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Research Article/ Review Article/ Perspective Article (Remove where relevant)

Aesthetics vs. Efficiency? Balancing Energy Performance and Architectural Appeal through Decision Support with Telegram Bot

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Abstract

Balancing energy performance and architectural appeal in building retrofit presents significant challenges, especially with regulations like the Buildings Energy Act (GEG) emphasizing energy efficiency. This study investigates which retrofit measures have the greatest impact on aesthetics. Through stakeholder analysis, the study examines the interests of key groups involved in retrofit projects, including property owners, architects and engineers. To identify potential conflicts between energy efficiency and aesthetic quality, thirteen interviews were conducted. Based on these findings, a Telegram Bot is proposed as a decision-support tool. In a case study, the bot demonstrates how it can provide tailored recommendations to balance energy performance and architectural appeal.

Keywords: Building retrofit; Energy efficiency; Architectural appeal; Decision Support

Highlights

- The study validates the conflict between energy efficiency and architectural aesthetics in German renovation practice, particularly in façade insulation, window replacement and PV integration.
- A practical framework of aesthetic criteria is established based on expert insights, showing that while such criteria are recognized, they are often overridden by budget constraints.
- An AI-based Telegram Bot is introduced as a decision-support tool, enabling product comparisons and allowing professionals to refocus on aesthetic design quality.

1 Introduction

The renovation of buildings presents a complex challenge of balancing energy efficiency with aesthetics, particularly under the influence of regulations such as the Buildings Energy Act (GEG), which prioritizes energy performance (Climate Policy Database, 2020). While energy efficiency is increasingly enforced through such regulations, there is often a lack of standardized mechanisms to incorporate aesthetics as an equally important goal in the renovation process. This gap is particularly evident in the growing emphasis on energy-efficient buildings, where the aesthetic qualities of a building are sometimes overlooked. Aesthetics are essential because they enhance the quality of our built environment. Furthermore, frameworks like the New European Bauhaus are working to address the integration of both efficiency and aesthetics (Bratu et al., 2024), yet their practical application remains underdeveloped in many renovation projects. In this context, this paper explores how to bridge the gap between energy efficiency and aesthetics in the building renovation process. Previous research has identified this conflict between energy efficiency and aesthetics as a key challenge in sustainable renovation efforts. The research gap lies in validating this issue specifically for the German context and exploring potential solutions, such as the development of a Telegram bot to assist in balancing these priorities effectively.

The following research questions were defined:

1. *Which renovation measures have the most significant impact on aesthetics?*
2. *How can a Telegram Bot support decision-making in balancing energy efficiency and aesthetics during building renovations?*

The paper is structured as follows: First, the methodology is presented. This is followed by the results of the stakeholder analysis and the interviews conducted on the conflict between energy measures and aesthetics. Next, the study exploring the extent to which a Telegram bot can support decision-making in renovation measures is introduced. Subsequently, the discussion of the results is provided, and the paper concludes with an outlook on future research.

2 Materials and Methods

2.1 Stakeholder Analysis

To conduct the stakeholder analysis, the "Three Rings" framework was utilized, which categorizes stakeholders into directly dependent, indirectly dependent, and supportive groups. The stakeholder categories were systematically identified and subsequently validated through a review of relevant literature.

2.2 Relevant Renovation Measures in Conflict with Aesthetic Criteria

To determine the criteria relevant for evaluating aesthetic quality, a series of 13 semi-structured interviews was conducted. These interviews aimed to identify renovation measures frequently associated with conflicts between energy efficiency and aesthetic considerations. The interviews were carried out by phone in January 2025, following a standardized interview guide (see Table 1). The interviews took in average 15 minutes and were conducted in German-speaking regions, therefore carried out in German, responses were subsequently translated into English. Participants represented

the supportive stakeholder group (architects and planners), as they play a pivotal role in balancing energy efficiency and architectural appeal through their design decisions.

Table 1: Interview questionnaire

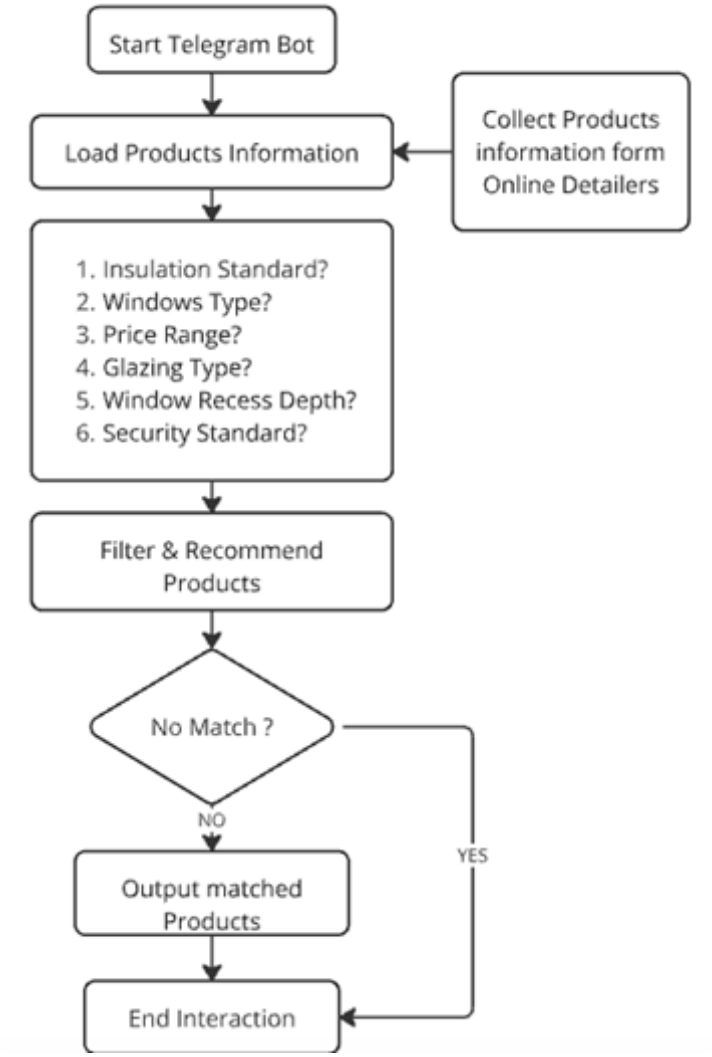
		Key question	***Control items***
1	*General*	What's your official job title?	E.g. architect, civil engineer
2	*General*	How many years of professional experience do you have in the area?	E.g. 5 years
3	*Which?*	Which energy-efficient refurbishment measures often conflict with the architectural appeal of buildings?	Give examples from real projects, e.g. insulation of external walls, installation of photovoltaic
4	*Who?*	Which stakeholders are involved in the assessment process?	E.g. owners and investors, tenants and users
5	*Why?*	Which criteria are decisive for assessing architectural quality?	E.g. Design (Proportion, Forms), Tactility (materials), Contextuality (Integration into the environment), Originality, Functionality (Usability, Adaptability), Cultural and Historical Aspects, Emotional impact
6	*How?*	How are aesthetics and energy efficiency weighed up?	Which criteria are included? How do they weight?
7	*Potential of AI*	How Artificial Intelligence (AI) technologies could assist the weighing process in the future?	E.g. ChatGPT to display design alternatives with energy-efficient categories, object detection in pictures

2.3 Telegram Bot as Decision Support

A Telegram Bot can facilitate decision-making in building renovation projects by providing users with comparisons of product options. This study focuses exemplary on the selection of windows by evaluating key factors including price, energy efficiency, and color. The development of the bot

involves the identification of comparison parameters based on expert interviews and a comprehensive literature review. To ensure up-to-date pricing and availability, product information is retrieved in real time from several online building product retailers. The collected data are systematically stored in a database designed for querying. Within the Telegram Bot, predefined questions guide users in specifying their preferences regarding cost, material, color, and energy efficiency. Based on users responses, the bot processes the input and searches for relevant product information from the database. Subsequently, it presents a selection of window products, along with their associated parameters, for further consideration. Finally, users are directed to configure and purchase the selected windows through an online shop.

Figure 1: Workflow of the Telegram Bot

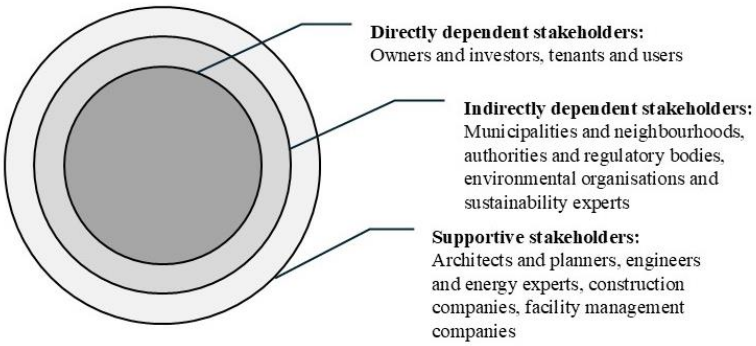


3 Results

3.1 Stakeholder Analysis

Figure 1 illustrates the three main stakeholder groups involved in balancing energy performance and architectural aspects. These groups represent different levels of influence and involvement, from direct decision-making to regulatory oversight and practical implementation.

Figure 1: stakeholder groups when balancing energy performance and architectural appeal



Directly dependent stakeholders: Owners and investors prioritize property value, cost-effectiveness, sustainability and aesthetics, and often make decisions that balance energy efficiency with architectural preservation. For example, the retrofitting of historic houses in the UK revealed a conflict between energy efficiency and heritage aesthetics, with owners prioritizing preservation (Sunikka-Blank & Galvin, 2016). Similarly, in Italy, owners worked with architects to integrate energy-saving technologies without compromising aesthetics, influenced by financial constraints and tenant needs (Berardi, 2013). Tenants and users, who experience building performance first-hand, prioritize comfort, functionality and visual appeal. In sustainable office designs, tenant feedback influenced adjustments to building systems for satisfaction and efficiency (Jailani et al., 2015). In a UK social housing project, tenants guided retrofit decisions to align energy measures with their living conditions and aesthetic expectations (Bright et al., 2019). A study of offices further highlights how user input balanced technical solutions with comfort and design preferences (Lassen et al., 2021).

Indirectly dependent stakeholders: The middle circle of stakeholders includes municipalities, regulators and environmental organizations. Municipalities influence urban planning and encourage energy-efficient design while preserving local aesthetics. For example, in Lublin, Poland, municipalities facilitated energy-saving renovations while maintaining aesthetic harmony (Rose et al., 2021). Similarly, in Portugal, cities integrated community input into sustainable urban renewal projects (Natividade-Jesus et al., 2019), and in Seattle, USA, local authorities consulted neighborhoods to improve design and functionality during retrofits (Ribeiro et al., 2018). Regulators ensure compliance - they mediate between competing goals, such as enforcing insulation standards while preserving historic facades (Jakhar & Jain, 2024). Environmental organizations and sustainability experts promote energy efficiency and sustainable materials. In a global assessment of green buildings, they addressed both environmental and aesthetic concerns (Hafez et al., 2023). Furthermore, sustainability experts in retrofit technologies balanced energy efficiency with aesthetic integration and stakeholder preferences (Benzar et al., 2019), and in deep retrofits they prioritized both energy conservation measures and cultural preservation (Gultekin et al., 2014).

Supportive stakeholders: The outer circle includes stakeholders responsible for the technical implementation of energy and architectural measures: architects, engineers, construction companies and facility management companies. Architects and planners integrate aesthetic and functional elements into designs. They balance energy improvements with architectural character and, where necessary, address heritage conservation. For example, architects in Turkey sought to harmonize the design of mass housing with local styles while improving energy efficiency (Aydin et al., 2019). In Malaysia, architects adapted historic buildings for energy optimization without compromising cultural values (Kamaruzzaman et al., 2011), and in the US, architects used a game-theoretic approach to balance energy efficiency and design appeal for office buildings (Zhuang et al., 2017). In Italy, engineers helped integrate sustainable materials into residential buildings (Berardi, 2013), and in commercial retrofits, engineers optimized mechanical systems while ensuring design appeal (Menassa & Baer, 2014).

3.2 Energy-Efficient Renovation Measures and Aesthetics

To identify relevant criteria that play a role in the trade-off between energy efficiency and aesthetics, the following three-step approach was defined:

1.) Identification of Energy-Efficient Renovation Measures: A comprehensive list of renovation measures that can improve the energy efficiency of buildings was compiled. This list was validated in a digital workshop with ten participants from the field of energy consulting. Feedback was requested to identify any important renovation measures that might be missing. The renovation measures were categorized into eleven main categories: exterior wall, roof, top story ceiling, basement ceiling, windows, building envelope, heat generator, hot water, ventilation, lighting system, and renewable energy. Within these categories, a total of 33 specific measures were identified. For instance, in the category exterior wall, measures included:

- Insulating exterior walls with ETICS (External Thermal Insulation Composite Systems)
- Installing an insulated, rear-ventilated façade
- Insulating the exterior wall from the inside
- Insulating the cellar wall against the ground

2.) Identification of Aesthetic Quality Criteria: Criteria influencing the aesthetic quality of buildings were grouped into seven overarching categories:

- Design: Proportions, forms
- Tactility/ Quality: materials
- Contextuality (Integration into the environment or consciously desired contrast)
- Originality or degree of innovation
- Functionality: usability, flexibility, accessibility, and adaptability to various requirements
- Cultural and Historical Aspects: Connection to cultural identity, preservation of historical elements (e.g., symbolic value for communities).

- Emotional impact (subjective perception and atmosphere)

The conducted interviews provided insights into aesthetic criteria of the predefined renovation measures. In comparing the interview results with the predefined criteria, several key similarities and differences emerge. The presentation of the results begins with similarities:

Materiality and Quality: A strong emphasis was placed on using high-quality materials, particularly natural and authentic ones, in line with the predefined criteria of Tactility/Quality. Most interviewees highlighted the importance of avoiding artificial materials, aligning with the notion that aesthetics is deeply tied to authenticity (Interviews 1, 2, 6, 7).

Contextuality: The majority of interviewees emphasized the importance of a building's integration into its surrounding environment. For example, interviews 2, 4, and 10 stressed the need to respect the context and architectural style of existing buildings when making renovations.

Originality: There was broad agreement that originality is crucial, especially in the context of renovation projects where the goal is often to preserve or enhance the building's unique character (interviews 4, 6, 9, 13).

Proportions and Form: Some interviewees referred to the importance of proportions, symmetry, and form in evaluating architectural quality (Interviews 1, 3, 10).

The discussion now continues with the differences:

Functionality: While the predefined criteria list includes Functionality as a key factor in aesthetic evaluation, this was less frequently mentioned or prioritized in the interviews. Functionality was only discussed in detail in relation to flexibility and usability (Interview 5, 10).

Emotional Impact: The Emotional Impact criterion was only briefly addressed in the interviews, with references to how certain materials or designs evoke specific emotional responses (Interview 5). However, it was not as explicitly emphasized as a distinct category, and experts tended to focus more on physical attributes (e.g., materials, proportions) rather than subjective emotional responses.

Cultural and Historical Aspects: While there were mentions of preserving historical elements or reflecting cultural identity (Interview 5, 8), the focus on cultural and historical aspects was less pronounced in the interviews compared to the predefined criterion.

In summary, the interviews largely corroborate the predefined criteria. However, some differences emerged in the emphasis placed on functionality, emotional impact, and cultural aspects. The interviews revealed that while aesthetic criteria are essential, practical considerations - such as cost and the feasibility of implementation - often influence the final aesthetic outcomes of renovation projects.

3.) Conflicts Between Energy-Efficient Renovation Measures and Aesthetics: The results from the interviews reveal both congruences and differences regarding the renovation measures that may potentially conflict with aesthetics, compared to the list of renovation measures initially identified. The presentation of the results begins with similarities:

Exterior Wall Insulation (WDVS): Many interviewees highlighted facade insulation as a prominent measure that may conflict with aesthetic values. This aligns directly with the identified renovation measures, where the external insulation system is seen as a primary point of contention, particularly for historical buildings (Interviews 1, 6, 9, 13).

Window Replacement: Several experts emphasized window replacement as a critical factor in aesthetic conflicts, particularly when the chosen windows lack the original profile or when cost-efficient alternatives are selected (Interviews 1, 9, 12).

Photovoltaic Systems: The integration of photovoltaic systems was frequently mentioned as a potential source of aesthetic conflict, depending on the installation method and its impact on the building's appearance (Interviews 4, 5, 6, 13).

Heating System Upgrades (e.g., Heat Pumps): The integration of heating systems, particularly air-source heat pumps, was highlighted as a significant concern in terms of aesthetics (Interviews 6, 10, 11). These systems, often installed in front gardens, can conflict with the visual appeal of a property. Their placement and design make them a critical consideration, as they are highly visible.

The discussion now continues with the differences from the predefined criteria:

Roof Insulation: The predefined list of renovation measures includes roof insulation as a common renovation step, but this was not as frequently cited in the interviews as a significant point of aesthetic conflict. Only a few interviewees (Interviews 7, 12) mentioned roof insulation as an issue, suggesting that it is often less visible or impactful on the overall aesthetic of a building compared to facade insulation or window replacement.

Lighting and Lighting Systems: The use of LED lighting systems and lighting systems with presence detectors (predefined in the list) was not mentioned as an aesthetic conflict in the interviews.

Table 2: Relationship between aesthetic quality criteria and renovation measures, Interview results

	Aesthetic Quality Criteria **Renovation Measures**	Design (Proportion, Forms)	Tactility	Contextuality	Originality	Functionality	Cultural and Historical	Emotional Impact
1	Insulation of Exterior wall	x	x	x			x	
2	Insulation of Roof							
3	Insulation of Top storey ceiling							
4	Insulation of Basement ceiling							
5	Replacing of Windows	x	x	x	x		x	x
6	Attaching Sun Protection Windows	x						

7	Exchange of Heat generator					x		x
8	Insulation of Heating Pipes							
9	Replacing the lighting to LED							
10	Lighting system with presence detectors							
11	Installation of a photovoltaic system				x			x
12	Other							

4.) Balancing Efficiency and Aesthetics: Many interviewees emphasize that energy efficiency often takes precedence due to regulatory requirements (e.g., GEG) and the need to meet specific performance benchmarks (Interviews 3, 10, 11, 12). Aesthetics are frequently described as a secondary consideration (Interviews 2, 4, 6, 10, 12). Some experts believe that efficiency and aesthetics can coexist, particularly with innovative solutions or when sustainability is reframed as an aesthetic quality (Interviews 1, 5, 9, 13). Many experts note that budget limitations heavily influence decision-making, often restricting aesthetic options (Interviews 2, 4, 6, 8, 12). Some interviewees suggest that cost, efficiency, and aesthetics should be equally weighted, but this balance is rarely achieved in practice (Interviews 5, 13).

5.) Opportunities for AI Technology to Support the Decision-Making Process: The interviews reveal that AI technologies are seen as valuable tools for supporting decision-making in building renovations. The primary applications identified include:

Variant Development: AI can generate design variants (e.g., facades, insulation techniques), enabling architects to select the most suitable option aesthetically and technically (Interviews 1, 2, 5, 6, 7).

Product and Material Analysis: Architects often struggle with the overwhelming volume of products and materials; AI-powered databases could significantly improve efficiency and decision-making. AI can streamline product selection by analyzing large datasets, filtering for specific criteria (e.g., energy efficiency, materiality, cost), and generating comparative tables (Interviews 3, 5, 7, 12).

Visualization: AI-generated renderings or visualizations of proposed renovations can support architects, clients, and other stakeholders in understanding potential outcomes and making informed decisions (Interviews 2, 8, 10, 13).

Collaboration and Communication: AI could bridge gaps between roles within renovation teams by acting as a mediator or facilitator, enhancing communication and collaboration (Interview 10).

To address these challenges, a Smart Product Recommender (Bot) could be developed - it would save time by presenting concise options. This would increase the likelihood of finding the product that best fits the project's needs. Moreover, it would allow architects to dedicate more time to focusing on aesthetics, rather than spending excessive time on product comparison and selection.

3.3 Decision Support with Telegram Bot

In the interviews, window replacement was cited as an important measure where aesthetics and efficiency were at odds, resulting in a relevant decision-making issue. However, the wide range of available products often complicates the decision-making process for stakeholders such as architects and planners. Check24, a Germany-based comparison platform widely used for services like insurance and energy contracts, serves as a key inspiration for the bot's functionality. Such platforms have proven effective in simplifying complex decision-making by employing data-driven approaches to provide tailored recommendations. Applying this methodology to the renovation sector could offer stakeholders objective, data-backed suggestions that align with their specific needs.

Table 3: Example of collected product information from online tailer stores

Product	ThermoMax 5 Classic
Material	Plastic
Price [€]	€72.47
Construction Depth	70 mm
Color	Not Available
Standard Glazing	Double-glazed
Standard Security	Basic security
Uf-Value [W/m^{2}K]	1.3
Ug-Value [W/m^{2}K]	Not Available
Design	Offset surface
Availability	Configure Now
Link	https://www.fensterdepot24.de/thermomax-5classic-kunststofffenster.html
Sealing Levels	2

In this context, a Telegram Bot serves as an interactive interface to facilitate real-time comparisons of renovation options. In the described use case, to ensure the accuracy and currency of product information, all key parameters related to windows were sourced directly from an online window retailer and stored in a database (refer to Table 3). This database forms the foundation for the Bot's functionality, enabling users to select suitable window replacements. Initially, the Bot prompts users with a series of questions to ascertain their preferences regarding cost, energy efficiency, and aesthetics. Based on the users' responses, the Bot queries the database, which contains up-to-date product information, and generates a selection of tailored window options that align with the specified

criteria. Users can then configure their chosen window and proceed with the purchase via a provided URL. This Use Case illustrates the potential of a bot to assist stakeholders by automating the comparison of objective factors, thereby enabling architects to dedicate greater attention to the creative and aesthetic dimensions of renovation projects.

4 Conclusion

This paper explores which stakeholders are relevant for the implementation of renovation measures. Subsequently, renovation measures were identified, as well as the criteria essential for evaluating aesthetic quality. Building on this foundation, the study investigated which renovation measures are prone to conflicts between energy efficiency and aesthetic quality. Finally, it examined how such conflicts can be mitigated. This was achieved by developing a Telegram bot connected to a database to support the selection of suitable products from a wide range of options, considering the life cycle of the building and the long-term impacts of renovation measures on both energy performance and architectural appeal.

A limitation of this study lies in its geographic focus, as it was conducted exclusively in Germany. This context undoubtedly influenced both the identification of renovation measures and the perception of aesthetic criteria. While the findings provide valuable insights into the interplay of aesthetics and renovation measures within a German context, the results may not fully capture regional differences in aesthetic expectations. Finally, the Telegram bot should be tested by architects and planners in practice to validate its functionality and demonstrate its added value.

Future research could explore how aesthetic expectations, and the prioritization of specific renovation measures differ across geographic and cultural contexts. By comparing these insights, it would be possible to identify universal principles of aesthetic renovation while also recognizing regional adaptations. This global perspective is particularly relevant, as the challenges of sustainable building renovations - balancing energy efficiency and aesthetics - are critical worldwide.

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Data Availability Statement
The study is based on interview notes, which are not publicly available due to confidentiality and data protection requirements. However, anonymised summaries may be made available upon reasonable request.

Conflicts of Interest
The authors declare no conflict of interest.

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