BUILDING RENOVATION ROADMAPPING: AN AUTOMATED METHODOLOGY FRAMEWORK FOR ENERGY EFFICIENCY IMPROVEMENT AND SUSTAINABLE RENOVATION PLANNING

Nikolaos Mpouzianas, Stavros Koltsios, Nikolaos Katsaros, Georgios Giannopoulos, Panagiotis Klonis, Ioannis Pastaltzidis, Panagiota Chatzipanagiotidou, Dimosthenis Ioannidis, Dimitrios Tzovaras
Information Technologies Institute, Centre for Research and Technology Hellas, Thessaloniki, Greece
nickbouzi@iti.gr, skoltsios@iti.gr, nkatsaros@iti.gr, ggiannopoulos@iti.gr, klonisp@iti.gr, gpastal@iti.gr, phatzip@iti.gr, djoannid@iti.gr, dimitrios.tzovaras@iti.gr

SUMMARY

This study presents a novel methodology for automated retrofitting scenario generation in buildings. The proposed schema is closely linked with the concept of Energy Performance Certificates (EPCs) and is in line with the latest EU regulatory framework. By utilizing BIM documentation, a well-informed representation of the examined asset can be obtained automatically. Based on the current condition, the asset's as-designed energy consumption is estimated and areas that require renovation are identified, including the framework estimates the asset's energy consumption as designed and identifies areas that require renovation, including both the building envelope and technical systems. A set of renovation solutions is then generated, resulting in a renovation roadmap that prioritizes changes with the greatest impact and meets the needs of stakeholders. The proposed methodology provides a promising approach to help building owners and stakeholders identify and prioritize energy-saving retrofitting measures, thus contributing to the achievement of sustainability and energy efficiency goals.

Keywords: EPC, BIM, energy performance upgrade, renovation roadmap, retrofitting, building renovation passports.

Introduction

The transformation of the European building stock is crucial for achieving the Green Deal's goal of climate neutrality by 2050. As the building sector is responsible for approximately 40% of the final energy demand and 36% of Carbon Dioxide (CO2) emissions, retrofitting actions should be prioritised to reduce emissions and improve the energy efficiency of the existing building stock (European commission, 2016). Despite the advantages of building renovations, owners often avoid energy-saving investments due to a lack of reliable information and uncertainties regarding their potential benefits (Sesana and Salvalai, 2018).

To address these challenges, the EU has implemented numerous initiatives to document the existing state of the building stock through Energy Performance Certificates (EPCs) under the Energy Performance of Buildings Directive (EPBD) (EU Parliament & Council, 2002). Furthermore, the EU has introduced the "Renovation Wave," building renovation passports, and digital building logbooks to tackle issues such as decarbonizing the building stock, reducing energy poverty, and facilitating informed decision-making for retrofitting projects (Sesana and Salvalai, 2018).

With the current advancements in digital technology and the growing trend towards industry 4.0, an opportunity arises for the building sector to enhance the efficiency and effectiveness of retrofitting processes. This study suggests a framework that automates the process of generating retrofitting scenarios, to facilitate building owners and stakeholders making informed decisions about retrofitting projects.

Methodology

The present study introduces an automatic recommendation mechanism for building retrofitting, aimed at facilitating the digital transformation and upgrade the energy efficiency of buildings in the EU. The proposed configuration in Figure 1 utilises BIM documentation to derive automatically the required information for the examined asset.

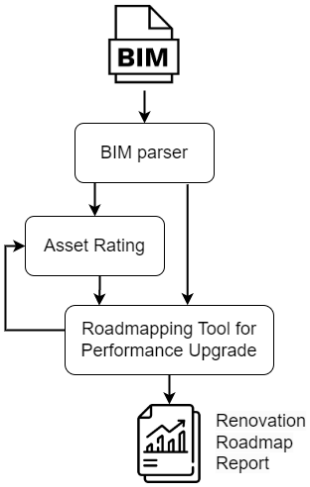

Figure 1. Proposed automated renovation workflow

The input BIM file is forwarded to the **BIM parser** component, which is responsible for extracting only the necessary information required for computing the asset's energy performance. Additionally, the parser component validates the BIM file and prompts the assessor to correct any errors or fill in missing fields. With a complete and accurate building description, the **Asset Rating** module can then calculate the *as-designed*

energy performance of the building, in compliance with the EN ISO 52000 standards.
The **Roadmapping Tool** takes as an input both the building documentation from the BIM parser and the Asset Rating results. The structural and technical characteristics of the examined building are examined by the **Asset Diagnosis** sub-component. More specific, the latter examines several characteristics both for the building's structural elements (e.g. U-values) and technical systems (Table **1**), and compares these values with a pre-defined list of specifications for the respective fields. The specifications can vary according to the type of target goal (e.g. compliance with the national building code limits, nZEB, Passive House standards) while they can also be modified by the assessor.

Table 1. Examined elements and attributes per renovation category

Renovation category	Type
1. Envelope	1.1. External Wall
	1.2. Roof
	1.3. Floor
	1.4. Windows
	1.5. Doors
2. Technical Systems	2.1. Heating
	2.2. Cooling
	2.3. DHW
	2.4. Lighting
3. RES	3.1. Solar Thermal Collectors
	3.2. Photovoltaic

If the examined building fails to meet the specifications for any given field, Asset Diagnosis creates a new building instance by replacing the deficient elements with ones that meet the specifications. For each proposed intervention, the Asset Rating component calculates the expected energy performance after the intervention. The results of each scenario are then sent back to the Roadmapping tool to calculate the renovation KPIs (Table **2**).
Afterwards, the component generates a sorted list of renovation actions based on the impact of each intervention and user preferences, such as payback years. The end-user can combine different individual scenarios from the roadmap, to create a comprehensive renovation plan according to their needs. The combined scenario is examined again by the Asset Rating component to calculate the expected impact of the entire renovation plan. Finally, the *Renovation Roadmap Report* is generated to provide an informative stepwise plan for increasing the assets energy performance.

Table 2. Calculated indicators of the Roadmapping tool

Calculated indicator	Measurement unit
Primary energy	kWh
Primary energy saving percentage	%
Annual Operational Energy Cost	€
Annual Operational Energy Cost Savings	€
Renovation cost	€
CO_2 emissions	kg CO_2
CO_2 emissions savings	kg CO_2
Payback period	years

Conclusion

The presented schema constitutes a flexible and customizable framework for generating and evaluating renovation scenarios for any building. The primary objective of this framework is to offer fast and precise guidance for stakeholders to improve their building's energy efficiency. Despite the highly automated procedures, the role of AEC industry stakeholders remains critical, as they will have to investigate the feasibility of the proposed solutions and proceed with the design and implementation face. Moreover, this study highlights the potential for future research to explore the dynamic performance of buildings and the concept of operational rating in conjunction with the proposed methodology. Overall, these findings represent a significant contribution to the field of sustainable building design and can support future energy related policy and decision making.

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