EVALUATION OF THE LIFESPAN AND QUALITY OF MULTI-FAMILY RESIDENTIAL BUILDINGS IN SERBIA: A TYPOLOGICAL PERSPECTIVE

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ABSTRACT

The lifespan of a residential building is a complex, multi-criteria process that can be evaluated through three key dimensions: physical, functional, and economic lifespan. A building's lifespan is determined by the preservation of its physical integrity, functional utility, and economic viability. Several factors influence the durability of a building, spanning from design and construction to ongoing maintenance. These factors can be categorized into legal regulations, environmental influences, and human actions. This paper focuses on evaluating the condition of Serbia's multi-family residential stock through the lens of building lifespan and the quality of the housing stock. Serbia's multi-family residential buildings vary significantly in construction period, size, construction methods and materials, and spatial organization. To comprehensively understand this diversity, the study proposes a typological classification of buildings that reflects the specific characteristics of different construction periods. These typologies are structured based on parameters assessed during a life cycle evaluation. The paper presents and analyzes three primary types of multi-family residential buildings, along with several subtypes representing the broader spectrum of the residential stock. Based on established evaluation criteria, an assessment of the multi-family housing stock in Serbia is conducted, providing insights into the current state of these buildings and offering guidance for potential renovation strategies.

KEYWORDS _ *Lifespan assessment, Residential buildings, Multi-family housing, Building typology, Building quality*

INTRODUCTION

Assessing a building's lifespan is a complex and multi-criteria process encompassing a much broader range of influences than just the durability of the materials from which the building is made. Researchers from various disciplines have addressed this topic, and the generally accepted conclusion is that the lifespan of a residential building can be viewed through three different categories: physical, functional, and economic, thereby covering all relevant parameters. A building is usable, and its life cycle lasts as long as the conditions of its physical integrity, functional usability, and economic viability are met (Rustempašić et Čaušević, 2014).

The topic of this paper is the condition of Serbia's multi-family residential stock from the perspective of their lifespan and, through this, an examination of the quality of this building stock. Multi-family buildings, as communities of a more significant number of apartments, represent the result of complex considerations of the functional organization of space, material selection, and type of construction. Their maintenance process is significantly more complex, and as such, they represent artefacts that significantly shape the city's structure. On the other hand, the residential building stock, in general, represents a significant resource for any country, and its quality directly reflects the quality of life of its citizens.

To examine the characteristics of this complex set, typological representatives that embody the characteristics of certain construction periods and are structured according to the parameters evaluated during the life cycle assessment must be identified. The paper identifies and analyses three basic types of buildings.

A vital part of the paper is the criteria for valuing the quality of the residential stock, where it was necessary to cover all the different aspects that affect the lifespan of a building and establish the measurability of each parameter and the valuation system. The paper aims to comprehensively examine the problems of residential stock from the perspective of its lifespan to define the directions for its maintenance, improvement, enhancement, and alignment with modern living conditions.

CLASSIFICATION AND REPRESENTATION OF THE MULTI-FAMILY RESIDENTIAL STOCK

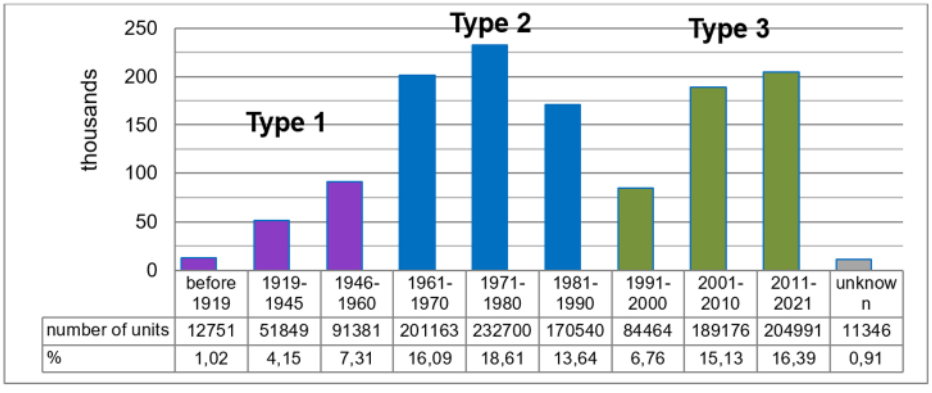
The structuring of the total multi-family residential stock in Serbia has been carried out through three basic types that represent the applied construction techniques, structural assemblies, used materials and systems, characteristic functional organization, and urban planning. In short, these are all the parameters that determine a building's physical, functional, and economic lifespan.

Type 1 buildings are structures built up to 1960, featuring massive structural assemblies with brick as the most commonly used wall material. Multi-family, multi-story buildings in Serbia appeared only at the end of the 19th and the beginning of the 20th century. These buildings are characteristic of urban-type settlements and are often located in central city areas. The spatial organization of such buildings corresponds to the type of salon apartments, which were built for wealthier citizens and modelled after Central European cities. During the interwar period, brick remained the dominant material for massive masonry structures, with changes in the construction of buildings seen in inter-floor ceilings, where reinforced concrete increasingly replaced wooden construction. After World War II, masonry construction remained in use, and what distinguishes this period from the previous ones is the maximum economization in construction due to post-war poverty and the need to eliminate the consequences of war destruction (Đukanović, 2021). In addition to construction within central urban zones, separate settlements outside the city centre were also formed. Since traditional construction methods characterise all these buildings, the application of massive masonry construction, largely ribbed inter-floor ceilings, and sloping roofs are classified under Type 1. According to the latest data from the 2022 Census of Population, Households, and Dwellings in Serbia, apartments belonging to the first type of masonry buildings account for 12.5% of the total multi-family residential stock

(Statistical Office of the Republic of Serbia, 2022) (Figure 1). Considering that the first type of buildings was constructed with massive masonry and brick as the construction material, covering the period up to the 1960s, this type of building ranged from 65 to 150 years (Figure 2).

Type 2 buildings represent structures that emerged during the housing construction boom between 1960 and 1990 when prefabricated construction methods in reinforced concrete were widely applied. The domestic IMS prefabricated system was most commonly used in the construction of residential buildings. This system is a prefabricated, skeletal, prestressed reinforced concrete structure consisting of columns up to three stories high, cassette-reinforced concrete ceilings, and cantilevered slabs. The system was primarily based on the assembly of the structure, while the facade could be built using a traditional system, prefabricated, or partially prefabricated methods (Marković et al., 1967). Many multi-family buildings across Yugoslavia were constructed using the IMS system, representing the post-war housing stock designated Type 2 in this study. During this period, so-called concentrated residential construction began in larger, unified urban areas where building a minimum of 1,000 apartments and applying prefabricated construction methods was necessary (Jovanović et al., 2013). This type of building encompasses the period when the trend of residential construction was on the rise, heavily utilizing prefabricated construction methods. These apartments account for approximately 48.5% of the total multi-family residential stock (Statistical Office of the Republic of Serbia, 2022) (Figure 1). The age of this part of the housing stock ranges from 35 to 65 years (Figure 2).

The latest period of residential construction since 1990 is characterized by political and economic changes that impacted the intensity of housing construction and changes in construction methods. During this period, sizeable state-owned construction companies collapsed, the construction industry was privatized, and the prefabricated construction method was abandoned in favor of a return to traditional construction systems, but at an improved level. The structural assembly of residential buildings became a combined skeletal-massive system, where the wall structure consists of hollow clay blocks, and the ceiling is cast-in-place reinforced concrete or semi-prefabricated with a combination of clay elements and reinforced concrete (Jovanović et al., 2016). At the beginning of this period, construction within the existing urban framework was typical, using private plots to construct multi-family buildings. Later, larger residential blocks were also formed. During this period, regulations on thermal protection of buildings were tightened with the introduction of the Energy Efficiency Rulebook in 2011 (Ministry of Environmental Protection, Government of the Republic of Serbia, 2011), which led to radical changes in the thermal envelope of buildings. The latest, third type of buildings, characterized by a return to improved traditional construction methods, accounts for about 38% of the total multi-family residential stock (Statistical Office of the Republic of Serbia, 2022) (Figure 1), and their age ranges up to 35 years (Figure 2).



	before 1919	1919-1945	1946-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010	2011-2021	unknown
number of units	12751	51849	91381	201163	232700	170540	84464	189176	204991	11346
%	1,02	4,15	7,31	16,09	18,61	13,64	6,76	15,13	16,39	0,91

Figure 1: Diagram of number of apartments and percentage representation according to construction periods and defined types of multi-family residential buildings

Type	T1	T2	T3
Constr. period	1900-1960	1960-1990	1990-now
Photograph of a representative example of a building type			
Structure assembly	**Massive assembly**	**Concrete prefabrication**	**Enhanced massive assembly**
Structural system	Masive structural system	IMS skeleton frame structure, panel concrete structure	Combination of massive and concrete skeleton structure
Position in an urban environment	patching in the central urban core (earlier) and construction within new urban blocks (later)	construction within new open urban blocks	patching in the central urban core (earlier) and construction within new urban blocks (nowadays)
Spatial organization	exclusive apartments - "Salon apartments" and rational and efficient spatial organization	rational and efficient spatial organization	rational and efficient spatial organization and flexible spatial organization
Foundations	hardened or reinforced concrete	reinforced concrete	reinforced concrete
Facade wall	double-sided plastered massive brick wall (old and new brick formats since 1931)	prefabricated concrete panels with minimal thermal insulation as part of the wall structure (thermal insulation 4-5cm)	massive wall of hollow bricks or concrete blocks with thermal insulation and facade finishing of plaster or facade brick / ventilated façade
Intermediate floor construction	concrete ribbed slab with a concealed floor and exposed ceiling	reinforced concrete solid or hollow slab with a floating floor	reinforced concrete slab or semi-precast beam and hollow brick construction with a floating floor
Roof type, roof construction and roof covering	pitched roof, traditional wooden construction, clay	flat concrete roof with minimal thermal insulation, gravel or concrete	pitched roof, modern wooden construction with thermal insulation, clay, or flat concrete roof with thermal insulation, bitumen
Thermal insulation in building envelope	no thermal insulation in the building envelope	minimal thermal insulation as part of the wall assembly - Tarolit or Styrofoam 4-5cm	thermal insulation - Styrofoam or mineral wool 5-8cm, later 10-15cm
Windows	wooden double frame windows, small individual windows on the building facade	wooden double frame windows, horizontal ribbon windows on the facade	PVC frame windows, individual windows on the building facade
Heating system	electric heating stove	district heating system	district heating system

Figure 2: Characteristics of types of multi-family residential buildings

DURABILITY OF APPLIED MATERIALS OF MULTI-FAMILY RESIDENTIAL STOCK

Many researchers have studied the lifespan of building materials through various historical periods and conditions of use. Based on the analysed literature in this field (Jackson, 2007; Thomsen & Straub, 2018; Rustempašić & Čaušević, 2014), a table (Table 1) has been compiled showing the expected lifespan of materials/components used in the construction of the primary structures of building types and the materials that form the building envelope. The lifespan of the applied materials is expressed in years.

Position on the building envelope	Material/component	Lifespan of the material/ component
Foundations	hardened concrete	>100
	reinforced concrete	
Walls	reinforced concrete	>100
	autoclaved aerated concrete	
	solid brick	
	hollow brick	
Intermediate floor construction	ribbed slab - concrete	>100
	reinforced concrete	
	prestressed concrete slab	
	brick + reinforced concrete	
Pitched roof const.	wooden rafters	60
Flat roof const.	reinforced concrete	>100

Position on the building envelope	Material/component	Lifespan of the material/ component
Thermal insulation	tarolit	50
	heraklith	
	expanded polystyrene	
	mineral wool	
Roof covering	clay	50
	sheat metal	10
	fiber-cement	25
	gravel	30
Windows	wooden frame	30
	PVC frame	15-20
Heating system	electric heating stove	15-20
	district heating system	

Table 1: Lifespan of the materials/components used in building's construction

The lifespan of materials provided in Table 1 served as the basis for forming a Gantt chart that illustrates the timeframes of the durability of the materials and components installed in each type of building. Additionally, it indicates the period during which maintenance or replacement measures need to be undertaken to extend the building's lifespan (Figure 3).

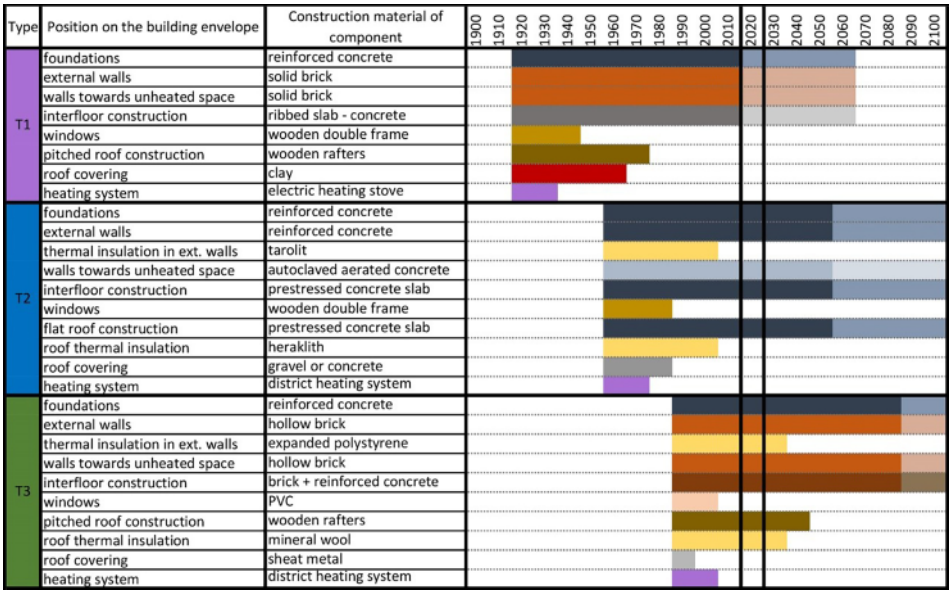


Figure 3: Gantt chart of durability of applied materials and components in building types

ASSESSMENT OF LIFESPAN AND QUALITY OF MULTI-FAMILY RESIDENTIAL STOCK

Assessing the lifespan of multi-family residential buildings involves analyzing various aspects of the building's life cycle, from design and construction to maintenance. To ensure the credibility of the building's lifespan assessment, the evaluation is based on criteria that encompass physical, functional, and economic lifespans. The rating system ranges from 1 to 3, where 1 indicates the lowest and 3 the highest quality level of the criteria. Precise evaluation, critical analysis of the lifespan and quality of multi-family residential buildings are precised by this system (Table 2).

Type of lifespan	*Criteria*	T1	T2	T3
Physical lifespan	Percentage of the multy-family residential stock	1	3	2
	Lifespan of the multy-family residential stock	1	2	3
	Lifespan of the construction materials	1	3	2
	Compliance with current thermal regulations	1	2	3
Functional lifespan / living comfort	Spatial adaptability of the residential unit	1	3	2
	Spatial comfort of the residential stock	2	1	3
	Light comfort of the residential stock	1	3	3
	Thermal comfort of the residential stock	1	1	3
	Acoustic comfort of the residential stock	3	1	2
Economic lifespan	Economic feasibility of maintenance	2	1	3
	Total score:	**14**	**20**	**26**

Table 2: Valorization of types of multi-family residential buildings according to defined criteria

The physical lifespan of a building encompasses its age and overall quality of the applied structure, and the materials and components used. To achieve a long physical lifespan for a building, it is necessary, during the design phase, to consider external location factors, foresee high-quality and durable construction materials and components, make an appropriate choice of structural system and execute construction works correctly during the realization phase. In the third phase, the physical lifespan of the building is influenced by the quality of its use, the quality of building maintenance, and continuous compliance with legal regulations. The first criterion shown in Table 2 defines the percentage representation of types of multi-family buildings in the total housing stock of Serbia, which also establishes the urgency of their renewal, with the least represented types receiving the lowest rating. Based on Figure 1, Type 1, with a 12.5% share, received the lowest rating. Type 2, with a 48.34% share, received the highest rating, while Type 3, with a 38.5% share, received an average rating. The lifespan of a typical building representing the housing stock is the second criterion evaluated, dealing with assessing the period during which buildings are functional and safe for habitation, considering the period when the building was constructed. Based on the Gantt chart (Figure 3), buildings built before 1919 require significant renovation, thus receiving the lowest rating. On the other hand, modern buildings and those constructed in the last 30 years have a longer lifespan and, therefore, receive the highest rating. Buildings built half a century ago, classified as Type 2, receive an average rating. The following criterion for evaluation is the lifespan of individual construction materials used in the typical building representing a particular construction period. The lifespan of materials used in building construction can be assessed based on the durability of materials (Table 1) and the Gantt chart (Figure 3). Type 1 is rated the lowest due to the significant proportion of materials and components whose lifespan has already expired and whose renewal and replacement are necessary to improve the quality of this housing stock. Type 3 receives an average rating, with a higher percentage of short-lifespan materials. Type 2 receives the highest rating due to applying a higher proportion of long-lasting materials in the building's construction. Compliance with current regulations primarily concerns thermal protection standards affecting energy efficiency. Buildings belonging to Type 3 are rated highly due to their compliance with modern thermal standards. Type 1 buildings, without thermal insulation, receive the lowest rating and need significant energy renovations. Type 2 buildings receive an average rating as they include thermal insulation, but are of insufficient thickness.

The functional lifespan of a building involves fulfilling all conditions of residential comfort and includes parameters such as spatial, lighting, thermal, and acoustic comfort. For spatial comfort, the application of flexibility and adaptability principles during the design phase is crucial. The rigidity of the spatial organization of residential units is a direct consequence of the applied structural assembly, precisely the structural elements' position, dimensions, and spans. The first functional parameter included in the evaluation of building types (Table 2) is the adaptability of the

residential unit, assessing its ability to adapt to different needs efficiently. Skeletal structures from the prefabricated construction period (Type 2) allow simple changes in spatial organization without demolishing primary structural elements and are therefore rated the highest. In contrast, buildings with massive walls have limited possibilities for spatial changes, requiring partial demolition of the primary structure, and are rated lower. Modern construction approaches return to an improved traditional approach, combining massive and skeletal systems, achieving medium adaptability. The following parameter of functional lifespan is the spatial comfort of residential units, evaluated based on apartment size, functionality, and quality. Apartments with minimal dimensions from the period of rational mass housing construction (Type 2) are rated the lowest. Salon apartments of Type 1, offering better spatial organization, received medium ratings. Modern Type 3 buildings, with high-quality spatial organization resulting from a combined structural assembly, are rated the highest. Light comfort is evaluated based on the quality of natural lighting in residential units, which is also influenced by the choice of structural assembly. Buildings of Types 2 and 3 predominantly feature large windows due to the skeletal and combined assemblies, thus rated the highest. Buildings of Type 1, with small window openings due to the specifics of the structure and applied materials, received the lowest rating. Thermal comfort in multi-family residential buildings is assessed based on their ability to maintain a pleasant indoor temperature, considering construction materials, thermal insulation, windows, and heating system efficiency. Buildings constructed after 2011, meeting modern thermal regulations (Type 3), are rated the highest. Type 1 and Type 2 buildings are rated the lowest and do not meet current regulations. Acoustic comfort is evaluated based on material quality, sound insulation, and floating floors. Buildings with traditional massive systems and old brick formats (Type 1) received the highest ratings for acoustic properties. Type 3 buildings received a medium rating, while Type 2 buildings, due to reinforced concrete and cost-saving measures, received the lowest rating.

The economic lifespan of a building is a criterion that represents the analysis of its maintenance costs to determine the most cost-effective approach for long-term maintenance of the housing stock. It is based on the initial cost of maintenance investment and considers the long-term savings and efficiency of the building. Type 3 buildings receive the highest rating due to their relatively young age, which results in lower maintenance costs. Type 1 buildings receive a medium rating because they predominantly consist of luxurious salon apartments in city centres, which justifies an economic investment in maintaining these old buildings. Type 2 buildings receive the lowest rating because they predominantly consist of small apartments outside the city centre, leading to less economic justification for maintenance investment.

CONCLUSIONS

According to Table 2, the evaluation results show that, based on the set of criteria, Type 3 multi-family residential buildings receive the highest rating in the assessment of lifespan and quality. The relatively young age of these buildings significantly influences their lifespan. Still, using a combined structural assembly, which allows for spatial flexibility, adaptability, and compliance with modern thermal and acoustic protection requirements, also affected the final analysis results. Type 2 occupies the second position, while Type 1 is in the lowest position due to the age of the buildings, the materials used, and the lack of compliance with contemporary energy efficiency regulations. Extending the lifespan and improving the quality of both Type 1 and Type 2 multi-family residential buildings is crucial for preserving the multi-family residential stock. Although these two types differ significantly in many aspects, such as construction, materials used, and spatial organization, they represent a significant portion of the multifamily residential stock. Therefore, their physical preservation and functional quality are essential.

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