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Implementation of an Innovative Model of the Comprehensive Energy Renovation Project of a Cultural Heritage Building in Ljubljana, Slovenia

N. Jejčič[1,*], M. Tomšič[2], M. Šijanec Zavrl[3]
[1] Building and Civil Engineering Institute ZRMK, Ljubljana, Slovenia, neva@gi-zrmk.si; [2] Building and Civil Engineering Institute ZRMK, Ljubljana, Slovenia, miha.tomsic@gi-zrmk.si; [3] Building and Civil Engineering Institute ZRMK, Ljubljana and New University, European Faculty of Law, Slovenia, marjana.sijanec@gi-zrmk.si,

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Abstract
Renovation of a building requires a comprehensive and targeted approach to managing the process from conceptual design to implementation and future use. Cultural heritage buildings are subject to specific legalities and restrictions in accordance with the conservation regime. The complexity of such a renovation process requires special knowledge and competence of the stakeholders involved. The key is constant and coordinated cooperation among the designer, the cultural heritage protection authority, the investor, the users, the supervisor and the contractor. This rationale inspired the creation of a model of the comprehensive energy renovation process, balancing heritage conservation with energy efficiency through nine key elements and quality guidelines, developed within the LIFE IP CARE4CLIMATE project. The model includes detailed steps of the renovation with quality guidelines for the conceptual design, inspection of the building's condition, financial planning, comparison of variant renovation measures, energy performance analysis and investigation of several other aspects, for instance fire and electric safety, earthquake resistance and the quality of the indoor environment. The model includes support to the investor in the preparation of tenders, contractor selection, supervision, and building management and monitoring plan. This innovative model has been successfully implemented in renovation of several heritage buildings in Slovenia. A more detailed description of its implementation in practice is presented on an award-winning renovation project of heritage building in Ljubljana, Slovenia.

Keywords: *comprehensive renovation; process model; cultural heritage buildings; best practice*

1. Introduction

Building management and maintenance are essential elements to ensure the good physical condition of any building, aiming to extend its lifespan and preserve its property value. This applies particularly to cultural heritage buildings. When renovating them, we must take special care to follow the basic principle of protecting and preserving the values of cultural heritage, as we are committed to safeguarding such buildings for both present and future generations.

Specific rules and restrictions apply to the renovation of heritage buildings. These define the permitted interventions that must be strictly

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adhered during renovation. The renovation should be comprehensive, as only this will enable the continued existence and enrichment of the cultural heritage.

The main principle for the renovation of heritage buildings is to achieve an acceptable balance between permissible measures in compliance with the protection regime and technical measures in line with the construction regulation. It is important to consider reasonable life cycle costs of renovation and the financial capacity of the investor as well as additional sources of financing, e.g. loans and subsidies.

2. Objectives

The objective of this paper is to present an innovative model developed for the comprehensive energy renovation process of cultural heritage buildings (residential and public) with nine key elements and embedded quality guidelines, and to illustrate its practical application in an award-winning multi-apartment building in Ljubljana, Slovenia.

2.1. National legislation

Cultural heritage is a constitutional category in Slovenia (Ustava Republike Slovenije (RS), 1991). We thus recognise its important role among the values that shape our country and statehood. Policies and regulations for the protection of cultural heritage are formulated in accordance with constitutional provisions.

Thematic directives and international guidelines have been adopted at the EU level, setting out the principles of integrated heritage conservation.

The umbrella act is the Cultural Heritage Protection Act (Zakon o varstvu kulturne dediščine, 2008), which stipulates that any interference with cultural heritage must first be subject to cultural protection conditions and then to cultural protection consent, balancing the reasons for interventions with the reasons for preserving the heritage in its existing form.

Any intervention must comply with the Spatial Planning Act (Zakon o urejanju prostora, 2022) and the municipal spatial implementation acts. The renovation must also comply with the essential requirements of the Building Act (Gradbeni zakon, 2022), insofar as they do not conflict with permissible interventions from the point of view of cultural heritage.

Guidelines for energy renovation of cultural heritage buildings (Ministrstvo za infrastrukturo RS in Ministrstvo za kulturo RS, 2016), which are currently being updated within the national targeted research project CRP V5-2358 (DEDIS), set out the basic principles for renovation. The guidelines emphasize finding solutions that respect heritage values while improving energy performance.

The 2050 Long-Term Strategy for the Energy Renovation of Buildings (Dolgoročna strategija energetske prenove stavb do leta 2050, 2021) sets out policies and approaches to decarbonise the national building stock by 2050 and outlines measures to support the set goals.

2.2. Technical aspects

The positive effects of the renovation can be achieved at several levels through sensible and professionally tested measures with solutions in cooperation with the heritage service: restoration of damage and defects in the structure and building envelope, moisture remediation and other building physics problems, reduction of energy costs and emissions to the environment, extension of regular maintenance intervals, etc. Achieving these benefits requires careful consideration of alternative solutions and selecting those most compatible with preserving the building's heritage values.

2.3. Challenges and needs

In practice, a protocol for steering a heritage renovation project is needed to follow the necessary quality assurance and thus consider heritage protection rules, technical legislation,

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comply with financing preconditions and finally reach the heritage building condition needed for future use. The development of a heritage building renovation quality assurance was subject to the LIFE IP CARE4CLIMATE project and upgrading of the national certification scheme Quality Label in Buildings and Construction (Building and Civil Engineering Institute ZRMK, Ljubljana, (GI ZRMK) 2010).

3. Methodology

The development of the Heritage Building Renovation model (HBR model) took place in several steps. It started at the theoretical level, with the study of policies, strategic and implementing acts, followed by research on end-users' and homeowners' needs in building renovation through consultations, and study of experience in developing and managing renovation projects.

The HBR model initially included more detailed renovation process steps during the planning and implementation phase. In pre-testing the HBR model on renovation projects in practice, it turned out that the model needed to be extended from conceptual design to implementation and monitoring, as well as to additional trainings for investors needed for better understanding the trade-offs between heritage protection and building renovation. The main obstacle proved to be in the financing of renovations - ranging from the large scale of the works required to the high labour cost caused by the lack of suitably qualified contractor' staff. The methodology of the heritage renovation approach defined in the HBR model has been demonstrated and verified on the case study of an award-winning multi-apartment building in Ljubljana, Slovenia, presented in more detail in Chapter 5.

4. Results

The elaborated HBR model contains nine key quality elements designed to ensure a high-quality outcome in the comprehensive renovation of heritage buildings. A schematic representation of the HBR model is shown in Fig. 1.

4.1. Quality Elements (QE)

Nine Quality Elements (QE 1-9) are presented and described below:

QE 1 - Preparation of the project brief with conceptual design. It involves the development of a detailed content and scope of work. Included is digitalisation of original plans with measurement control and a review of the actual state of the building. Digitalisation of plans is the

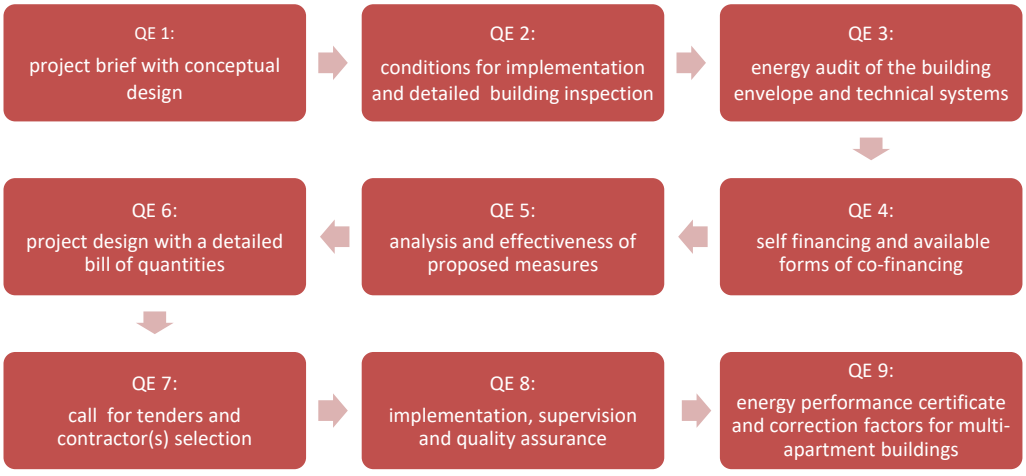

Fig. 1 – *Schematic representation of the project flow HBR model* (GI ZRMK, 2021).

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basis for creating the conceptual design, the key document for obtaining cultural protection and other conditions, as well as for creating a BIM model for building management.

QE 2 - Conditions for implementation and detailed general survey of the building's condition. The actual conditions and possibilities for implementation are checked. A detailed general survey of the building's condition is carried out, such as design features, cracks and other deformations in the structure and terrain, the state of fire and electrical safety, the condition of the roof, façade, windows, doors and protected heritage elements. This is crucial for understanding the building's specific heritage values and vulnerabilities.

QE 3 - Energy audit of the building envelope and building technical systems. An extended or simplified energy audit of the building envelope (floors, walls, ceiling or roof), building technical systems (heating, cooling, ventilation, lighting), and indoor conditions (e.g., presence of mould, daylighting, air quality) is carried out.

QE 4 - Financing and other forms of co-financing. An analysis is made of the feasibility of measures based on financial capabilities of the investor and possible sources of co-financing and the availability of loans and other financing mechanisms.

QE 5 - Analysis and effectiveness of proposed measures. A detailed analysis with calculations of the effectiveness of alternative measures and assessment of their impact on aspects of sustainable construction is prepared. In the case of a cultural heritage building, cooperation with the competent conservator is essential. Different technical solutions (e.g., thermal insulation, texture and colour of the plaster) should be evaluated, choosing those that most effectively combine energy efficiency with the preservation of heritage features. Renovation is always preferred over replacement where technically feasible and appropriate from the conservation perspective.

QE 6 - Project design. The project design is prepared with detailed specifications, which include restoration works and a detailed bill of quantities. The planned measures are coordinated and approved by the competent authority, which gives cultural heritage conditions and consent to the project implementation.

QE 7 - Call for tenders and contractor(s) selection. The tender for the selection of the service provider(s). Contains clear and transparent criteria based on technical and technological aspects, the desired level of quality, and the financial statement of the bidders.

QE 8 – Implementation, supervision and quality assurance. A quality assurance protocol is crucial during the implementation phase. In addition to construction supervision, the conservation service also oversees the work. The supervision ensures that all work is carried out in accordance with the accepted construction and heritage standards.

QE 9 - Energy performance certificate and heat billing correction factors for multi-apartment buildings. After the completion of all work, an energy performance certificate of the building is issued at the request of the clients. This is otherwise mandatory under the Act on Energy Efficiency (Zakon o učinkoviti rabi energije, 2020), and applies when selling or renting out, even for cultural heritage buildings other than sacral. If the renovation involves a multi-apartment or other building connected to district heating or another common heating source, correction factors are calculated to ensure fair sharing of heating costs.

4.2. Monitoring

It is recommended to monitor the effects of the energy measures implemented for at least two years after the renovation. Every renovation requires a comprehensive and timely insight into the project, its implementation and monitoring of the effects of the measures, which can also be

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carried out gradually or in steps. This means that necessary structural reinforcements and consolidations are carried out first to increase the strength, stability and seismic resistance of the building. Measures to eliminate and prevent moisture (e.g., roof leaks, preventing capillary moisture from rising) also have a high priority. In the next step, an energy renovation of the building envelope is undertaken, and in the final step, measures on the building technical systems are implemented.

5. Discussion – case study verification

The principles of heritage conservation and adherence to the HBR model were verified in the energy renovation of several buildings. Here, the case of a two-story workers' multi-apartment building from 1922 at Einspielerjeva 25 (E25) in Ljubljana, Slovenia, is presented. The project took place from late 2021 and was completed in the spring of 2024. Monitoring will continue until 2027.

5.1. Description of the building

The building E 25 (Fig. 2) has an irregular shape, divided into three parts with three entrances with staircases, and 16 apartments. On the ground and the first floor there are two-room apartments with an eat-in kitchen and sanitary facilities. In the attic, which has a wooden gable roof, there are two original one-room apartments, and larger apartments built after 1970. The building is traditionally built with old-format brick, known as the “Austrian” format.

The basement is located under the central part of the building. Above it is a massive ceiling made of steel beams and brick arches, while the rest of the floors have wooden ceilings. The windows have already been replaced and some of them are equipped with shutters in different shapes, colour shades and designs.

The roof was covered with brick roof tiles a few years ago, except two small sections on the central attic are covered with the original metal.

Most of the apartments are heated via district heating, some use a gas boiler. Ventilation is natural, through window openings. Individual external units of air conditioning devices were randomly mounted on the façade. Mould appeared on the interior walls in several spaces.

On the north side, there is a green area separated from the road by a fence and trees, and on the south side, there are parking spaces and the alley.

Fig. 2 – *View on the north, main façade before renovation* (GI ZRMK, 2021).

The building has gradually become disorganised and externally neglected due to haphazard interventions, and its installations urgently need renovation.

5.2. Renovation – the HBR model application

The spatial acts indicate that the building is listed in the cultural heritage register as part of the settlement heritage. This designation means its external appearance, including specific façade elements, contributes significantly to the character of the area and requires protection. The key renovation processes are presented in more detail below, summarized in the planning, implementation, and financing chapter.

5.2.1. Planning Process (QE 1 – QE 6)

The first step, a discussion and on-site inspection of the building were conducted with the investors (the building manager and homeowners) to identify their goals and capabilities. Based on this, a conceptual project has been designed with defined goals, content, and scope of the

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renovation. The original plans were obtained from the Archives of the RS (Fig. 3). This was followed by the digitalisation of the plans with on-site measurement control (QE 1).

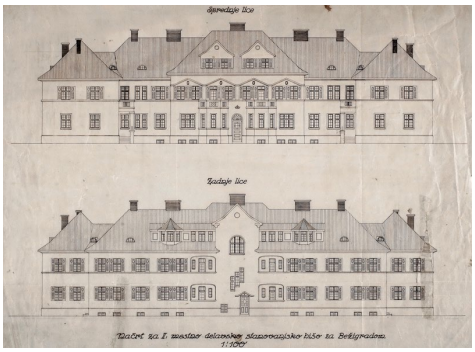

Fig. 3 – *The original plan of the north and south façades* (Arhiv RS).

Simultaneously, a detailed survey of the actual condition and living conditions in the building was conducted (QE 2), along with a simplified energy audit. Measures were planned for the building envelope and technical building systems related to cooling and air conditioning. This was done in close and dynamic cooperation with the conservation service, investors, and the building manager (QE 3). In parallel, possible sources of financing were examined (QE 4). Variant renovation solutions were evaluated, particularly concerning the acceptable thickness of the external thermal insulation and shutter design to ensure the preservation of its original proportions and detailing (QE 5).

Due to the protection regime, which aims to preserve the building's external appearance (a primary heritage value), and considering previous solutions, a slightly smaller thickness of thermal insulation (10 cm) was deemed permissible on the façade. This contrasted with the thicker layers (16 cm) required by the Rules on the efficient use of energy in buildings at that time, U<0.20 W/(m²K), (Pravilnik o učinkoviti rabi energije v stavbah, 2010) and Eco Fund's tender conditions for the allocation of non-refundable financial incentives. This decision, made in close consultation with the conservation service, represents the key aspect of balancing heritage protection with energy efficiency goals.

The protected elements on the façade, which exhibit one of the most important heritage values, were coordinated with the conservation service. Cornices, ornaments, medallions, originally rendered in stamped plaster were meticulously replicated in the same form using the chosen thermal insulation material, which was then finished with a final layer (several samples of different granulation, composition, textures and colours).

As noted in Section 5.1, most of original windows had already been replaced haphazardly over time. Therefore, the intervention focused on improving the overall coherence and energy performance of the existing windows. This involved unifying the appearance with replacement of authentic wooden shutters throughout the building. In this project, the focus was on the new shutters and reinforcing existing dormer windows to improve their structure and image, giving the building a uniform appearance.

An installation of outdoor air conditioning units in exposed locations was not allowed. The openings for the ventilation system on the south façade and the proposed ventilation method in the window reveals on the north, street-facing façade (appearance protected) were unified.

The interior of the building is not protected, so thermal insulation was added to the basement ceiling and above the staircase entrance in the central part (14 cm), and in the common attic area and under the roof by the eaves (26 cm), in accordance with the requirements of the mentioned Eco Fund tender.

Two small parts of the attics received a new metal (zinc-copper-titanium (Zn-Cu-Ti)) roofing. The metal flashings at the roof eaves, gutters, rainwater pipes (Zn-Cu-Ti) and the snow guards (metal) were replaced with original material. The terraces were thermally insulated and waterproofed and unified railings were added to protect external appearance (QE 6).

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5.2.2. Implementation (QE 7 – QE 8)

The tender for the selection of the contractor was conducted at the level of the Municipality of Ljubljana (MOL) (QE 7). The implemented measures on the building envelope were accompanied by other vital interventions, such as creating an opening for stairs to the loft from common areas, reinforcing dormers windows, unifying the railings of subsequently constructed terraces in the attics, and improving fire safety. In addition to the regulations in this area, the guidelines for Fire Protection in Cultural Heritage Buildings (The Confederation of Fire Protection Associations Europe, 2013) were also considered for fire safety.

In addition to installing fire barriers at the height of ceiling structures and near parking areas along the façade and entrances, it was necessary to install fire doors in the basement, dividing the building into three fire sectors. The relocation of the gas boiler flue from the *façade* to above the roof was carried out, and obstacles on the staircases were removed for safe evacuation in case of fire or other emergencies. The renovation also included the electrification of basement areas and the modernization of common electrical installations on the staircases, as well as the illumination of building entrances (Fig. 4).

Fig. 4 – *Depiction of the renovated north, main façade.* (GI ZRMK, 2024).

The quality assessment and control during implementation involved regular site visits by the MOL and GI ZRMK supervisor, designer, and heritage conservator to ensure adherence to the approved plans and heritage protection conditions and consent, particularly regarding the repetition of the façade details using appropriately shaped insulation material (QE 8).

An energy performance certificate and heat billing correction factors were produced (QE 9).

5.2.3. Financing of the renovation

The renovation of E25 was financed by the owners' resources previously collected in the reserve fund (obligatory monthly contribution), a factoring loan, the Ljubljana – My City (MOL. Ljubljana - moje mesto) mechanism covering 25 %, by Eco Fund, Slovenian Environmental Public Fund (Eko sklad, js), subsidy for thermal insulation (20 %), and partially from the owners' own funds.

6. Conclusion

An energy renovation of a cultural heritage building is a unique challenge and an opportunity to revive and preserve the building structure and its protected values post-renovation. The success of the renovation largely depends on the implementation of the quality assurance in the process of project conception, planning and detailed design, preparation of the tender and selection of the contractor, implementation of the works, monitoring and control, as well as the support to end-users in the post-occupancy phase. The HBR model conceived on this base, with nine quality elements supporting heritage building renovation, has been verified on several case study buildings in Slovenia.

The HBR is adaptable to all types of heritage buildings, although specific technical solutions and heritage constraints would naturally vary. A holistic approach is emphasised, as heritage conservation and energy efficiency often require interconnected solutions; partial interventions might compromise structural integrity, heritage values, further use or its existence. The HBR model, with its adaptations, is suitable for renovating also non-protected buildings. The E25 renovation project in Ljubljana received the Successfully Completed Renovation Award 2024

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by the expert committee of the School of Renovation, demonstrating the effectiveness of the applied methodology in the HBR model (https://solaprenove.si/priznanja/).

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