and modernization; to develop new progressive methods and technologies to carry out reconstruction activities and carry out construction and installation works under challenging conditions of reconstruction; to create a material base for the repair and construction complex with appropriately trained specialists, machinery, and equipment [31].

The prefab industry takes many forms, from small factory-produced flat elements to large-scale, fully factory-ready bulk units. Modularity is one of the main requirements for the construction of prefabricated panels. This, in turn, requires using methods of unification of design solutions. The repeatability of elements is a possible solution for the use of industrial methods in construction, which is especially effective for the reconstruction of mass housing.

However, an average annual renewal rate of at least 3% is required to achieve the required level of energy efficiency. Even in developed European countries, renovation levels are around 1%. In the European Union, less than 3% of housing stock has an energy efficiency certificate A (a building that consumes almost no energy).

97 percent of existing buildings need to be renovated in order to become buildings with near-zero energy consumption. If the renovations of the buildings continue at the current rate and according to the current standard policy, it will take one to four centuries to improve the building stock to the level of energy consumption of the current new construction [20].

One solution is using prefabricated building elements to automate the reconstruction of the existing housing stock. An industrialized process for new designs is widely used throughout Europe, but is not yet well established [19]. The method is that the above-ground enclosing parts of the building are insulated with prefabricated modular panels measuring ~2.7x9m, consisting of a wooden frame structure filled with mineral wool. Existing balconies are rebuilt as additional space (Fig.6).

This method of pre-fab construction is already becoming widespread in Europe [15-17] and is an effective solution for energy renovation, allowing for quick reconstruction without the use of scaffolds. The speed of installation will allow increasing the amount of reconstruction. According to estimates, the insulation of external walls with the help of ready-made panels will take not more than 2-3 weeks compared to 2-3 months with modern technologies.

Current estimates show that the possibilities of significantly reducing the cost of production only by simplifying prefabricated elements are limited. Through economies of scale and higher production volumes, future reductions in costs can be achieved. The prefabricated retrofit solution could be widely used in future projects if these are achieved.

1) 2) 3)

Figure 6. Examples of reconstructing existing objects from foreign practice: 1) **Social Housing Grand Parc Bordeaux**. Architects: Lacaton & Vassal architects. Source: https://www.archdaily.com/915431/transformation-of-530-dwellings-lacaton-and-vassal-plus-frederic-druot-plus-christophe-hutin-architecture. Fot. Philippe Ruault; 2) **Ellebo Housing Renovation**. Architects: João Moura Fagulha, João Prates Ruivo, Raquel Maria Oliveira, Beth Hughes, Source: http://for-a.eu/Outside.html; 3) **"Square Vitruve", Paris,** Design: Atelier Du Pont**,** fot: Luc Boegly, Source: https://divisare.com/projects/239448-atelier-du-pont-luc-boegly-rehabilitation-of-the-shell-of-a-social-housing-building

Facade decoration of these pre-fabricated structures is possible with plaster, wood, metal, glass, and even slate [16,17]. Some examples of reconstruction of social housing made to improve its living environment, add public spaces, and increase the attractiveness can be seen in Fig. 6:

1) Social Housing Grand Parc Bordeaux, where extension and addition of balconies were provided;
2) Ellebo Housing Renovation. - method of reconstruction consists of adding new balconies to the existing buildings as additional space, protected by a glass wall;
3) "Square Vitruve", Paris - the authors proposed to add balconies to provide the apartments with additional open space and completely redesign the architecture of the facades. This new facade was installed without the use of cranes or other machinery. Installation of the balconies is done from the roof, and all technical solutions have been designed to avoid overloading the existing structure and disrupting residents' daily lives.

4. Discussion

The main advantages of the introduction of prefabricated modular construction in the field of reconstruction are as follows:

1. Reconstruction of the building with prefabricated elements of the facade and roof changes the architecture of the apartment building. This can be seen as an opportunity to improve the architecture and quality of existing enclosure structures. However, if it is necessary to preserve the architecture of the existing apartment building, then traditional reconstruction measures should be preferred.
2. From an economic point of view, prefabricated technologies are competitive compared to traditional reconstruction measures, but not necessarily cheaper. Two types of renovation have great potential to become cheaper than traditional technologies: simple and repetitive facade and roof renovation (without complex building shapes) and complete renovation of buildings with significant changes (window sizes, room extensions, new roof apartments).
3. An efficient construction process with prefabricated elements creates a "residential construction site" without evicting residents. However, temporary eviction for 3-6 months is recommended for the complete modernization of the building.
4. Energy savings for heating and hot water supply can reach 80%. This means the electricity consumption of less than 17 kWh/(m²·year). This is quite possible when using photovoltaic systems and reducing energy consumption for domestic needs close to zero.

Regarding prefabricated elements, the following observations may be made:

1. Manufacturers of prefabricated facade elements prefer significant elements for logistic purposes. They usually have a height of 2.8-3.3 m and a length of up to 12 m.
2. Facade modules are mostly made of wooden frames and cement or fiberboard. Integrated ventilation channels have special fire protection.
3. Pre-assembled modules are manufactured with high precision with an accuracy of ±1 mm. It is essential to determine the necessary tolerance between the building and the modules and to accurately fix the support brackets of the modules around the building.
4. The use of scaffolding is recommended for the installation of prefabricated facade elements.
5. Central ventilation systems with facade-integrated air distribution were efficient. Ventilation systems for individual rooms integrated into facade modules are also possible.

The construction industry has already adopted the concept of retrofitting buildings using ready-made retrofit modules as an effective way to modernize existing buildings. However, it will take more time to become a

widespread technology. The construction industry, as a rule, is very conservative. It will take some time to restructure existing construction processes and further develop new concepts, but it is clear that the new technologies demonstrated offer great opportunities for a sustainable built environment.

Today, the basis of any reconstruction should be to increase the value of housing. Focusing exclusively on optimizing energy efficiency does not meet the general requirements.

Therefore, prefab industrial technologies are no longer just the domain of new buildings. They have great potential for building renovations, where they offer better quality crafts and a faster construction process.

The advantages of these prefab industrial technologies include the following:

1. Enhancing energy efficiency and comfort for existing multi-apartment buildings.
2. Optimized designs, comfort, and economic efficiency due to pre-fabricated manufacturing.
3. The possibility of creating an attractive new living space in the attached attic based on prefabricated panels and adding former balconies to the living space.
4. Fast upgrade process with minimal disruption to residents.

5. Conclusions

Research has established that the housing of the first mass series, which constitutes 30 to 50% of the existing housing stock today, does not meet all the requirements of urban planning and sanitation and hygiene standards and requires reconstruction and modernization. Most current building renovations involve replacing components like roofs, facades, or heating systems. It was established that the most promising is the holistic renovation of the quarter of the 1950s and 1960s, which includes demolishing some buildings and reconstruction of others, replacing engineering networks, and developing infrastructure and public spaces.

The existing methods of renovation of the housing with changes in the structural scheme, the volume of the building and its facades were studied. The authors consider building reconstruction using prefabricated modular panels to be the most progressive, ensuring the energy efficiency and comfort of existing multi-apartment buildings. The method is that the above-ground enclosing parts of the building are insulated with pre-fabricated panels made of a wooden frame structure with mineral wool inside. Existing balconies are rebuilt as additional living space. This pre-fabricated construction method is already spreading in Europe and is an effective solution for energy renovation. The facade decoration of these pre-fabricated structures is possible with plaster, wood, metal, glass, and even slate. Prefabricated modular construction provides energy efficiency, improved living conditions, optimized designs, quality, and economic efficiency. The effectiveness of this study can be traced to social, economic, and architectural aspects.

In economic terms, the proposed renovation methods contribute to an effective solution for energy renovation and allow immediate reconstruction without scaffolds, which leads to the sustainable development of urban settlements. In social terms, it is reflected in increasing comfort and improving the living environment, which leads to an increase in the attractiveness of affordable housing. In architectural terms, renovation principles enable rationally to form affordable housing structures in connection with the UN goals, giving an expressive architectural and planning effect.

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