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Sustainable Renovation Framework: Introducing three levels of Integrated Design Process Implementation and Evaluation

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Abstract: Future sustainable building renovation is a balance between the economic and environmental impacts related to the desired social activities facilitated by the renovated building. A review of recent research has revealed that the present efforts on sustainable objectives fulfilment in renovation projects are not sufficient. This paper investigates processes and frameworks in building renovation. It aims to deal with simplification of the existing complexity due to involvement of various types of stakeholders, sustainability criteria and potential renovation technologies in design process. Moreover, it facilitates understanding of the design process implementation through identification of the different activities, which need to be carried out. Hereafter, two frameworks by application of different Multiple Criteria Decision Making (MCDM) methods are developed and for each one, three levels of decision-making and the required activities are provided. Finally, the decision-making at the third level is considered as a scientific design approach and is introduced as an integrated design process implementation and evaluation for the use of sustainability value-oriented criteria in design process. It helps stakeholders in the renovation process to discuss their project "on the same level" and results to make transparent decisions in a rational order.

Keywords: Building renovation, Decision making, Sustainability, Multiple Attribute Decision Making (MADM), Multiple Objective Decision Making (MODM)

Introduction

Renovation of existing buildings is currently achieving increased attention in different European countries (Jensen and Maslesa, 2015). The reason is that buildings are responsible for the largest untapped potential for cost effective energy saving and CO_2 reduction potential (BPIE, 2013). This potential was quantified by the European Commission [EC] (2014) to be about 40% of total energy consumption and 36% of CO_2 emissions in the European Union. However, increasing energy efficiency and reducing carbon emission are often not the only goals in building renovation projects. Projects may benefit from adopting a more broad approach to sustainability which seeks to decrease operation and maintenance costs; reduce environmental impacts; and can increase the building's adaptability, durability, and resilience towards future challenges. Consequently, the building may be less costly to operate, may growth in value, last longer, and contribute to a preferable, healthier, more convenient environment to the occupants (Kamari et al, 2017b).

There may be various reasons for why an existing building is to be renovated, and consequently different degrees of how extensive the renovation is. Common reasons for renovation is a need for general upgrading, functional changes and additions, replacement of equipment, and/or improving comfort (Burton, 2012). When all of these interventions are summated, they can move the renovation case towards the goal of overall sustainability which demands new and more holistic design processes. As response to this, the Danish research project RE-VALUE [1] (Value Creation by Energy Renovation, Refurbishment and Transformation of the Built Environment, Modelling and Validating of Utility and Architectural Value) has been initiated to establish a more holistic approach to the assessment of value creation in building renovation projects. The present paper builds upon previous work by the authors towards a holistic approach to carry out a sustainable retrofitting (Kamari et al, 2017a). In this work, a HMSR (Holistic Multi-methodology for Sustainable Retrofitting) was developed which aims to deal with the complexity and "soft" nature of the retrofitting problem involving different decision makers with different priorities. As the result of this effort, a multi-methodology based on mixing certain Soft Systems Methodologies (SSM) with Multiple Criteria Decision Making (MCDM) methods including eight steps was developed. Furthermore, a new sustainability framework to audit, develop and assess building renovation performance and to support informed decision-making throughout the project's life cycle was developed. This previous research was inspired by a number of sustainability assessment methodologies (Jensen et al, 2016) using SSM (Checkland, 2000) and Value Focused Thinking (Keeney, 1992). The product was a Value Map consisting of three categories – *Functionality*, *Accountability*, and *Feasibility* – with a total of 18 sustainable value-oriented criteria (Kamari et al, 2017b).

The research study of this paper intends to match the HMSR to the Value Map, and articulate different levels of decision-making throughout the process. Introducing these levels will facilitate understanding of the design process implementation through identification of the different activities, which need to be carried out. The paper evolves around the process of generating renovation scenarios [2] and selection of different renovation technologies/actions. The paper therefore outlines two typical decision-making frameworks which uses two different types of decision-making methods, in order to 1) ensure that the proposed levels will deal with the existing complexity in the process, 2) outline a systematic approach that includes the typical activities of an integrated renovation design process, and 3) encompass the different levels of decision-making where issues related to alternative renovation solutions must be agreed on. Finally, each of the two frameworks is divided into the proposed three levels: *Exploration*, *Assessment* and *Scientific Decision-making*. In this perspective, the research in section 2 investigates the notion of decision-making for building renovation and provides information about two different MCDM approaches. Later in section 3, it represents two frameworks including three steps of integrated design process implementation and evaluation for building renovation. Further, it discusses that a decision can be made at the end of each of the three steps and hence it defines three levels of decision-making process based upon the three stages. Finally, section 4 outlines a brief conclusion and possible future of the current research project.

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[1] Participated by Brabrand Housing Association – with energy renovation in the Aarhus suburb of Gellerup – as well as DEAS, an administration company on the private rental housing market (for more info: http://www.revalue.dk)

[2] The term "renovation scenario" used in this study means a selection and combination of some different renovation technologies/actions (i.e. insulation of the external walls or replacement of the windows are each a renovation action) that together build an alternative renovation scenario/package and subsequently is applied in a renovation project.

Building renovation through a decision-making framework

Building renovation can be regarded as a problem-solving activity terminated by a solution deemed satisfactory. It is a type of action with a purpose or for a specific purpose. Therefore, it is a process that can be more or less rational, and based on explicit or tacit knowledge. From one perspective, the process can be regarded as a cognitive process resulting in the selection of a most appropriate renovation scenario, selected out of the set of *m* common standard scenarios, which usually is the case for experienced architects or design engineers or consultant companies. In order to evaluate the *m* number of standard scenarios, *n* number of criteria/objectives e.g. from the list of 18 identified criteria in Kamari et al. (2017b), will be shortlisted. Next, the pre-generated *m* number of standard scenarios is compared to the *n* number of criteria with the aim to select the most satisfactory scenario for the renovation project (see option "A" in Figure 1).

The improvement of existing buildings involves two major steps: current condition assessment and future upgrade strategies (Juan et al, 2010). Most of the methods focus on the first step of the improvement process, understanding or predicting energy usage but no generation of possible renovation scenarios. While the latter is about proposing of the future upgrade renovation strategies. In this process perspective, it is not a question of assessing standard renovation scenarios/packages but a process of developing scenarios for the individual renovation project bottom-up. In this case, *i* number of renovation actions will be identified and combined in order to make a ranking of the *j* number of building renovation scenarios. To this end, some objectives such as energy efficiency, water efficiency, cost etc. will be shortlisted and to some extent get enhanced by combination of the most fitted renovation actions (e.g. assuming two objectives as object 1 and object 2 as shown in option "B" in Figure 1). The goal can be to find a representative set of Pareto optimal solutions (Pareto, 1896), and/or quantify the trade-offs in satisfying the different objectives, and/or finding a single solution that satisfies the subjective preferences of a human decision maker. Using prospect of decision making for building renovation, both of the two options (A and B) demonstrated in Figure 1 are regularly being researched and used in practice. In order to proceed with the options, the research can find the roots in decision-making era where a decision is made by explicitly evaluation of multiple conflicting criteria [sustainability criteria] over various existing alternatives [renovation technologies].

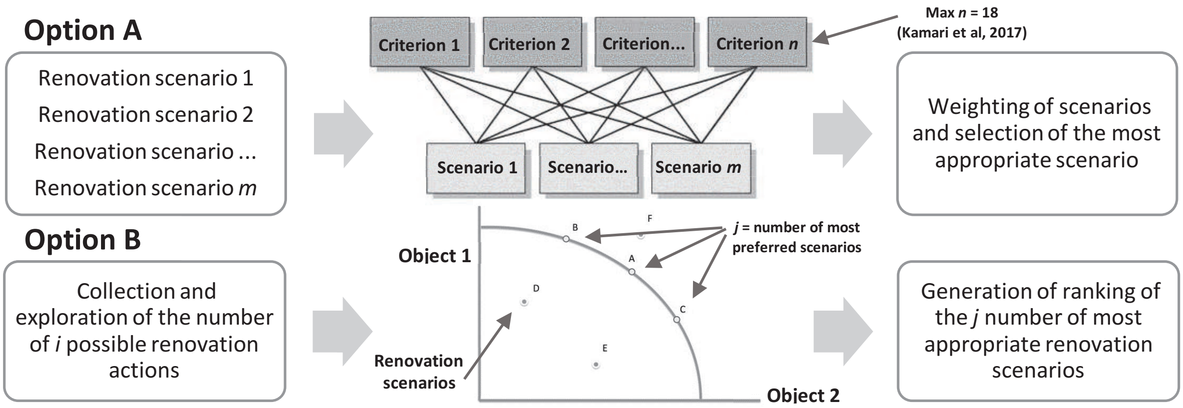

Figure 1. Building renovation throughout multiple decision-making frameworks

Hereafter and depends on working with either option A or B, different types of Multiple Criteria Decision Making (MCDM - Triantaphyllou et al, 1998) methods can be utilized. MCDM basically facilitates the process of resolving the trade-off between criteria (typically based on the preferences of a decision maker) when a solution performs well in all criteria. MCDM have been categorized into different groups and methods (Wang et al, 2009). The more popular MCDM categories are Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM) (Climaco, 1997). MODM can be used for decision problems in which the decision space is continuous (option “B” in Figure 1) while MADM (option “A” in Figure 1) can be used for problems with discrete decision spaces (Triantaphyllou et al, 1998). Taha and Daim (2013) discuss that the decision problem in MADM is characterized by the evaluation of a set of alternatives against a set of criteria rather than, as in MODM, the existence of multiple and competitive objectives that should be optimized against a set of feasible and available constraints. The Analytic Hierarchy Process (AHP) by Saaty (1980) is one of the most popular methods in MADM area. Similarly, for MODM area, Genetic Algorithms (GA) is regarded as an effective analytic tool and stochastic search technique to solve large and complicated problems using ideas from natural genetics and evolutionary principles (Juan et al, 2010).

Sustainable Retrofitting Framework – Option “A” using MADM methods

The option “A” shown in Figure 1, is related to processes which uses MADM decision-making methods, and hence the trade-offs among the criteria are estimated and addressed based on the interdependent relations among the selected criteria and renovation scenarios (Volvačiovas et al, 2013). For this reason, all the quantifiable criteria including quantitative and qualitative should also be converted to quantitative criteria using for instance “1-9” scaling system proposed by Saaty (1980), or “1-5” Likret scale (1932).

Sustainable Retrofitting Framework – Option “B” using MODM methods

The option “B” shown in Figure 1, is related to processes where decision-making includes considerations of all possible renovation actions and their trade-offs in order to generate an optimal solution. The criteria are selected, assessed and optimized by proposing a combination of the most appropriate renovation actions. It is similar to optimization problems in other domains (Ascione et al, 2015). For option “B”, a Decision Support System (DSS) needs to be developed in order to assess the building conditions and to recommend an optimal set of sustainable renovation strategies upon consideration of the trade-offs between selected criteria (Juan et al, 2010). DSS have been a major research area in the Information Systems (IS) field. Petkov et al (2007) classified DSS field into (a) computer based automation of problem solving heuristics; (b) computer based model development and manipulation; (c) problem formulation in organizations. All of the three approaches can be considered useful for identifying a solution in option “B”. The difference between the option “A” and “B” here is related to where the ranking of the renovation scenarios is made. Combining problem-solving algorithms from MODM with the principles of evolution, GA demonstrates great operations for combinatorial renovation solution optimization (Juan et al, 2010; Lee and Kim, 2007). However, it seems that all of the existing sustainability criteria cannot be addressed within a DSS, due to the soft nature of some of them (i.e. sociality, identity, spacial etc.). For this reason, and in order to address overall sustainability criteria within a successful renovation scenario, the DSS must be developed into a comprehensive design process in which the process is equipped by a mix of MCDM and SSM methods (Kamari et al., 2016a).

Introducing three levels of Integrated Design Process Implementation and Evaluation

The discussions of options "A" and "B" in Figure 1 have led to the formulation of two different integrated design frameworks (see Figures 2 and 3). The main reason for development of such a framework is primarily to facilitate understanding of the design process implementation through identification of the different activities, which need to be carried out. Moreover, this also deals with simplification of the existing complexity due to involvement of various types of stakeholders, sustainability criteria and potential renovation technologies in design process. Consequently, the level of complexity for decision-making increases when trade-offs between design criteria and stakeholders priorities need to be addressed; the frameworks seeks to establish a platform for facilitating decision-making under these circumstances. Figures 2 and 3 hold information about the relevant activities for each proposed three level of decision-making. The framework in Figure 2 has been developed by the principles discussed as option "A" using MADM, and Figure 3 by the principles discussed as option "B" using MODM during previous section. Based on the types of the activities that need to be carried out for each level as well as how a decision is processed, they have been named as I) *Exploration*, II) *Assessment* and III) *Scientific Decision-making*.

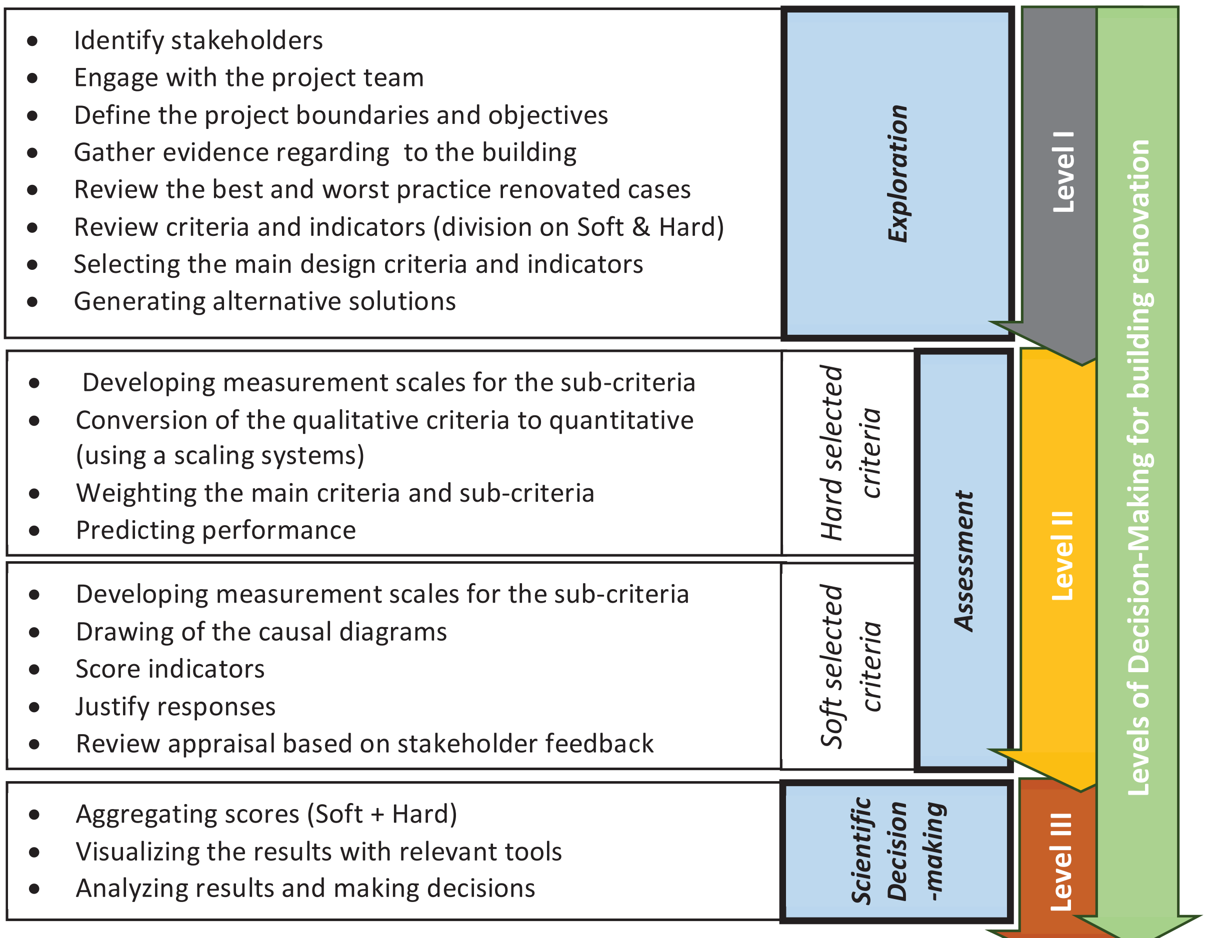

Figure 2. Sustainable Retrofitting Framework – Option "A" using MADM methods

<u>Level I</u> - The *Exploration* stage targets the identification and addressing the conditions and details regarding to the buildings and the stakeholders who are involved in the process. The decision that is made at the end of this level is often relevant for renovation of the detached and small buildings i.e., detached residential buildings. It is usually the case for experienced

consultant companies that their work scope specifically relates renovation of the similar types of buildings. It sounds logical since the buildings that located in a same region, have 1) similar functions (i.e. dwelling), 2) similar types including shapes and materials, as well as 3) customers with similar range of budgets, ultimately need to be renovated via application of the similar renovation scenarios. Renovation scenarios for these projects are generated while buildings are being explored. For this reason, there are methods such as the Danish - Total Value Model (Schunck, 2011) and/or RENO-EVALUE (Jensen and Maslesa, 2015) and/or STBA[3] (2012) that has been developed, specifically in order to finalize the decision for selection of the alternative renovations solutions at level 1, and can be applied for better decision-making.

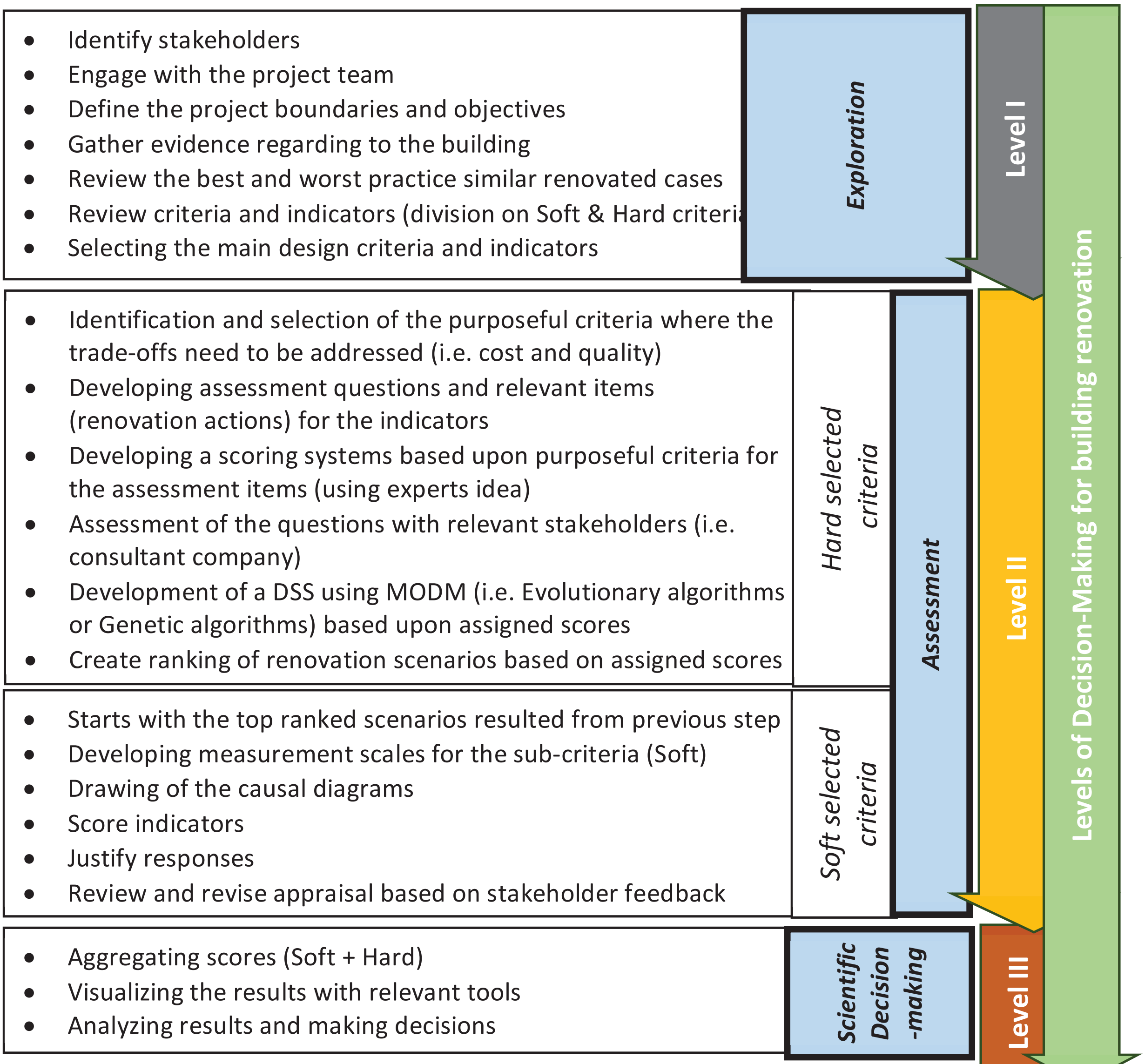

Figure 3. Sustainable Retrofitting Framework – Option "B" using MODM methods

Level II - Next, the Assessment stage intends to address the trade-offs or correlations between the sustainability criteria and renovation scenarios, using MCDM methods (Figure 1 - option "A" or "B"). The milestone here is about where the soft and hard (quantifiable) criteria have been separated early in the Exploration stage and subsequently can be assessed and

[3] http://responsible-retrofit.org/wheel/

addressed in Assessment level, scientifically. It is called "scientifically", due to the terms defined as scientific design in (Cross, 2001). It should be underlined that the MCDM methods here are able to apply on hard/quantifiable criteria. Next, the soft criteria are addressed upon the outcomes of hard/quantifiable criteria regarding to either pre-designed renovation scenarios (option "A" – Figure 2) or generated ones using DSS (option "B" – Figure 3) and finally the decision is made using brainstorming between the stakeholders.
Level III - The major difference between level 2 and 3 is process of fully scientific decision-making. This level has been named Scientific Decision-makings since it is considered to aggregate and validate the scores regarding to the both hard and soft criteria using MADM methods.

Comparing the frameworks which have been developed in this section, for option "A" the scenarios are generated during the level 1 where a problem is being explored; in the contrary for option "B", the scenarios are developed in level 2 (the *Assessment*) concentrating on addressing the trade-offs between criteria. It is worth noting that, the decision-making at level 3 using option "B" (Figure 3) is introduced as a fully scientific approach for building renovation. Therefore, following the description provided in section 1 (Introduction), the decision-making at level 3 of option "B" is referred in order to match the HMSR on Value Map.

Conclusion and future research work

Looking at a project holistically for potential energy savings invariably means using an integrated design process. It is then developing a design process, which explores the interdependency between different building systems and renovation goals towards achieving sustained prosperity at the end of the day. This paper explored decision-making processes and frameworks in building renovation context, which identifies a need for introducing three different decision-making levels to help stakeholders in the renovation process to discuss their project "on the same level" and make transparent decisions in a rational order. As such, two frameworks were structured based on the two different MCDM methods including MADM and MODM. Each framework were divided through three levels consisting of the different activities. The decision-making at the third level was considered as a scientific design approach and is introduced as an integrated design process implementation and evaluation for the use of Value Map and in HMSR. Further regarding to the RE-VALUE project, the effort is the development of a scientific decision-making approach where a decision can be made at the third level of decision-making. Therefore, future studies will concern the development of a conceptual framework of a possible DSS concentrating on MODM and thus use of the second developed framework (option B) in the present paper.

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