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Holistic sustainable buildings renovation: a case study from Switzerland

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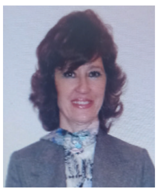

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Subject review

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Holistic sustainable buildings renovation: a case study from Switzerland

Renovation is a pivotal element in realising sustainability objectives in the construction industry, as established by the EU Commission. By analysing a real-life case study in Switzerland, this study provides insights into strategies and measures crucial not only for attaining an energy-efficient building state but also for achieving broader sustainability goals encompassing social and economic aspects. In addition, a general decision-making framework for residential building renovations is provided. The presented case study may serve as a role model for the successful sustainable renovation of other similar residential buildings and stimulate further research that facilitates effective holistic sustainable renovation.

Key words:

building renovation, energy efficiency, holistic sustainable renovation, residential buildings

Pregledni rad

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Održiva sveobuhvatna obnova zgrada: studija slučaja iz Švicarske

Europska komisija je utvrdila da je obnova ključni element u ostvarivanju ciljeva održivosti u građevinskoj industriji. Analizirajući studiju slučaja iz stvarnog života u Švicarskoj, ona daje uvid u strategije i mjere ključne ne samo za postizanje energetski učinkovite zgrade, već i za postizanje širih ciljeva održivosti koji obuhvaćaju društvene i ekonomske aspekte. Osim toga, dan je opći okvir za donošenje odluka o obnovi stambenih zgrada. Prikazana studija slučaja može poslužiti kao uzor za uspješnu održivu obnovu ostalih sličnih stambenih zgrada i potaknuti daljnja istraživanja koja potiču učinkovitu održivu sveobuhvatnu obnovu.

Ključne riječi:

obnova zgrada, energetska učinkovitost, održiva sveobuhvatna obnova, stambene zgrade

1. Introduction

The emerging global energy crisis and the broader challenges of rising living costs have created a strong motivation to replace fossil fuel-dependent heating systems with more environmentally friendly sources [1]. This process is closely interconnected with a wide range of social, economic, and environmental parameters that must be considered before adopting transition measures and regulations. The idea of triple-bottom-line sustainability, that is, the social, environmental, and economic dimensions, first introduced by Elkington [2] to assess sustainability performance, is now widely recognised as a crucial framework for achieving long-term success in the construction industry and beyond. This ensures that the transition measures not only benefit the environment but also consider the social and economic impacts. By emphasizing integration and inclusiveness, human well-being, quality of communal life, historical and cultural legacy, and visual appeal [3], and additionally considering the economic aspect, the construction sector can ensure that the transition to more environmentally friendly energy systems is fair and equitable for all stakeholders involved. However, these practices and the available literature have significant limitations, including the subjectivity of sustainability indicators, absence of stakeholder participation, predominance of environmental criteria, and variability of indicator sets [4, 5].

In Europe, residential buildings account for more than 75 % of the total building stock and are responsible for a significant portion of environmental pollution, energy crises, resource depletion, and excessive waste output [6]. Specifically, the construction sector is responsible for 32 % of the global energy consumption, 40 % of the global CO_2 emissions, and approximately 40 % of the world's solid waste creation [6, 7]. One of the primary strategies by which the EU aims to reduce CO_2 emissions, save energy and material resources, and improve social sustainability issues is the renovation of the construction industry [7]. Despite a substantial proportion of buildings requiring upgrading, the renovation uptake remains low, with annual rates ranging from 0.4 % to 1.2 % in EU countries [8]. Owing to their significant impact on the urban fabric, sociological consequences, and financial and environmental sustainability, in many cases, it is not justified to replace old buildings, regardless of the problems posed by their energy inefficiency and structural inadequacies. Alternatively, a more favourable approach would be to prioritise renovation/retrofitting to extend the lives of existing buildings. However, renovation policies have traditionally emphasised energy upgrading, overlooking the other two pillars of sustainability. Relying solely on building energy upgrades fails to address other critical vulnerabilities, potentially resulting in misconceptions regarding the extent of savings achieved [9].

The authors in [6] argue that there is a lack of agreement over the primary criteria and indicators for social sustainability, as well as the appropriate renovation processes, tools, and techniques. According to [10], the diversity of social sustainability criteria and indices can be attributed to several key factors: variations in multicultural dimensions, scarcity of research on social sustainability in relation to building assessment tools, climatic conditions, and frequently, a dearth of expertise in the construction sector. Furthermore, the lack of a well-defined and all-encompassing framework for evaluating human wants and desires, as well as establishing connections with specific design elements, makes the social side of implementation uncertain and challenging [11, 12]. In addition to variations in climate and geography, the broader adoption of the current assessment tools and methodologies is impeded by disparities in the potential for renewable energy generation, resource consumption (such as water and energy), building stock characteristics, construction materials, technology and techniques employed, government policies and regulations, population growth, preservation of historical heritage, community awareness, and other factors [13].

In this paper, we analyse and demonstrate successful strategies and measures in the conceptualisation and design of comprehensive sustainable building renovation through a real case study, which is in accordance with the regulations in Switzerland and the City of Zurich guidelines for sustainable renovation of residential buildings [14-18]. Overall, these success strategies demonstrate a holistic and sustainable approach to urban residential housing that emphasises affordability, long-term planning, social dimensions, and adaptability to evolving needs.

In this paper, the term "renovation" or "retrofitting" will be used as a general term referring to improving the performance of an existing building. It can be in the form of rebuilding, refurbishing or retrofitting of a building as part of modernisation or adaptation to a changed use. Buildings of cultural or heritage value, or those located in places of special value, are beyond the scope of this study.

2. Materials and methods

2.1. Description of case study: Multi–family building Zürich-Schwamendingen

The multi-family building Zurich-Schwamendingen (Figure 1) is located at the centre of the Zürich-Schwamendingen district and 5.5 km from the centre of Zurich. Considering that the building is 45-years-old (and only basic maintenance works have been carried out in all these years), and given the building's high energy consumption, as well as the deterioration of furnishing facilities and linings, the owner/investor [19] decided to renovate the building in conformity with sustainability principles.

The first step in arriving at an adequate solution for renovating a building is to analyse the building's existing condition and its context. This includes assessing the structural integrity, quality of the building envelope, interior functionality of spaces, materialisation, fixtures, quality of building services (mechanical, electrical, etc.), energy efficiency, and social services and practices [20]. For this purpose, the web-based tool 'Quick Check Ersatzneubau' [21] was suggested. This tool

Figure 1. Multi–family building Zürich-Schwamendingen: a) before renovation; b) after renovation (photo credit: Kämpfen für Architektur [19])

provides a straightforward evaluation of the most significant building attributes from all three sustainability perspectives. Consequently, it aids in making informed decisions by enabling transparent comparisons between different design options (Figure 2). Furthermore, it assists in identifying areas that require improvement and finding an appropriate balance between opposing requirements and objectives.

The results of the building diagnosis showed that the environmental sustainability indicators of energy efficiency ('Energy efficiency' in Figure 2), such as energy consumption and utilisation of renewable energy sources, and quality of building elements ('Building substance' in Figure 2), such as building structural elements, building envelope, and furnishing facilities, are quite unsatisfactory. Furthermore, the social indicators ('Social cohesion and mixing' in Figure 2), including flexibility of building space, social mixing, and quality of space design and materials used, were also assessed to be unsatisfactory. Further, the economic aspect of the building was estimated to be relatively modest ('Economic value' in Figure 2) due to the deterioration of materials, linings, building services (mechanical, electrical, water, etc.), energy inefficiencies, and unsatisfactory financial gains from renting, the building is exclusively used for renting. Therefore, during renovation, the main elements and attributes of all three dimensions of the building's sustainability must be improved.

The renovation process in this case was conducted in a sensitive manner, considering the particular characteristics of the building and its context, occupants/investors' needs, climatic conditions, investors' financial limits, and cultural values. Occupant participation in defining renovation goals and priorities was encouraged to eliminate or minimise existing and potential conflicts between occupants.

Finally, the following main environmental goals of the building's sustainable retrofitting were set by the design team in accordance with the owner's and occupants' needs: improving the building's energy performance in accordance with environmental sustainability criteria, increasing indoor comfort, and using local and environmentally friendly materials. The main goals from the social aspect were optimising space use in addition to improving the functional and aesthetic quality, diversifying the social, cultural, and age-related mix, barrier-free design, preserving low rental costs, and ensuring the possibility of occupants' return to their previous apartments in a period of one year. The goals from the economic aspect were affordable rents, balanced lifecycle costs, completing the renovation in one year, and ensuring that the total renovation costs do not exceed the value specified by the owner.

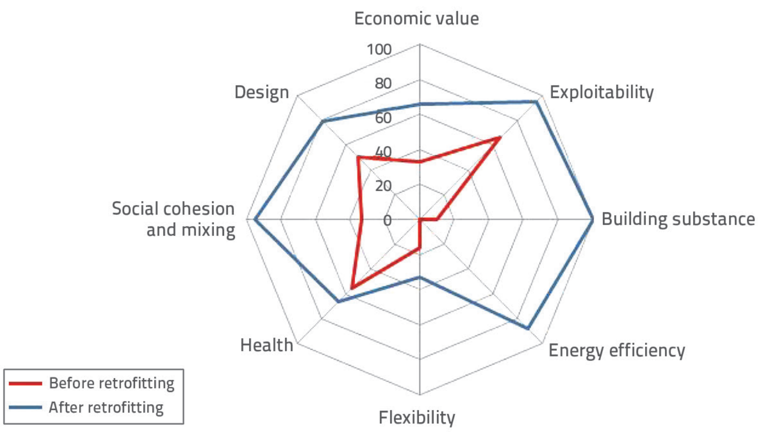

Figure 2. Results of building diagnosis before and after renovation, assesses using the computer tool 'Quick–Check Ersatzneubau' [21]

Considering the building characteristics and building's context and seeking to improve the environmental sustainability performance, which indirectly contributes to the aesthetics of the building (i.e. social aspect) and the better health and well-being of occupants, the design team [19] proposed a concept that integrates solar collectors (STCs) on the façade walls and photovoltaic panels on the roof (Figure 1b). This concept was mainly motivated by the following

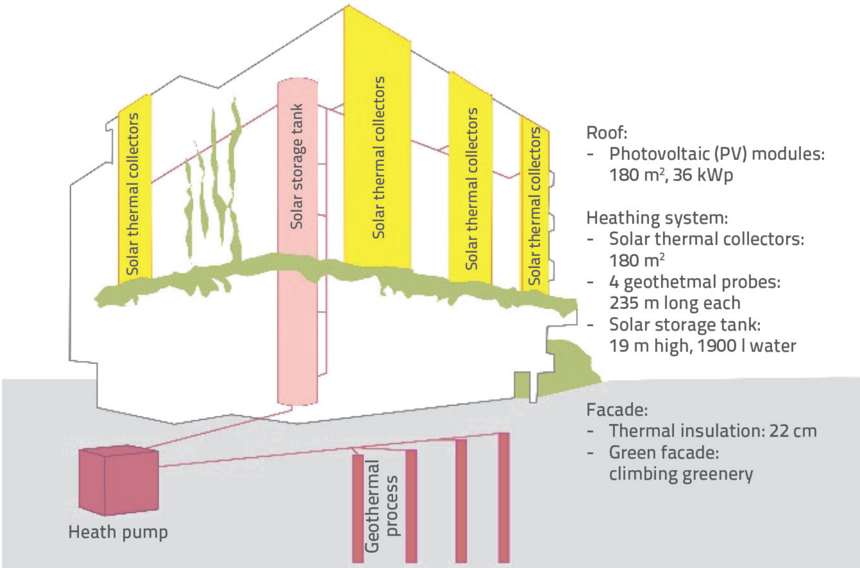

Figure 3. Energy concepts based on solar and geothermal sources and position of green systems (Photo credit: Kämpfen für Architektur [24])

three building characteristics: a) the façade has large, closed, rectangular areas, completely sunlit throughout the year, b) the building's high hot water consumption, and c) the centrally positioned ventilation shaft (approximately 3 m²) of the parking garage that passes through all floors which is undesirable for sound and fire protection, as well as cooling of the building. This also ensured that the rules set out in the national model building code [22] were satisfied. For example, the minimum energy standard for new buildings and renovations restricts the types of heating systems that can be installed (central direct electrical heating is prohibited) and requires both new and existing buildings to use renewable energy sources (RES). A previous study [23] provides a clear illustration of how different national standards affect the energy efficiency of a building. Specifically, this study presents a comparative analysis of the energy performance of buildings constructed in Turkey adhering to current standards and explores different improvement scenarios using Austrian building standards.

The integrated STCs were designed to be vertically positioned (Figure 1b) and light in colour, changing from light grey to bronze to ensure greater social acceptability. They were also optimised in relation to sunlight gain and heating needs by adequate positioning: 36 m² of STCs were integrated on the east and 108 m² and 36 m² of STCs on the south and west façades (Figure 3).

In this way, façades enable energy production throughout the day. On the northern façade, dummy STCs were also integrated (they do not produce energy but serve only as a regular façade lining) to achieve better harmony between the façade walls, and thus contribute to the aesthetics of the building. While this clearly increased renovation costs, such a compromise was chosen for the sake of aesthetics, which is a subjective social factor that is often highly valued and appreciated by occupants. In addition, a vertical green system (VGS) was implemented, partially covering the façade (Figure 3). This system improves the energy efficiency and environmental conditions of the building. A previous study [25] comprehensively analysed the benefits of using VGS on residential building façades to enhance energy efficiency and mitigate environmental impacts.

The ventilation shaft was replaced by an exhaust pipe of only 30 cm in diameter owing to the much lower gas emissions of contemporary cars compared to those from the 1970s, which freed up space for a 19-meter-high water reservoir with a capacity of 20,000 litres, serving as the core of the newly established energy system. The heat pump was located in the basement near the solar tank and connected to ground geothermal probes with short lines (Figure 3). The proposed alternative of adding a new floor while transforming existing balconies into conservatories to address the issue of thermal bridges and increase indoor thermal, acoustic, and spatial comfort was abandoned to avoid the creation of extra gross floor area limited by Zurich urban planning conditions. The final alternative involved the addition of a new level/attic (Figure 4) and the installation of an acoustic

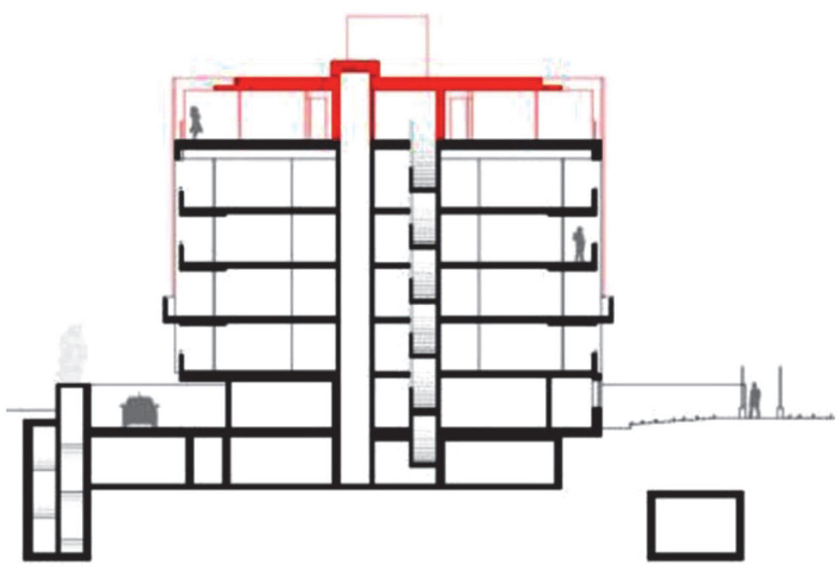

Figure 4. Vertical intersection of the building (floor added during retrofitting, red), Photo credit: Kämpfen für Architektur [24]

Table 1. Energy-related data before and after the renovation of the multi-family building Zürich–Schwamendingen [24]

Heated floor area [m²]	Before renovation			After renovation						
	1748			2132						
	Energy needs			Energy needs			Energy production			
	kWh/m²a	%	kWh/a	kWh/m²a	%	kWh/a		kWh/m²a	%	kWh/a
Hot water	30	15	52 493	3.4	8	7 249	PV rooh (230 m²)	183	46	42 066
Space heating	106.6	53	186 368	4.3	10	9 168	Solar thermal collectors (181 m²)	134	27	24 177
Electricity	64.1	32	112 047	35.0	82	74 620	Energy self-supply		73	66 243
Total	200.7	100	350 908	42.7	100	91 037	Energy supply from electrical grid		27	24 794

and heating system. In this way, comfort was increased, and owing to the removal of the previous heat distribution elements (i.e. convectors in front of the windows), the apartments were also made more spacious and comfortable for occupants. This improvement in comfort corresponded to the interior comfort conditions examined in this study [26].

A horizontally mounted 36 kWp (kWp is kilowatt "peak" power) PV system on the building's roof produced approximately 42.000 kWh annually and met the building's electricity needs around the year, excluding November to February. Technical data related to building energy demands and production from various sources are listed in Table 1. In the assessment phase, this concept (alternative) was rated the best among several other alternatives, considering social aspects in addition to the environmental and economic dimensions.

Figure 5. Typical (left) and attic (right) floor plans (1–room, 2–room, wheelchair–accessible apartments, 2.5–room, –3.5–room –ventilation shaft). Photo credit: Kämpfen für Architektur [24]

Thus, the building, initially characterised by high fossil fuel-based energy consumption, was transformed into the first retrofitted multifamily building in Switzerland certified with the label Minergie-A, demanding less than 1/4 of the initial energy needs after retrofitting (i.e. 91.037,00 kWh/a vs. 350.908,00 kWh/a before retrofitting, Table 1). Moreover, the building self-produces 73 % of the total energy needs, requiring only 24.794,00 kWh/a from the electrical grid (Table 1). Additionally, the building offers high-quality housing in terms of social sustainability criteria. To fulfil the specified social sustainability goals, which include improving the functional and aesthetic aspects, maximising space utilisation, promoting diversity in terms of social, cultural, and age groups, and maintaining affordable rental prices, the design team made several changes to the building's interior. This involved combining one-room apartments to create 2.5-room apartments, renovating and preserving some units (Figure 5), and modifying others to make them wheelchair-accessible.

The addition of an extra floor/attic facilitated the creation of 2.5- and 3.5-room apartments in the attic (Figure 5), resulting in the arrival of new residents and the enhancement of social and age-related diversity. Furthermore, the efficient renovation process enabled previous occupants to move back into the renovated apartments within a span of just 10 months.

In this way, the average living space of only 35 m² per person, including a staircase and a common room on the ground floor, designed to promote contact among occupants, led to lower energy consumption per person and helped maintain low rental rates in 50 apartments (previously 48), which was one of the primary economic goals. Further, the total renovation cost was 6.5 million CHF, which is 2/3rd the cost of constructing a new building, and it only accounts for approximately 1/3rd of the embodied energy of the new building [24], thus proving to be ecologically, socially, and economically (cost-benefit) effective.

3. Decision-making flowchart for building renovation

To assess the potential for sustainable renovation of buildings and arrive at an optimal renovation solution, the first preparatory steps include the adoption of a set of sustainability principles, followed by the definition of a set of sustainability

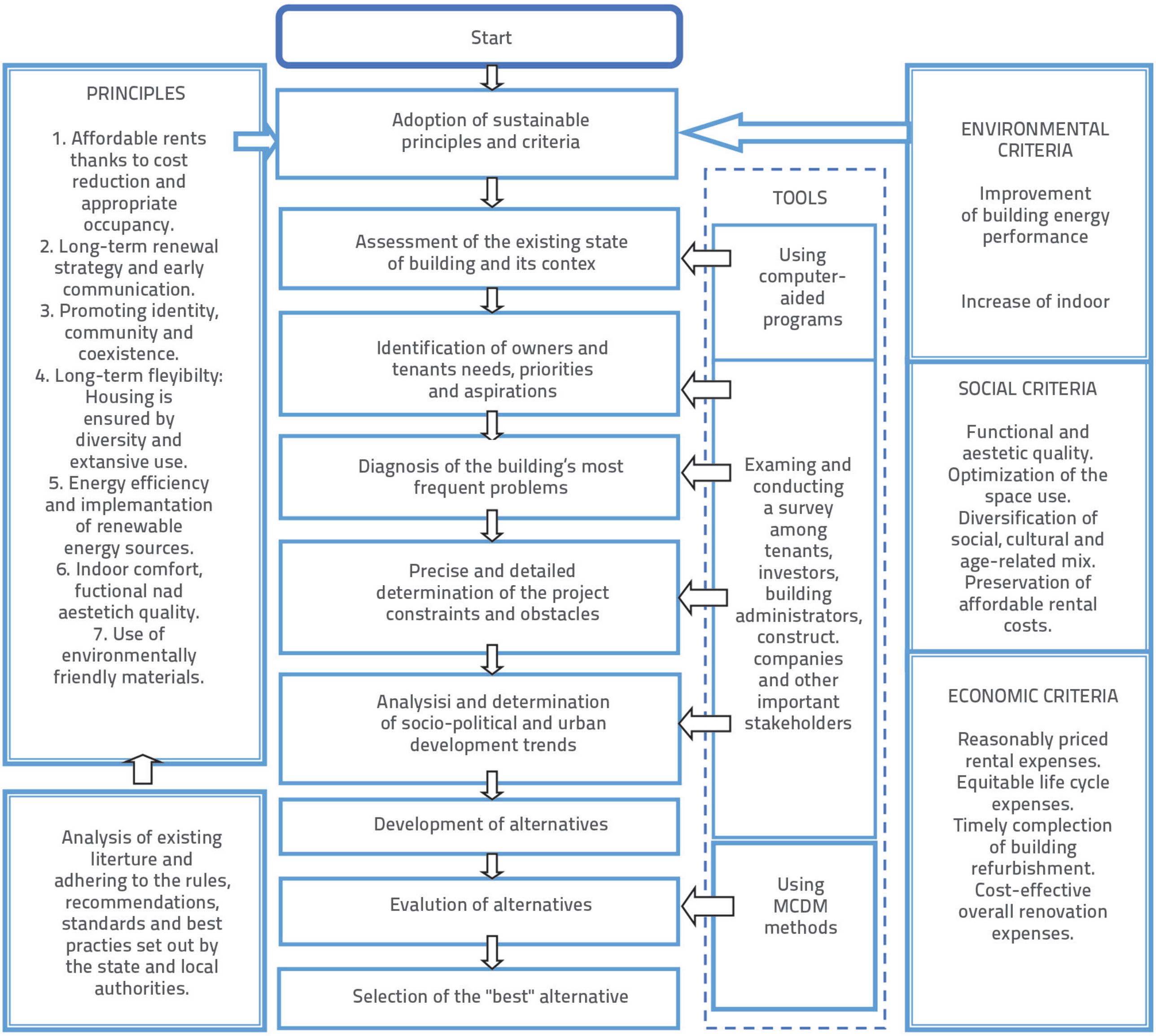

Figure 6. Decision-making flowchart for the conceptualisation and design of building renovation

goals and criteria from all three aspects of sustainability (steps 1 and 2 in Figure 6). The selection of appropriate principles and goals was based on a literature analysis and adherence to the rules, recommendations, standards, and best practices set out by state and local authorities.

Subsequently, other preparatory activities include studying and assessing the present state of the building and its surroundings (step 3 in Figure 6). Experts might consider using computer tools such as 'Quick-Check Ersatzneubau' [21] or similar tools to perform a thorough building diagnostic. The program supports the evaluation of several factors including building substances, energy efficiency, indoor environmental quality, design, adaptability, social mixing, and economic value. Specialists can analyse many renovation scenarios and determine the cost associated with each scenario. The results of assessing the building's state are presented as a spider-web diagram in Figure 2, which provides a clear visual representation of a building's performance across different categories, allowing specialists to easily identify areas requiring improvement. Additionally, refer to [27] for recommendations on strengthening and structural performance evaluation, and [28] for structure restoration procedures after earthquake-induced damage.

However, to ensure that the renovation solution considers the specific needs and aspirations of all parties involved, further steps involve identifying the needs of owners and tenants, diagnosing frequent building problems, determining project constraints, and analysing socio-political and urban development trends (steps 4, 5, 6, and 7 in Figure 6). This involves conducting surveys among stakeholders to ensure that the renovation solution considers the needs and aspirations of all parties. Additionally, by considering socio-political and urban development trends, renovations can align with broader goals and contribute to community improvement.

In some cases, when there are several renovation solutions with similar performance scores (i.e. Pareto optimal solutions), specialists may use data from the analysis to prioritise certain areas (by giving them higher weights) based on the defined values of the stakeholders and their preferences. To select the optimal renovation solution, a multicriteria decision-making (MCDM) method may be used to assist specialists in making informed decisions regarding the most suitable renovation strategies. MCDM methods such as the Analytic Hierarchy Process (AHP) or the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) can provide a systematic framework for evaluating various criteria and weighing their importance in the decision-making process. By applying these methods, specialists can ensure that the selected renovation strategies align with sustainability, cost-effectiveness, and overall building performance improvement goals. Furthermore, by involving stakeholders and incorporating their input throughout the renovation process, specialists can foster a sense of ownership and community engagement, leading to a more successful and sustainable transformation of the building.

4. Conclusion

Through a selected real-life case study, this study highlighted the need for simultaneous consideration of parameters from all three dimensions of sustainability to allow and control an adequate 'trade-off' between opposing goals from different pillars of sustainability and arrive at the best solution that satisfies all specified sustainability goals. Accordingly, the project goals in the presented case study were fully achieved by following these strategies: a) adequate and comprehensive analysis of the building's existing state and surroundings, b) identification of investors' and tenants' needs, priorities, and aspirations, c) diagnosis of the building's most frequent problems (problems in renting, maintenance, occupants' structures, etc.), d) analysis and determination of socio-political and urban development trends, e) precise and detailed determination of the project constraints and obstacles, f) adequate setting of project goals, considering not only the investor's needs but also tenants' needs and stimulating their active participation, g) high-quality retrofitting design solutions (as a result of the design team's thorough knowledge, expertise, and design experience), and h) support from an excellent network of construction technology companies throughout the project implementation and well-coordinated execution as recommended in [29].

In this way, the total renovation cost was only 2/3rd the cost of constructing a new building, and it only accounts for approximately 1/3rd of the embodied energy of a new building [24]. Therefore, this case study shows that while sustainable retrofitting is challenging from both architectural and urban planning perspectives, it can be ecologically, socially, and economically effective. Furthermore, it highlights the potential of retrofitting as a viable solution for creating more sustainable and resilient cities by preserving valuable resources, promoting a more efficient use of space and resources, and offering high-quality housing in terms of social sustainability criteria, which include improving functional and aesthetic aspects, maximising space utilisation, and promoting diversity in terms of social, cultural, and age groups.

REFERENCES

[1] IEA: Heating, Paris, IEA, 2022. Available from: https://www.iea.org/reports/heating. Elkington, J.: The triple bottom line. Environmental management: Readings and cases, 2 (1997), pp. 49-66.

[2] Elkington, J.: The triple bottom line. Environmental management: Readings and cases, 2 (1997), pp. 49-66.

[3] Ajmal, M.M., et al.: Conceptualizing and incorporating social sustainability in the business world, International Journal of Sustainable Development & World Ecology, 25 (2018) 4, pp 327-339, https://doi.org/10.1080/13504509.2017.1408714

[4] Fernández-Sánchez, G., Rodríguez-López, F.: A methodology to identify sustainability indicators in construction project management—Application to infrastructure projects in Spain. Ecological Indicators, 10 (2010) 6, pp. 1193-1201. https://doi.org/10.1016/j.ecolind.2010.04.009

[5] Abbasi, M.H., et al.: A framework to identify and prioritise the key sustainability indicators: Assessment of heating systems in the built environment. Sustainable Cities and Society, 95 (2023), 104629. https://doi.org/10.1016/j.scs.2023.104629.

[6] Kamari, A., Corrao, R., Kirkegaard, H.: Sustainability-focused decision-making in building renovation. International Journal of Sustainable Built Environment, 6 (2017) 2, pp. 330-350. https://doi.org/10.1016/j.ijsbe.2017.05.001

[7] Park, J., Yoon, J., Kim, K.H.: Critical review of the material criteria of building sustainability assessment tools. Sustainability, 9 (2017) 2, pp. 186. https://doi.org/10.3390/su9020186

[8] European Commission-Energy Performance of Buildings, 31.07.2014. https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/overview

[9] Hashempour, N., Taherkhani, R., Mahdikhani, M.: Energy performance optimization of existing buildings: A literature review. Sustainable Cities and Society, 54 (2020), Article 101967. https://doi.org/10.1016/j.scs.2019.101967

[10] Atanda, J.O.: Developing a social sustainability assessment framework. Sustainable Cities and Society, 44 (2019), pp. 237-252. https://doi.org/10.1016/j.scs.2018.09.023

[11] Dempsey, N., Bramley, G., Power, S., Brown, C.: The social dimension of sustainable development: Defining urban social sustainability, Sustainable Development, 19 (2011) 5, pp. 289-300. https://doi.org/10.1002/sd.417

[12] Atanda, J.O., Öztürk, A.: Social criteria of sustainable development in relation to green building assessment tools. Environment, Development and Sustainability, 22 (2020), pp. 61-87. https://doi.org/10.1007/s10668-018-0184-1

[13] Alyami, S.H., Rezgui, Y.: Sustainable building assessment tool development approach. Sustainable Cities and Society, 5 (2012) 1, pp. 52-62. https://doi.org/10.1016/j.scs.2012.05.004

[14] SNBS-SNBS 2.1 Hochbau KRITERIENBESCHRIEB, Nutzungsarten Wohnen, Verwaltung, Bildungsbauten, Gewerbenutzung im Erdgeschoss, https://nnbs.ch/wp-content/uploads/2023/05/Kriterienbeschrieb_SNBS-Hochbau-2.1.pdf, 11.01.2021.

[15] Schweizerischer Ingenieur und Arhitektenverein (SIA)-Empfehlung SIA 112/1:2017 Bauwesen (in German). Nachhaltiges Bauen - Hochbau, Verständigungsnorm zu SIA 112. https://www.schaeublinarch.ch/portfolio/0737-ish/?_sft_jetpack-portfolio-type=wohnen+projektierung&from=werkliste&fformid=119, 1.09.2017.

[16] Stadt Zürich, Novatlantis and SVW-Checkliste nachhaltige Gebäudeerneuerung für gemeinnützige Wohnbaugenossenschaften (in German). Bundesamt für Energie (BFE), https://www.econcept.ch/media/projects/downloads/2018/04/635_Checkliste_Genossenschaften_definitiv_0706_25.pdf, 25.06.2007.

[17] Stadt Zürich, Novatlantis and SVW, Bundesamt für Energie (BFE)-Checkliste und Entscheidungstool nachhaltige Gebäudeerneuerung (in German), https://www.econcept.ch/media/projects/downloads/2018/04/635_be_Materialienband_zu_Checkliste_definitivmit_anhang.pdf, 25.06.2007.

[18] Stadt Zürich, Amt für Hochbauten-Guide "Success factors of socially sustainable replacement buildings and renovations, https://www.stadt-zuerich.ch/prd/de/index/stadtentwicklung/gesellschaft-und-raum/entwicklung-wohnstadt-2/sozialvertraegliche-innenentwicklung/sozialnachhaltigbauen/leitfaden_sozialnachhaltige_Sanierungen_Ersatzneubauten.html, 04.06.2006.

[19] Kämpfen für Architektur. https://www.kaempfen.com/projekte/umbauten/apartmenthaus-zuerich-schwamendingen-2017 (accessed 22. 06. 2024).

[20] Golić, K., Kosorić, V., Lau, S.K.: A Framework for Early Stages of Socially Sustainable Renovation of Multifamily Buildings with Occupants' Participation, Sustainability, 12 (2020), 8823. https://doi.org/10.3390/su12218823

[21] Online tool Quick-Check Ersatzneubau, Green Building, (2019). Available online: http://www.greenbuilding.ch

[22] EnDK-Mustervorschriften der Kantone im Energiebereich (MuKEn), https://www.fhnw.ch/plattformen/energieapero/wp-content/uploads/sites/272/MuKEn-Energieapero-2_20150616-Mathys.pdf, 9.01.2015.

[23] Kalfaoglu Hatipoglu, H., Cetin, R., Hatipoglu, A.: Sustainable housing: Analysis of energy performance potential in Turkey with translation of building standards of Austria, GRAĐEVINAR, 74 (2022) 8, pp. 647-659, https://doi.org/10.14256/JCE.3332.2021

[24] Fritzenwallner, C.: Vom Vielfrass zum Energieproduzenten, Sanierung und Aufstockung eines Mehrfamilienhauses in Zürich, in Deutsche Bauzeitung, 3 (2019), pp. 118-121.

[25] Trkulja, T., Radujković, M., Nikolić-Topalović, M.: Vertical greenery system: a model for improving energy efficiency of buildings, GRAĐEVINAR, 74 (2022) 7, pp. 561-571, https://doi.org/10.14256/JCE.3370.2021

[26] Ayçam, İ., Görgülü, L.S., Soyluk, A.: Post-occupancy evaluation in indoor comfort conditions for green office buildings, GRAĐEVINAR, 74 (2022) 9, pp. 721-737, https://doi.org/10.14256/JCE.3179.2021

[27] Erdem, R T., Karal, K.: Performance assessment and strengthening proposal of an existing building, GRAĐEVINAR, 74 (2022) 1, pp. 51-61, https://doi.org/10.14256/JCE.3250.2021

[28] Pojatina, J., Barić, D., Anđić, D., Bjegović, D.: Structural renovation of residential building in Zagreb after the 22 March 2020 earthquake, GRAĐEVINAR, 73 (2021) 6, pp. 633-648, https://doi.org/10.14256/JCE.3195.2021

[29] Milovanović, B., Bagarić, M.: How to achieve Nearly zero-energy buildings standard, GRAĐEVINAR, 72 (2020) 8, pp. 703-720, https://doi.org/10.14256/JCE.2923.2021