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Criteria to Evaluate the Quality of Building Envelope Retrofits

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Abstract

The construction industry is progressively moving from designing and building new towards redesigning, upgrading and maintaining existing buildings. Concurrently, the increasing demand for urban renewal calls for architectural interventions. Success and the meeting of set goals is typically assessed using an established framework.

Architectural tradition offers methodologies to evaluate built structures based on characteristics like build quality, engineering performance, functionality, spatial design, and effects on the living environment.However, in addition to these qualities, building refurbishments target energetic, economic, environmental and social improvements. They respond to complex requirements set by an extensive network of stakeholders. A qualitative building assessment based on architecture alone does not sufficiently reflect the aims of such processes, and a holistic means to analyze refurbishment designs is lacking.

This paper presents a review of existing building assessment methodologies, and suggests a new, simple set of evaluation criteria for interventions on the building envelope. The proposal is demonstrated by assessing three cases illustrating different approaches to such processes. Evaluation results prove the usability of the method to assess the variation in extent and aims of implemented measures. Coupled with quantitative estimations, it could aid the decision making process in residential housing cooperatives. Future development should include further cases and more extensive building refurbishments.

Keywords: building envelopes, build quality, evaluation criteria, refurbishments, energy retrofits, qualitative building assessment.

Introduction

The construction industry is progressively moving from designing and building new to redesigning, upgrading and maintaining existing buildings. The context is complex and the regulatory framework is increasing. Refurbishments should target not only structural and energetic, but also economic, environmental and social improvements.

A major difference, as compared to new build, is the position of the end-user as main client and stakeholder. In Finland, the end-user is often also the sole investor, as the majority of our residential households are owner-occupied (Official Statistics of Finland 2016). Hence, qualitative improvements and added value for the end-user should be a main outcome of refurbishment processes.

The decision making process is challenging. Finnish residential multi-story buildings are typically organized as Limited Liability Housing Companies and led

Building refurbishments respond to a complex set of requirements from an extensive network of stakeholders. A holistic means to analyze refurbishment designs is lacking.

by a board of laymen. Decisions are taken as a majority vote among shareholders, being the owners and usually also users of the building. Motivations for a voting decision can vary significantly. Typically, a refurbishment process starts with a project planning phase overseeing various scenarios for building works and required initial investment cost. Based on presented material and set requirements the board selects among numerous alternatives a few choices to be decided on by the shareholders. Minimum requirements are usually identified based on immediate needs, like leakages, and the long-term maintenance plan of the housing company. As laymen are involved personal preferences may also affect, for example, the setting of requirements and the selection of alternatives to be taken forward. Overall, there is a tendency towards avoiding high cost measures. (Cronhjort and le Roux 2013.) In this context, very seldom any actual assessment framework is applied. One reason being the cost. Hence, the alternatives might be limited to known solutions responding to limited requirements. Added value is seldom discussed.

To develop building retrofits the client needs to be educated on what to demand and how, and be offered tools to better evaluate proposed solutions. As the client in a building refurbishment often is also the end-user, the assessment should not only include quantitative aspects but additionally aid the understanding of the qualitative end result and added values of the proposal. The decision making process of housing companies calls for cost efficient assessments based on both quantitative and qualitative criteria, including architectural aspects. This study proposes one approach illustrated with three cases and discusses the results as well as needs for further development.

Section one of the article focuses on the methodology. Section two presents a literature review. Section three explores requirements set on building envelope retrofits and suggests a set of evaluation criteria. Section four demonstrates the method by assessing selected cases. Sections five and six discuss and conclude the results.

Methodology

The study includes a literature review of existing architectural assessment and complementary evaluation frameworks for building refurbishments, and suggests an interdisciplinary set of qualitative evaluation criteria reflecting current aims in construction. The proposal is demonstrated by evaluating three different approaches to facade retrofits of residential buildings.

An essential part of this research is the motivation for selecting and deciding on evaluation criteria. The motivations are as follows:

1) As the study is limited to facade retrofits, evaluation criteria base on structural parts that exist in the facade and measures that can be taken during a refurbishment process.
2) Added value for the end-user is the focal point. Hence, suggested measures are evaluated from the viewpoint of the end-user and direct effects on living, like comfort of the occupant.
3) Aims and goals are regulated by European Directives and national building codes. Such standards offer a basis for comparison when deciding on level of improvements regarding, for example, energy efficiency.
4) The study adds new knowledge to architectural research. The architectural tradition offers itself a holistic view on the art of building suggesting the user and his experiences as focal point. A key message of this research is placing the user back in the centre, building on this tradition. Hence, architectural frameworks are also investigated.

Additionally, a means to convey the results must be chosen. The target group for communications consists of laymen and hence the final outcome should be easily and readily understood. To support this target the results are formatted into radar charts as suggested, for example, by Malm et al. (2014) and the developers of the Design Quality Indicator (Construction Industry Council).

Literature review

Methodologies and software exist to evaluate building performance. The emphasis of such is often on single indicators like energy efficiency or environmental impact (Horvat and Fazio 2011; le Roux and Cronhjort 2012). Tools to evaluate *Life Cycle Analysis* (LCA) and *Life Cycle Costs* (LCC) exist and the use is increasing. From the viewpoint of current European agreements this is sufficient; according to the recast Directive 2010/31/EU building retrofits should be done to a high standard of energy efficiency and in a cost efficient way (Buzek and López Garrido 2010).

However, researchers do argue that building projects should add value, not only to the built environment, but also to the end-user and client in the form of commercial and social benefits, and call for methodologies to holistically quantify the aspects of good design (Adamson 2004; Thomson, Austin, Devine-Wright and Mills 2003; Vestergaard 2011).

Project *Sustainable Refurbishment of Building Facades and External Walls*, *SUSREF*, presents one attempt suggesting a holistic and systematic evaluation tool of facade retrofits (SusRef). The method comprises fifteen aspects to be assessed, including the evaluation of aesthetic design in addition to energy efficiency, structural stability and safety, interior air quality, environmental performance, costs, and social impacts (Häkkinen 2012). The SusRefTOOL presents criteria for eight out of fifteen variables on a scale from -2 to +2. The aesthetic quality of the design is suggested to be assessed by a panel of experts (Häkkinen ed. 2012.). However, evaluation criteria remain undefined. The project provides a separate calculation tool for LCA and LCC for sustainable refurbishments of external concrete sandwich wall elements in the Nordic countries and Central Europe. It uses the VTT database and a cradle-to-gate approach. (SusRef.)

The architectural quality of ambitious facade retrofits on residential buildings has been assessed by Vestergaard (2012) in a case study discussing four projects from Denmark, Austria and Finland in her article *Architectural freedom and industrialized architecture – retrofit design to passive house level*. She concludes that despite offered opportunities, retrofitted buildings still express a similar repetition as the original designs of mass-produced housing. However, she does not either suggest any concrete evaluation criteria.

In the United Kingdom, the evaluation of architectural quality in construction, both new build and refurbishments, has been explored from the viewpoint of lean culture looking at architecture as part of the value delivery process (Thomson, Austin, Devine-Wright and Mills 2003; Gann, Slater and Whyte 2003). The meaning of value delivery, and the difference between quality and value in building design has been discussed by Thomson, Austin, Devine-Wright and Mills (2003). They suggest that "[…] the quality of a product is an assessment of how well its qualities (that is its features or attributes) meet the customer needs." Value is defined as a subjective perception, but it is recognized that it can have different meanings depending on stakeholder. However, the authors conclude that value can be viewed as an output-input balance and objectively assessed by comparing benefits and expense or sacrifices. To establish delivered value for the customer, delivered quality is assessed based on the qualities of the design and product. (Thomson, Austin, Devine-Wright and Mills 2003, 337.) The authors suggest using the *Design Quality Indicator* (DQI) developed by the Construction Industry Council in 1990. It was launched online in the United Kingdom in 2003, in the

United States in 2006 and by 2014 it was used in over 1 400 projects. (Construction Industry Council; Wikipedia 2014.)

The Design Quality Indicator proposes an assessment of architecture based on functionality, build quality and impact. It is a modern interpretation of Vitruvius´ tenets of architectural design.

The DQI builds on the foundation established by Vitruvius, translating "[…] Vitruvius´ principles of commodity, firmness and delight into the three indicators of functionality, build quality and impact for use in modern context." (Thomson, Austin, Devine-Wright and Mills 2003, 341). *Functionality* refers to the user experience including use, access and space; *Build quality* describes the engineering performance of the building including engineering systems and construction; and *Impact* the human perception of the building based on character, form, materials used, the interiors, the relationship with the surrounding community and built environment. The importance of stakeholder involvement is emphasized and the DQI is primarily intended for use during the preplanning and design (value delivery) process (Thomson, Austin, Devine-Wright and Mills 2003; Construction Industry Council; Wikipedia 2014). However, it is applicable throughout the lifecycle of a building (Gann, Salter and Whyte 2003). Figure 1 illustrates the three pillars of architectural quality assessment in accordance with the DQI.

The DQI is a comprehensive evaluation method including extensive stakeholder engagement and used for complex projects like e.g. hospitals (Construction Industry Council). Based on lessons learnt the developers of the DQI also recognize a need to continue work by furthering the understanding of design quality in terms of stakeholder participation, life-cycle design, the interactions of process and products, learnings from other sectors, organizational learning, validation and the feeding back of results (Whyte and Gann 2003).

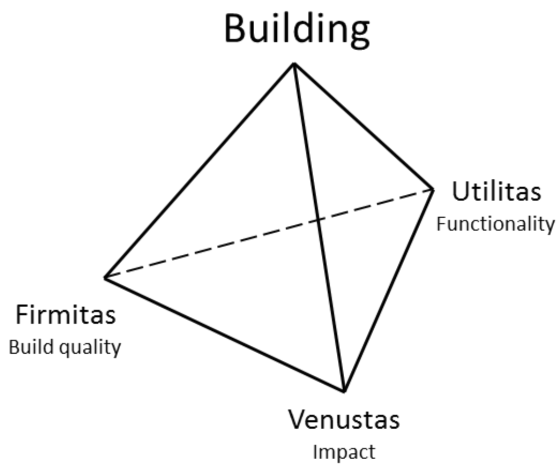


Figure 1. Three characteristics of architectural design. The Design Quality Indicator (DQI) proposes an assessment of architecture based on functionality, build quality and impact. It is a modern interpretation of Vitruvius´ tenets of architectural design.

Macmillan (2006) has discussed the concept of good design through the viewpoint of added value to a building. He distinguishes between three different types of values in accordance with DEGW & Technibank (1992): (1) use value – customized and owner-occupied buildings, (2) exchange value – buildings designed to maximize trade value, and (3) image value – designed to maximize the image of the building. To these he suggests the addition of social, environmental and cultural value. He recognizes the difficulty in defining design-based added value, but argues that the absence of a quantification of delivered value causes "[…] a perennial risk of building down to a cost rather than up to a value." (Macmillan 2006, 268.).

The aim is to illustrate the extent of improvements in user experience, engineering, energy efficiency, and architecture achieved with the suggested facade retrofit design.

Qualitative assessment of building envelope retrofits

Building refurbishment projects and facade retrofits are here considered as value delivery processes with the end-user as primary client. The aim is to improve an existing built structure to better respond to changed requirements and needs, and deliver value for the customer. However, as Thomson, Austin, Devine-Wrigth and Mills (2003) suggest, value is a subjective perception.

In building refurbishments, key aims and values are established in the initial project planning phase. Regarding building envelopes, qualitative needs are often concrete, like new windows replacing old ones at the end of their lifespan, reduced draft and increased thermal insulation. In addition, immaterial aims might be stated, such as an improved image. Drivers are often diverse and can include, for example, an increased exchange value of the building as an asset.

The process requires an investment. Regarding residential buildings and especially in the case of owner-occupied housing companies, the investment capacity and interest is limited. This boundary condition leads to an input-output balancing act affecting added value for the end-user. Decision making is demanding without objective means to compare alternatives.

Proposal for evaluation criteria

The emphasis in building codes is on energy and cost efficiency, with resource efficiency upcoming. Building retrofits should be done to a high standard of energy efficiency and in a cost efficient way.

Tools to evaluate cost efficiency exist. Life Cycle and Whole Life Costing are established concepts. However, early project planning in housing companies typically relies on initial investment cost figures and payback time calculations only, even if the aim is for an extended lifetime of built structures. This could be changed by introducing, for example, the SusRefTool limited to the building envelope, and developed specifically to aid facade retrofits in the Nordics. It includes both LCC and LCA.

Missing is a simple tool for qualitative analysis of the projected outcome in the planning phase.

Building qualities typically addressed in a facade retrofit include the structural condition, energy efficiency (thermal insulation and airtightness), user satisfaction and architectural image (quality). With an increasingly aging population, accessibility is also an important aspect to address even if the opportunities as part of a building envelope retrofit are limited.

To evaluate qualitative improvements and added value for the end-user, I propose using a framework based on the three-pronged approach of DQI including functionality, build quality and impact. However, due to the discussed context and the aim for simplicity, I suggest limiting the assessment to aspects relevant for a facade retrofit only. Characteristics evaluated are listed in Table 1. They include accessibility, ventilation, lighting conditions, the structural frame, external cladding (facade material), window U-value, thermal insulation, airtightness, visual appearance of the building and the building volume (form). All of these also affect the user experience of the facade, building, and living spaces. The variables are evaluated on a scale from 0 to 3. As the aim should be for improved user experience, negative scores indicating a weakening of some aspects are excluded.

Table 1. Suggested criteria and scale to evaluate facade retrofits.

Level of measures		Status Quo	Minor Improvement	Upgraded	Excellent
Score		0	1	2	3
USER EXPERIENCE (FUNCTIONALITY)	Accessibility	No change	Small changes including, for example, added handrails	Accessibility on the refurbishment design agenda	Accessibility measures like an improved access to the balcony / added new balconies to facilitate outdoor areas to apartments
	Ventilation	No change	Openable windows or air inlets, mechanical exhaust air system	Openable windows and air inlets, mechanical exhaust air system	Air ventilation system with heat-recovery
	Light	No change	Small changes including, for example, narrower window frames	Limited amounts of larger window area or some new, additional windows	Extensive amount of larger window areas and/or new windows
ENGINEERING AND ENERGY EFFICIENCY (BUILD QUALITY)	Frame of the facade	No change	Maintenance and repair work	Structurally improved	New
	External cladding/ facade material	Maintenance, minor repairs	Repair of the existing material	New, maintenance requirements close to original	New, expected lifetime up to 50 years or more, limited maintenance requirements
	Windows U-value	No change	New windows, U-value less than current building regulations for new built or national aim for building retrofits	New windows, according to current building regulations for new built or national aim for building retrofits	New windows, average value of all windows as installed U≤ 0.85 W/(m²K) in accordance with the EnerPHit suggestion (Feist 2010)
	Thermal insulation	No change	Added thermal insulation as compared to state prior to facade retrofit	According to current building regulations for new built or national aim for building retrofits	Passive house level local standard or better
	Airtightness	No change	Minor repair	According to current building regulations for new built or national aim for building retrofits	n50 ≤ 1.0 h-1 as a limit, target value n50 ≤ 0.6 h-1 in accordance with the EnerPHit suggestion (Feist 2010)
ARCHITECTURAL QUALITY (IMPACT)	Visual appearance of the building	No change	Small changes in visual appearance affecting only parts of the building	Aim to change visual appearance of the single building by e.g. changes in a monotonous original visual image of the building; visual changes limited	Aim to change visual appearance of the single building and affect the surrounding built environment by, for example, changes in a monotonous original visual image of the building; strong architectural vision
	Building volume/form	No change	Small changes affecting only parts of the building	Aim to change visual appearance of the single building by e.g. changing the original building volume with a new roof; visual and structural changes limited	Aim to change visual appearance of the single building and affect the surrounding built environment by, for example, changes in the building volume like building extensions; strong architectural and structural vision

The assessment aims not to compare factors with each other, but to evaluate to what extent each factor has been taken into account in the facade retrofit design. It is up to decision making to select which factors are given priority. For ease of use, the results are examined as a radar chart, visualizing the scores. Hence, more coverage indicates a more holistic refurbishment design including a larger extent of measures and qualitative upgrades.

Cases

To demonstrate the suggested methodology in use three retrofit and upkeep options are evaluated. Cases include (A) a building envelope retrofitted using prefabricated timber-based element systems *(TES EnergyFacade*), (B) a building facade retrofitted using thermal insulation and rendering (conventional), and (C) a facade subject to maintenance only. Figures 2−4 show built examples.

The proposed methodology is demonstrated by evaluating three different facade retrofit and upkeep options.

Case A uses *TES EnergyFacade*, which exemplifies a holistic approach to facade retrofits. The wording derives from the acronym of research project *Timber based element systems to improve the energy efficiency of the building envelope* (TES EnergyFacade 2009). The project demonstrated the method (later further developed) for retrofitting building facades using large-scale, prefabricated, timber based elements and hence introducing an industrial approach to building refurbishment. The separate wooden frame in the new facade elements allows for extensive amounts of thermal insulation. Coupled with an additional airtight layer, the energy efficiency of the building can be improved even up to passive house standard. Figure 5 illustrates the retrofit process of the discussed case. The presented project was a pilot and the first building in Finland to be retrofitted with *TES EnergyFacade*. The amount of thermal insulation after refurbishment totals between 350 and 400 millimeters (Lylykangas 2011).

A state-of-the-art alternative for facade improvements in Finland today is exemplified by *Case B*, using external insulated render. The existing facade is upgraded by adding new thermal insulation directly onto the existing wall. The thickness typically varies between 50 and 100 millimeters. The surface is completed with several layers of rendering. In a building from, for example, the early 1970´s the thermal insulation level of the facade after refurbishment is less than required for new built according to the National Building Code of Finland.

The third example is continuous maintenance of the facade including for example, patch repairs, the re-seaming of concrete sandwich elements and a renewal of windows to triple paned. *Case C* represents this option.

The alternative solutions are illustrated with realized projects; three neighbouring residential buildings originating from the 1970´s, and located in the area of Peltosaari, Riihimäki. The area is a typical representative of a Finnish suburb and the urban planning of its time, with large areas erected at once and forming a homogeneous built environment. The houses were built with similar building designs using a contemporary structural concrete system. It is based on prefabrication, with load bearing frames of concrete and non-load bearing facades of concrete sandwich elements (Betoni Elementti Systeemi BES (Finnish), Concrete Element Systems; SBK 1979). The original building envelope contains a maximum of 90 millimeters of thermal insulation and double pained windows. The buildings are originally equipped with mechanical exhaust air ventilation.

The investment cost for the three retrofit alternatives varies substantially. The maintenance cost of concrete element facades is negligible, including mainly re-seaming every 15 to 20 years. In Finland, the average cost of more extensive repair works varies between 50 and 100 euros per meter square (€/m^2). The cost for the conventional option including a 50−100 mm layer of additional thermal insulation and rendering or, alternatively, a facade of cement fiber boards varies with an average between 150 and 200 €/m². (Mattila 2010.) The cost of an energy retrofit using timber-based elements can, as assembled and based on early pilots in several European countries, vary between 800 and 1000 €/m² (le Roux 2014, Lichtblau 2014). However, the price for single elements is close to the price for the conventional option.

Figures 2-4. Cases illustrated. To demonstrate the suggested evaluation method three options of building envelope retrofits are assessed. The images illustrate built examples. From the top; A) a building envelope retrofitted using prefabricated timber-based element systems *(TES EnergyFacade*), B) a retrofit using thermal insulation and rendering (conventional) with new windows and glazed balconies, and (C), a facade with upkeep consisting of continuous maintenance and optional glazing of balconies. All buildings originate from the 1970´s, were built using similar building plans and the same structural concrete system. Images by the author.

Figure 5. The *TES EnergyFacade* retrofit process of Case A visualized. Stages from the left: 1) original building, 2) removal of old balconies, the external layer of concrete and old thermal insulation (old windows are still intact for weather protection), 3) the assembly of soft thermal insulation as adaption layer, 4) the assembly of an airtight layer, 5) the assembly of vertical, pre-fabricated, timber-based new facade elements including new passive house standard windows and the removal of old windows beneath, 6) finalization of the renewed facade with a new roof and detailing, 7) the assembly of new balconies. Image by Ville Riikonen, Aalto University.

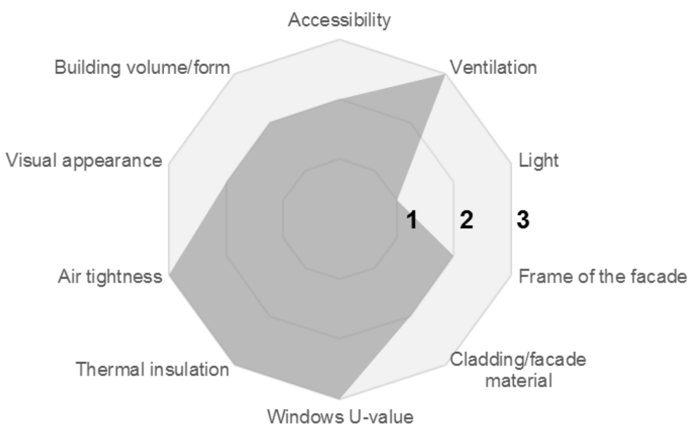
Figures 6-8. Evaluation results. Case (A) *TES EnergyFacade*. Next page: case (B) conventional retrofit, and case (C) maintenance and repair. A *TES EnergyFacade* retrofit attends a larger amount of aspects of the building envelope improving user comfort on many levels, as compared to a conventional retrofit. The dark grey area of case (B) illustrates the outcome if the window U-value is not up to current standard for new built and the total amount of thermal insulation as built varies. In an optimal case, the points for windows and thermal insulation would be 2 (light grey). Case (C) might include the renewal of windows (dashed line). Lighting and accessibility are still considered only to a limited extent in facade retrofits, regardless of used technology.

Evaluation results

A comparison of the facade retrofits using the above defined criteria illustrates clear differences in goals and outcomes. The results are presented as radar charts in Figures 6−8.

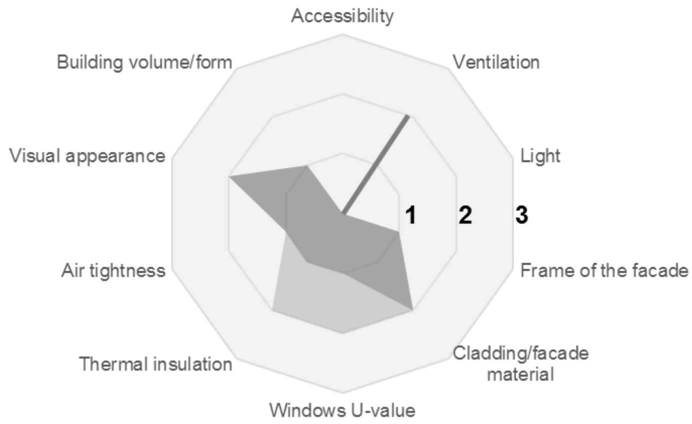
A typical Finnish concrete multi-story building from the 1970´s, without any renovation or retrofit measures (case C), scores 2 points for ventilation as openable windows and a mechanical air ventilation system for exhaust air is originally included. Other attributes score 0 points. A conventional facade retrofit including renewed windows (typically done separately), a layer of added thermal insulation on top of the existing facade or on a partly demolished facade covered with rendering on site (case B), mainly addresses the look of the building with 2 points for Visual Appearance. The results show the extensiveness of a *TES EnergyFacade* retrofit (case A), attending not only the building appearance but also energy efficiency. However, in this comparison, no difference between the architectural impact in cases A and B can be identified. Figure 9 shows the collected results; *TES EnergyFacade* is the most extensive but also the most holistic approach to repairing a building envelope.

A) TES EnergyFacade



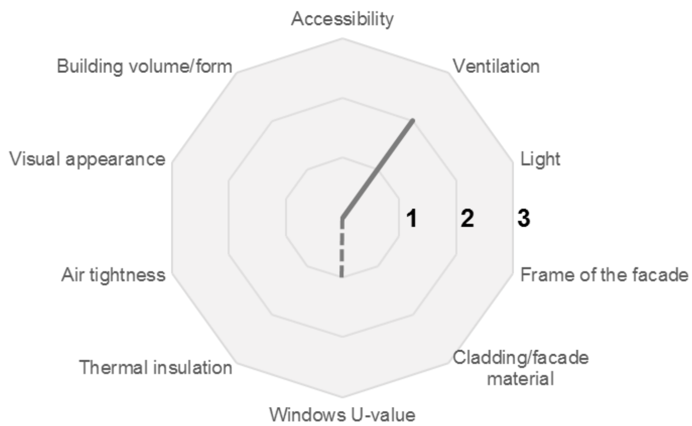
Level of measures: 1 Minor improvement **2** Upgraded **3** Excellent

B) Conventional retrofit



Level of measures: 1 Minor improvement **2** Upgraded **3** Excellent

C) Maintenance and repair



Level of measures: 1 Minor improvement **2** Upgraded **3** Excellent

Differences are also reflected in total scores. Points achieved with the *TES EnergyFacade* retrofit (case A) total 23 out of a maximum 33, with conventional measures (case B) 11(or 12-13, depending on windows and thermal insulation level) and with maintenance only (case C) 2. *TES EnergyFacade* is a costly solution but the price reflects the extent of improvements.

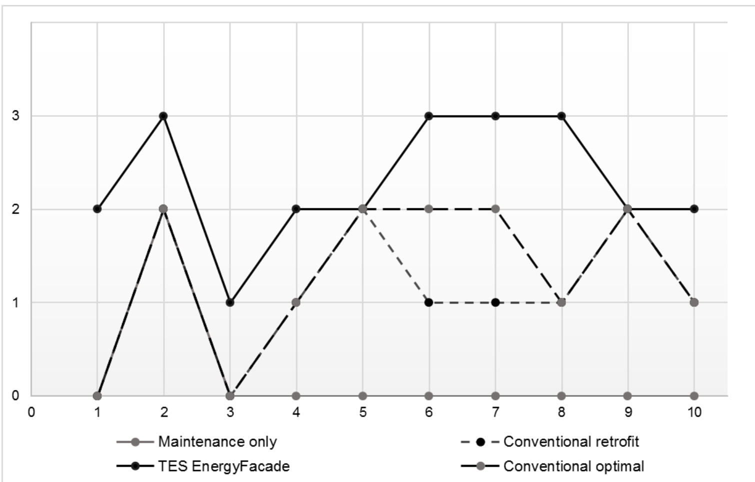


Figure 9. Evaluation results compared. The Y-axis lists scores achieved on a scale from 0 to 3, the X-axis assessed variables from the left as follows; (1) accessibility, (2) ventilation, (3) light, (4) frame of the facade, (5) external cladding (facade surface), (6) windows U-value, (7) thermal insulation, (8) airtightness, (9) visual appearance of the building, (10) building volume (shape). The results illustrate the difference in extent and aim of refurbishment measures, explaining also the large variation in costs.

Discussion

Building upgrades do no longer include maintenance and repair work only, but target extensive technical and architectural improvements. The overarching aim is for increased energy efficiency and urban renewal of our existing building stock and areas.

Evaluation results reflect the variation in extent and quality of measures and the development of building refurbishments towards increasingly holistic approaches. The method could aid decision making in residential housing cooperatives.

Literature provides suggestions for evaluation methods to assess environmental impact, whole-life costing or architectural quality. However, a building assessment based on quantitative indicators only, does not sufficiently reflect the aims of modern retrofit processes with added values for the end-user as focal point. A holistic means to qualitatively assess refurbishment designs is lacking.

This paper suggests a set of evaluation criteria reflecting the quality and extent of refurbishment measures undertaken in a facade retrofit. Variables are narrowed down to aspects of the building envelope. One can argue that such measures seldom are undertaken separately, but often as included in a larger project. However, the aim of this study is to explore a new means to assess refurbishment processes using the limited context of facade retrofits as an example. Further research should extend the scope.

The proposed method is demonstrated by evaluating three building facades illustrating different amounts and types of measures including maintenance only, a conventional retrofit using external insulated render, and an extensive intervention using prefabricated timber-based elements, *TES EnergyFacade*. The results reflect the difference in extent, number and quality of measures employed in the three cases. The evaluation clearly illustrates the holistic approach of *TES EnergyFacade* explaining, for example, differences in initial investment costs.

Evaluation results also illustrate the development of building refurbishments from including only a few measures like new windows towards increasingly holistic approaches. However, the assessment is limited. A more extensive comparison of various options available could visualize the alternatives for laymen even better.

Regarding architecture, the extent of the intervention and vision shows in the results. However, variation in architectural quality is difficult to identify. Regarding the architectural end-result, it comes down to a subjective opinion. This view is supported by literature suggesting architectural quality to be evaluated by, for example, a panel of experts.

Conclusions

Means to evaluate quantitative aspects of building refurbishments like investment costs, life cycle costs, energy efficiency and environmental impact exist. However, a holistic means to evaluate and reflect qualitative aims and results of a planned refurbishment is lacking, even if the qualitative outcome is a priority for the end-user, a key stakeholder and client in such processes.

The proposed qualitative assessment method reflects the outcome of a facade retrofit in terms of end-user comfort and improvements in functionality, build quality and impact of a building. Coupled with quantitative estimations, it could aid the decision making process in Finnish residential housing companies. The methodology also includes an indicator for architectural vision. However, the results fail to reflect differences in architectural quality.

To develop the method further a larger number of cases and facade retrofit alternatives should be analysed. Further research could also explore the evaluation of more extensive building refurbishments, complementing the criteria correspondingly.

Acknowledgements

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