

Correlation Between Renovation Type and Structural Scheme of Residential Buildings

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Abstract The issue of housing for humans has been extensively studied and remains highly relevant. While multi-story buildings in both large and small cities have addressed the need for residential accommodations, key aspects essential to ensuring comfortable living and human activity have often been neglected. A potential solution lies in the renovation of existing structures to enhance housing quality while preserving the original framework. This paper aims to explore the relationship between renovation approaches and the structural systems of residential buildings. It examines case studies of building renovations utilizing various materials, highlighting their features and applicable solutions. The analysis includes examples from multiple countries with diverse social, economic, and climatic conditions. Renovation is defined in this study as the process of modernizing residential buildings and their surrounding areas. Through an evaluation of architectural strategies employed in building renovations, the study identifies general trends and principles applicable to the refurbishment of standard residential structures. Based on these findings, the authors propose recommendations for renovation strategies tailored to different structural types. The outcomes of this research offer a framework for implementing revitalization projects, urban regeneration efforts, and building adaptation initiatives.

Keywords Renovation, Modernization of Buildings, Residential Buildings, Urban Renewal, Housing Architecture

1. Introduction

Renovation of residential buildings is a natural process occurring in large cities worldwide. Renovation projects address issues related to aging building stock, improve energy efficiency, and preserve established social connections. The objectives of renovation have been extensively studied and substantiated by numerous academic studies. At the same time, decision-making regarding renovation often demonstrates a somewhat flexible approach. Given that decision-making is influenced by the stakeholders involved and their preferences, as well as by the technical characteristics of existing buildings, it is essential to identify the relationship between building load-bearing structures and renovation types. The necessity for this research lies in accelerating the entire renovation process, as stakeholders will be informed in advance of possible renovation options, allowing them to clarify their preferences accordingly. Moreover, selecting an appropriate type of renovation for buildings with varying structures ensures protection against potential errors by architects and engineers.

2. Materials and Methods

2.1. Literature Review

The complexity of the renovation process lies within the very concept of renovation itself. Jensen [1] describes renovation as a multifaceted process encompassing

preservation, modernization, building adaptation, reconstruction, and more. Consequently, despite the clear objective of improving existing buildings, the selection of design solutions can vary widely and is dependent solely on the renovation stakeholders. This is supported by Kamari's studies [2, 3], which identify the most challenging phase as defining the scope and stakeholders involved in the renovation.

Contemporary research on renovation builds upon foundational works by Jane Jacobs [4], Christopher Alexander [5], Jan Gehl [6], and other authors [7-12] concerned with the relationship between architecture and human well-being. This is evidenced by the focus on the social impact of renovation. [13] Additionally, Colin Ellard compellingly demonstrates the influence of architecture on human psychophysiological states. [14] In his work, he found that urban environments lacking organized complexity, a characteristic of natural settings, adversely affect human health. In other words, there is an undeniable connection between human health and the surrounding architecture. However, the methods for achieving residents' well-being in architectural environments remain somewhat ambiguous. Kamari [3] argues that different methodologies lead to different outcomes, underscoring the need for scientifically grounded design solutions for buildings of various structures.

2.2. Methodology

According to the aforementioned studies, the clear challenges in renovation include a lack of experienced renovation specialists, the absence of standardized solutions, and ambiguity in decision-making methodologies. This article aims to address the first two interrelated issues. First, it should be noted that renovation often involves the comprehensive renewal of postwar buildings [1]. Buildings constructed after World War II tend to have a bleak character and lack adaptive architectural qualities [15]. Consequently, analyzing successful building renovations can help identify relevant solutions for buildings with specific construction types. Thus, the primary focus of this study will be on multi-apartment residential buildings constructed during this period.

As previously noted, different decision-making methodologies lead to varying outcomes. Therefore, the primary objective of this study is to identify patterns between renovation types and the structural schemes of buildings. The first stage of this research involves examining renovation examples documented in books and academic articles. Table 1 presents an analysis of these examples, highlighting the country, structural type, renovation type, building height, and the material used in the load-bearing structures.

Table 1. Analysis of renovation examples of multi-apartment residential buildings

Residential buildings	Structural type	Material	Number of floors	Renovation type
Bosnia and Herzegovina [16]	frame	wood	1	modernization, energy efficiency improvement
Tomsk, Russia [17-19]	load-bearing walls	wood	1-2	adaptation into administrative buildings
Ukraine [20]	load-bearing walls	clay brick	1-2	conversion into hotels
Madrid, Spain [21]	load-bearing walls	brick	3	addition of a fourth floor, adaptation of the first floor for public functions, creation of a safe courtyard
Grønby Strand, Brøndby, Copenhagen, Denmark [22]	frame	concrete, brick	2, 4, 16	connection with urban areas, renovation, addition of balconies, adaptation of the ground floors for public functions
Im Gut apartments, Zurich, Switzerland [22]	monolithic, load-bearing walls	concrete, brick	3, 5, 7	construction of a screen building, facade renovation, connection with urban areas
Kings Crescent Estate, London, United Kingdom [22]	load-bearing walls	brick, concrete	5-12	construction of new buildings, connection with urban areas, repurposing of ground floors
Tongerren Paspoel, Tongeren, Belgium [22]	monolithic	concrete	5-8	construction of additional levels, resolution of courtyard safety issues, privacy of spaces, apartment reconstruction
Zuidwestkwadrant, Osdorp, Amsterdam, Netherlands [22]	frame	concrete	4-12	construction of new buildings of various types, creation of a park zone, renovation
La Chesnaie, Saint Nazaire, France [22]	monolithic	concrete	10	metal extension to existing buildings, floor reorganization, facade renovation

Table 1 continued

Tybalds Estate, Camden, London, United Kingdom [22]	monolithic	concrete	10	facade renovation, creation of pedestrian pathways, addition of extensions on three sides
Ellebo Garden Room, Ballerup, Denmark [22]	frame	concrete	4	expansion of blocks by adding volumes made of reinforced concrete structures, installation of winter gardens on balconies, utilization of rooftop space, replacement of all facades, creation of gardens within the development
Rozemaai Apartment Blocks, Antwerp, Belgium [22]	monolithic	concrete	10	installation of new staircases and elevators, addition of a glazed gallery to reduce road noise and create winter gardens in the apartments; removal of partition walls between small apartments to combine them into spacious, comfortable units
Splayed Apartment Blocks, Ommoord, Rotterdam, Netherlands [22]	monolithic	concrete	14	organization of apartment entrances on the ground floor for elderly residents, addition of new staircases and elevators, facade renovation, and creation of service rooms on the ground floor
Colville Estate, Hackney, London, United Kingdom [22]	load-bearing walls	brick	3-6	renovation of existing buildings and construction of two high-rise residential buildings
Academy Street, Enfield, London, United Kingdom [22]	load-bearing walls	brick	3	demolition of buildings, addition of attic floors, landscaping of adjacent areas, and development of spaces adjoining the streets within the development
South Kilburn Estate, London, United Kingdom [22]	load-bearing walls	brick	4	facade renovation, addition of balconies, terraces, and winter gardens
The Bacton Low Rise Estate, Camden, London, United Kingdom [23]	frame	concrete, brick	3-5	construction of a new block between existing buildings
Goldsmith Street, Norwich, United Kingdom [22]	load-bearing walls	brick	2	creation of separate apartment entrances from the street, reorganization of buildings, modification of street dimensions
Hanoi, Vietnam [24]	load-bearing walls	brick	2	preservation of commercial spaces on the ground floors, expansion and reorganization of the second floors
Germany [25]	panel	concrete	4-5	rehabilitation, window replacement, replacement of heating equipment, facade renovation
St. Petersburg, Russia [26]	panel	concrete	5	construction of an attic floor
Tomsk, Russia [27]	panel	concrete	5	construction of an attic floor
Vienna, Austria [28]	load-bearing walls	brick	3-4	construction of modular attic floors made of wood
Moscow, Russia [29]	frame	concrete	5	addition of four floors
Estonia [30]	panel	concrete	5	demolition of balconies and loggias, and facade renovation using modular elements – energy-efficient panels with a thickness of 340-380 mm

The second stage of the research involves identifying building structure types and renovation types. Based on the analysis of examples, the following structural schemes of buildings with corresponding materials for load-bearing structures can be distinguished:

Table 2. Structure types of residential buildings

1.	Wooden frame/clay brick
2.	Bearing walls/brick
3.	Frame/reinforced concrete
4.	Panel/reinforced concrete
5.	Monolithic/reinforced concrete

The renovation types shown in Table 1 fully describe the work carried out in each individual example and represent a wide range of renovation options. However, the analysis allowed for the generalization and structuring of the renovation types as follows:

Table 3. Renovation types of residential buildings

1.	conversion into administrative buildings
2.	reorganization or reconfiguration
3.	adaptation of the ground floor for public functions
4.	addition of one floor
5.	addition of an attic floor
6.	addition of more than two floors
7.	facade renovation
8.	facade extension (addition of balconies, winter gardens)
9.	construction of additional volumes
10.	improvement of energy efficiency (replacement of windows, heating equipment, engineering systems)

The third stage of the study involves correlating the type of constructions (Table 2) with the type of renovations (Table 3) to identify the relevant renovation types for various buildings (Fig. 1).

	Wooden frame/clay brick	Bearing walls/brick	Frame/reinforced concrete	Panel/reinforced concrete	Monolithic/reinforced concrete
conversion into administrative buildings	●	●	○	○	○
reorganization or reconfiguration	○	●	●	●	●
adaptation of the ground floor for public functions	○	●	●	●	●
addition of one floor	○	●	●	○	○
addition of an attic floor	○	●	●	○	○
addition of more than two floors	○	○	●	○	○
facade renovation	●	●	●	●	●
facade extension (addition of balconies, winter gardens)	○	●	●	●	●
construction of additional volumes	○	○	●	●	●
improvement of energy efficiency (replacement of windows, heating equipment, engineering systems)	●	●	●	●	●

Figure 1. Relevant renovation types for buildings with different structures (source: authors)

3. Results and Discussion

3.1. Relevant Types of Renovation

3.1.1. Wooden Frame/ Clay Brick

Buildings with wooden frames or clay bricks are typically classified as part of historical development, for which restoration is the most common approach. However, an analysis of renovation projects revealed that residential buildings with such construction are often adapted for commercial and public functions, such as offices, museums, and retail spaces. It is important to note that all other types of renovations are unsuitable for these construction types due to the significant structural loads they impose on the buildings.

3.1.2. Bearing Walls/ Brick

In many cities around the world, multi-apartment brick residential buildings have been preserved to this day. These buildings were typically constructed with two to four stories. An analysis of renovation projects identified the following types of renovations applicable to this construction type:

- conversion into administrative buildings
- reorganization or reconfiguration
- adaptation of the ground floor for public functions
- addition of one floor
- addition of an attic floor
- facade renovation
- facade extension (addition of balconies, winter gardens)
- improvement of energy efficiency (replacement of windows, heating equipment, engineering systems)

A key feature of renovation projects for buildings with load-bearing brick walls is the emphasis on protection against excessive structural loads. Consequently, only an additional one or two stories can be added. Additionally, the strong load-bearing capacity of the walls and the possibility of creating openings allow for the reconfiguration of ground floors for public functions.

3.1.3. Frame/ Reinforced Concrete

Buildings with reinforced concrete frames are a common type of residential housing worldwide. An analysis of renovation projects for this construction type has identified the following types of renovations:

- reorganization or reconfiguration
- adaptation of the ground floor for public functions
- addition of one floor
- addition of an attic floor
- addition of more than two floors
- facade renovation
- facade extension (addition of balconies, winter gardens)
- construction of additional volumes
- improvement of energy efficiency (replacement of windows, heating equipment, engineering systems)

For buildings with reinforced concrete frames, nearly all types of renovations identified in this study are applicable. The framed load-bearing system enables modifications to internal layouts without compromising the structural integrity. Moreover, it is important to note that structural reinforcement allows for the addition of more than two extra stories.

3.1.4. Panel/ Reinforced Concrete

Panel residential buildings are emblematic of the industrialization era, with panel construction becoming particularly widespread in countries affected by World War II. Today, numerous studies critique panel houses and large-scale developments. Nevertheless, renovation projects for these buildings are actively being implemented worldwide. The analysis has identified the following types of renovations applicable to panel houses:

- reorganization or reconfiguration
- adaptation of the ground floor for public functions
- addition of one floor
- addition of an attic floor
- facade renovation
- facade extension (addition of balconies, winter gardens)
- improvement of energy efficiency (replacement of windows, heating equipment, engineering systems)

The primary characteristic of these buildings is their load-bearing panels, which impose limitations on apartment reconfiguration and the creation of additional openings. However, Germany's experience has demonstrated the successful renovation of panel buildings, including a complete transformation of their appearance. It is important to note that the main issue with panel houses is the uniformity of their facades and the lack of architectural scale and detail. Consequently, renovation projects are primarily focused on altering facades, redesigning entrance groups, and giving the buildings a distinctive and original appearance.

3.1.5. Monolithic/ Reinforced Concrete

Buildings made of monolithic reinforced concrete are typically high-rise residential structures with up to 14 floors (Table 1). The renovation of such buildings predominantly involves the addition of extra volumes. It is important to note that the addition of extra floors is not considered for buildings with this structural design. This decision is not related to the load-bearing capacity of the structures; rather, it reflects the preferences of residents or architects. In addition to expanding volumes, renovation efforts often include facade upgrades and interior reconfiguration.

3.2. Recommendations for Residential Building Renovation

This study enables the formulation of a general decision-making strategy for the renovation of buildings

with various structural systems. A common feature of all the analyzed projects is their focus on the urban planning context. Most renovation decisions pertain not to individual buildings but to the development as a whole. It is important to emphasize the multifaceted nature of the renovation process, which may include upgrading, preservation, and new construction. Therefore, in the initial stage, project participants should define the project concept and identify the specific, evident problems at the neighborhood or city level that the project aims to address.

The second key aspect in decision-making is the social impact. The analyzed renovation projects demonstrate significant benefits for apartment owners, primarily through the improvement of their living conditions. Notably, some renovation decisions aim to strengthen neighborly relations and foster a shared interest in enhancing their homes.

The third aspect is the economic impact. Based on the analysis of case studies, it is evident that all renovation projects are aimed at improving the performance characteristics of buildings. Enhancing energy efficiency through facade upgrades and the installation of new engineering systems clearly yields economic benefits. Additionally, adapting ground floors for public use contributes to economic efficiency by providing effective servicing of the residential building. Extensions and additions directly influence economic outcomes, as they increase the appeal of the property by offering additional living space.

4. Conclusions

Renovation is a complex process that requires architects to consider various factors and nuances. Without a proper understanding of the workflow, the outcomes of renovation may fail to meet the residents' expectations and could negatively impact the development and the city as a whole. This study has identified a relatively clear decision-making mechanism (Figure 2). However, the decision-making model represents a generalized approach, encompassing numerous tasks that demand specific solutions.

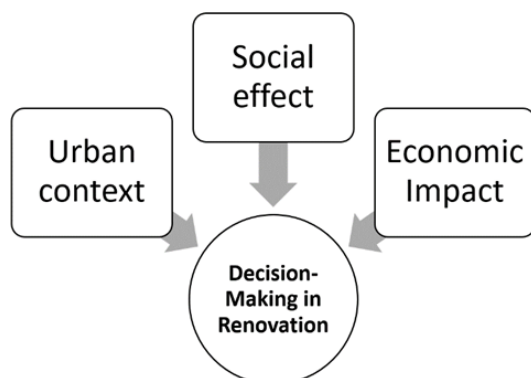


Figure 2. A decision-making model for renovation (source: authors)

As mentioned earlier, the absence of standardized solutions and the need to define the boundaries of renovation complicate the process. The findings of this study can serve as a framework for further refinement of renovation projects. Naturally, depending on the analyzed examples, the types of renovation may be expanded and clarified. Nonetheless, the results of this research provide a foundation for establishing a renovation trajectory for buildings with specific structural systems. Thus, during the stage of discussions with residents, all stakeholders in the process can already consider potential options and, more importantly, agree on the boundaries of the renovation.

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