



REDIS: A value-based decision support tool for renovation of building portfolios

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ABSTRACT

Renovation of the existing building stock is getting increased attention in many European countries. One decision to be made by the professional building owner is the prioritization of which buildings to renovate within a building portfolio. This article proposes a new, value-based decision support tool, REDIS, which can support the professional building owner in this process. REDIS provides a framework for dialogue in the pre-design stage of renovation projects, and calculates a Renovation Value Factor for each building, based on a number of criteria weights, building status data and estimated renovation costs, indicating which buildings give the building owner most value for money if renovated. The REDIS tool is demonstrated through an application example using real data from a case of selecting which school buildings to renovate within a portfolio of 56 schools. Representatives from the municipality that owns the 56 schools compared the results of the REDIS tool to the results of their original decision process, where ten out of the 56 schools were chosen for renovation. The result from the tool differed from the original decision results. The evaluation results indicated that the REDIS tool supports the building owner in choosing which buildings to renovate within a building portfolio. The contributions of this study are the proposed decision support framework and the tool prototype, with the major contribution being to encourage a structured dialogue among the decision makers.

1. Introduction

In Europe, around 35% of buildings are more than 50 years old. During their lifetime, these buildings deteriorate and become less attractive if not maintained properly. At the same time, the building stock accounts for 40% of the total energy use worldwide and is responsible for one-third of the total CO₂ emissions. This substantiates the increasing focus on building renovation in many European countries, in terms of not only saving energy but also improving the environmental, social and economic qualities of the buildings. Even though the potential of building renovation is widely recognized, the amount of actual renovation activity is limited in most countries [1]. Research on the barriers for building renovation has shown that one important obstacle is the lack of simple and holistic tools that can assist the building owners in prioritization and decision-making in the early stages of building renovation projects [2,3], and that new tools are needed to fill this gap [4–6].

Decision-making in the construction industry is becoming increasingly complex [7]. Multiple decisions, often involving multiple decision-makers and numerous criteria, have to be made in building

renovation projects. One decision the professional building owner has to make is the initial choice of which buildings to renovate within a building portfolio. An important aspect of this decision is to ensure shared objectives among the decision-makers involved so as to identify a preferred course of action. In practice, this step involves setting goals for sustainability, either based on the building owner's own criteria or by deciding that the renovated buildings should be assessed using an existing sustainability assessment scheme such as BREEAM, LEED or DGNB. Regardless of whether the goal is to assess the finished renovated buildings using a sustainability assessment scheme or not, the project goals may vary from project to project and from building owner to building owner. This entails the need for flexible tools, which can encompass project-specific criteria and take the preferences of the decision-makers into account.

Various decision support tools for building renovation already exist. Forty-three decision support tools for building renovation were identified in a literature review by the authors [5]. Nine of these tools included the aspect of setting goals for sustainability, two of these focusing explicitly on the discussion of objectives among the decision-makers, and the rest providing a fixed set of criteria but leaving the

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weighting of the criteria open to the decision-makers. The tool RENO-EVALUE [1] is a value-based tool that encompasses the different interests and values of the stakeholders involved, providing a framework for dialogue, and a holistic evaluation of renovation projects. MCDM-23 helps the decision-makers to specify and prioritize criteria in large building designs to ensure that the design team starts with a clear understanding of the project priorities [8,9]. The Total Value Model [10] is aimed towards the building owner and provides a framework for setting strategic objectives in renovation projects. EPIQR [11] was developed to support apartment building owners in prioritizing renovation activities within a building portfolio and provides a framework for registering the current state of the apartments. The EPIQR software identifies the most appropriate renovation actions, along with an initial cost estimate. Another tool that provides a registration framework of existing buildings is BR-DSS [12], which, based on the deterioration state of a building, helps the decision-maker to select the most efficient renovation alternatives. In addition to the tools included in the literature review, several new tools have emerged in the construction literature. Hansen et al. [13] developed a new dialogue and prioritization tool based on gamification, with the aim of making complex issues of sustainability available to the decision-makers in housing organizations. Nägeli et al. [14] proposed the DREEM tool, intended to help housing companies develop economically and environmentally optimal near-zero energy building refurbishment concepts for multi-building scale refurbishment actions. A Value Map framework has been proposed by Kamari et al. [15], for characterizing essential areas and initiatives to achieve a holistic building renovation in the early design stages and to evaluate different retrofit options. A conceptual framework called the Rebo model, which defines, describes and puts a value on sustainable renovation objectives, was proposed by Thuvander and Femenias [16]. The emerging development of new tools reflects the growing focus on renovation, and the need for efficient tools to support dialogue, communication, and decision-making in the early stages of renovation projects. However, the majority of the existing tools focus primarily on the design stage of renovation projects [5], whereas few support the decision-maker in the pre-design stage.

The REDIS (Renovation Decision Support) tool presented in this article is a new decision support tool for sustainable building renovation. The tool is value-based and can support the professional building owner in choosing which buildings to renovate within a building portfolio, or which renovation actions to initiate across multiple buildings, based on the preferences of the decision-makers, the actual state of the buildings, and renovation cost estimates. Based on the results, the building owner can make an informed decision at this early stage of which buildings should be renovated. Furthermore, the tool can support the communication among the decision-makers involved in the pre-design stage of the renovation process, to ensure shared objectives and identify the preferred course of action. The novelty in the proposed concept lies in its applicability in the pre-design phase of renovation projects, whereas the majority of the existing tools are designed to be used during the design process [5]. Also, the REDIS tool emphasizes early dialogue among decision-makers and provides a flexible framework that can be adapted to specific renovation projects, in contrast to the majority of existing decision support tools for renovation that provide a fixed set of criteria and do not invite dialogue among the decision-makers. The REDIS tool is demonstrated through an application example as a proof-of-concept.

The article is structured as follows. First, the overall methodology is presented, along with the methods used for developing and evaluating the tool. Then, the REDIS framework and the design process leading to the proposed framework and prototypes are presented. The evaluation results are then presented, demonstrating the utility of the REDIS tool through the application example, including feedback from the building owner regarding the outcome of the REDIS tools versus the outcome of the original decision, along with the applicability of the REDIS tool prototype. Then, the results are discussed in relation to the

requirements and existing decision support tools. Lastly, the conclusions of the study are summed up.

1.1. Terminology

In this article, the term “renovation” is used as a general term for improvements of the performance of existing buildings, ranging from medium to major interventions. “The decision-maker” primarily refers to the professional building owner, who has knowledge and experience in the field of building renovation, and has a professional team of specialized advisors and designers. “Building owner” is used to describe either a single building owner or a building owner organization, such as a municipality or a housing association. The terms “sustainability” and “sustainable renovation” are used to describe an approach to building renovation where economic, environmental and social aspects are encompassed in a balanced way, based on the definition in the Brundtland report [17]. The “pre-design stage” refers to the very early stage of a renovation project, where objectives for the project are determined before any renovation alternatives are generated. “Renovation criteria” are used to describe criteria and objectives for renovation projects. The flexibility of the REDIS tool allows the user to define the renovation criteria, whereas the formulation of the criteria might be done in different ways depending on the users. The term “artifact” is used to describe different levels of an IT artifact in the form of a construct, which is the vocabulary and symbols used to define problems and solutions, a model, a method, or an instantiation, which refers to a type of a system solution for a particular set of design principles, following the design science research terminology [18].

1.2. Problem statement and tool requirements

To achieve the aim of developing the REDIS tool, a comprehensive literature review was made of existing decision support tools applicable in building renovation projects [5] to identify the knowledge gaps. The findings of the literature review led to the following tool requirements:

- The tool should be flexible with regard to renovation criteria.
- The tool should emphasize the aspect of setting sustainability goals.
- The tool should be made freely available online to improve knowledge-sharing.

With the emphasis on the goal-setting aspects of the decision-making process, the concept of value-focused thinking, introduced by Keeny in 1992 [25], has been applied as a theoretical foundation for the tool requirements. Keeney argues that focusing early and deeply on values when facing challenging problems will lead to more desirable outcomes, and that thinking about values helps discover the reasoning for each objective [25]. Applying value-focused thinking in the context of sustainable renovation emphasizes the preferred values of the decision-makers involved, and the creation of relevant criteria based on these, with the aim of generating renovation alternatives. The concept of value-focused thinking is in contrast to alternative-focused thinking, which, as the name implies, focuses on the alternatives [25]. Looking at existing decision support tools for building renovation, the majority include the analysis of different renovation alternatives, whereas few encompass the values of the decision-makers as a point of departure [5]. This motivates the development of a value-focused decision support tool for building renovation, and leads to the following tool requirements:

- The tool should provide a framework for weighting criteria based on the preferences of the decision-makers.
- The tool should highlight disagreements among the decision-makers as a foundation for a value-based dialogue.

To align the theoretical foundations with the practical needs of

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