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Renovation Process Challenges and Barriers †

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Abstract: The implementation of Nearly Zero-Energy Buildings (NZEB) renovation packages in Europe needs to be accelerated to meet the decarbonisation goals. To achieve this level of performance, building renovation strategies should shift towards industrialised solutions that incorporate a multitude of passive and active components, increasing the complexity and cost of the execution. Moreover, it requires the involvement of different stakeholders of the building supply chain, resulting in additional difficulties in communication and coordination. To address this challenge, this study aims at mapping the renovation process and at addressing the respective bottlenecks. The objective is to identify the type of information that the stakeholders require during the different renovation phases and provide a framework to structure the workflow between all actors. By structuring the information along the renovation process phases, the different stakeholders can identify when the information can be provided and how the different types of information link to each other.

Keywords: building renovation process; zero-energy buildings; stakeholders' communication

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1. Introduction

Accounting for almost 40% of energy consumption in the European Union [1], the role of existing building stock is instrumental in energy transition and the carbon neutrality goals of the built environment. To achieve this goal, it is crucial to improve the way we carry out building renovations [2], increasing both the rate and depth of renovations [3,4]. An effective renovation plan that aims at zero-energy buildings, which balance a reduced energy demand against locally generated power, is essential to attain this goal. The integration of many components increases the complexity and the cost of those renovations, which is why industrialised solutions have been explored to improve the productivity of the construction industry [5], benefiting from high-performance results while minimising on-site construction time by prefabricating retrofitting components [6]. Nevertheless, the industrialization of renovation solutions needs to be made part of the supply chain operation and be prioritized in strategic decision-making [7], which requires the involvement of different stakeholders of the building supply chain, resulting in important difficulties in communication and coordination.

To this end, the main goal of this paper is to map the renovation process and address the most important bottlenecks to make the renovation process more efficient. The objective is to identify the type of information that the stakeholders require during the different renovation phases, which can be used to structure the workflow between all actors. The study builds on previous experiences in research and practice, regarding identified relevant information and data that support the different phases of the renovation process. In the next step of the framework development, the findings of the analysis were used as base materials for designing an experts' questionnaire, which had the dual purpose of validating these parameters while gathering relevant information about the renovation process in a systematic and organized manner.

2. Method

To identify the type of information that the stakeholders require during the different renovation phases and provide a framework to structure the workflow between all the actors involved during the renovation process, two main methodological steps were executed: (1) exploration of the current renovation workflow and (2) analysis of the experts' interaction. First, a general overview of the current literature review and data available regarding the façade retrofitting processes was developed. The analysis considered 17 relevant R&I projects, retrieved from CORDIS [8].

Based on this exploration, an experts' questionnaire was developed to collect relevant information in a systematic and organised manner. Forty-two complete questionnaires were gathered after the campaign was over, considering different types of stakeholders in the building industry. Finally, an experts' workshop was executed to validate the findings from the literature review and the questionnaire. The results of both steps are integrated in Section 3, addressing the main topics of the study: (1) renovation process: phases and tasks; (2) information flow; and (3) main perceived bottlenecks.

3. Results

3.1. Renovation Process: Phases and Tasks

The exact number of phases and subphases might vary in the different publications [9–11], but there is consensus on the main broad stages. These are the pre-project, which defines the need for the project; the pre-construction, when an appropriate design solution is developed; the construction, which implements the solution; and the post-construction, which aims at monitoring and the maintenance of the project.

In renovations, which are still construction projects, the phases mentioned above also apply [12–14]. However, since renovations deal with an existing building, the pre-project phase includes the analysis and diagnostic of the building to define the intervention's scope. Moreover, the current occupants, who might be there during construction, have a significant role in the execution phase, such as in the time planning. Industrialised renovation follows the same phases, but some sub-phases are specific or more essential compared to on-site renovation construction, particularly regarding the existing building analysis, the renovation design, and the components' production. In the context of this study, the renovation phases have been defined as shown in Table 1. The questionnaire followed those phases and elaborated on the core tasks per phase.

Table 1. Overview of renovation process phases and tasks.

Phase	1	2	3	4	5
Name	Pre-project	Concept design	Final design	Execution and hand-over	Post-construction
Description	Defines the need for the project, the problems, the ambition. Setup the design team	Identification and comparison of strategy, interventions, design principles	Tender, specification of products, engineering of components	Manufacturing, assembly off-site and on site, hand-over	Post-occupancy evaluation/ optimization loops
Core tasks included	Setting objective and criteria Diagnosis of existing condition Definition of client requirements Cost initial estimate Selection design team	Identification of renovation measures Decision on industrialised components design concept Assessment and optimization Preparation of permit applications	Detailed design for industrialised renovation Survey of existing building Engineering of the components Tender and products specification	Manufacturing Transport Mounting Site Construction Construction quality control Hand-over	Building operation optimisation Monitoring Post occupancy

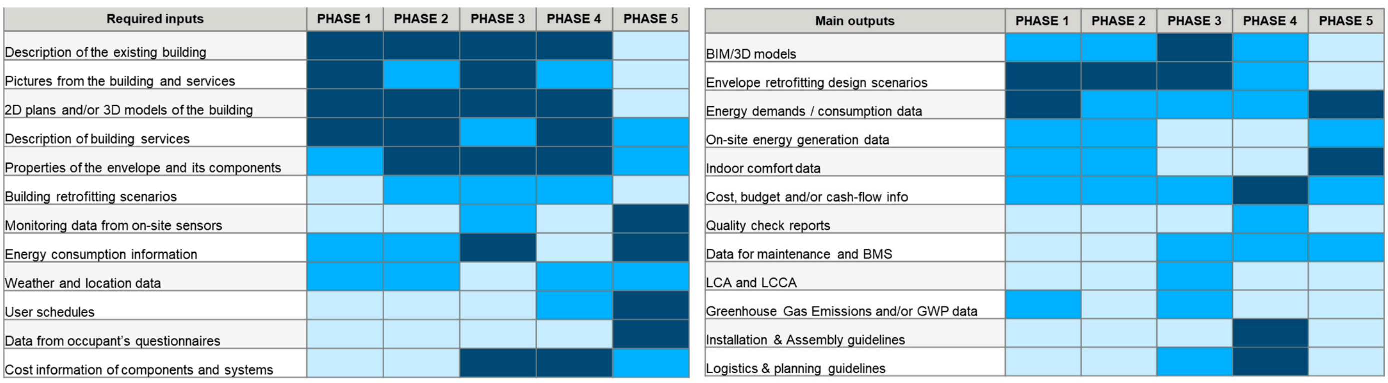
Table 1. *Cont.*

Phase	1	2	3	4	5
Phase outcome	Project brief approved by the client, and confirmed feasibility	Renovation strategy approved by the client	All design information required to manufacture and construct the project completed	Manufacturing, construction, commissioning completed and hand-over	Building used, operated, and maintained efficiently.
Leading stakeholder	Client team	Design team Specialist consultants Client team	Design/construction team Specialist subcontractors	Construction team Specialist subcontractors	Client Facility management Specialist consultants

3.2. Information Flow

The information flow between the stakeholders is essential for the renovation process. Regarding the information that is required as inputs, most of them refer to information from the existing building, its envelope, and services. Moreover, other inputs refer to its occupation and operation, to information from the climate context, and cost data of building components and renovation activities. On the other hand, the main outputs along the renovation process refer to the generation of renovation scenarios and Building Information Models (BIM), energy flows data (consumption and generation), quality check and maintenance reports, Life Cycle Assessments (LCAs), and evaluations related to the cash-flow of the intervention.

During the experts' interaction, the respondents stated the inputs they require to perform their tasks during each phase and their main outputs along the process. Figure 1 presents the responses from the sample at each renovation phase, with colour codes based on the number of mentions for an easier appraisal of the results. Figure 1a depicts the input types that are more commonly required by the sample of professionals, showing the relevance of counting with enough information about the building from the initial stages to construction. Cost information is particularly relevant as an input at the final design and construction phases, while operation inputs, although relevant throughout the whole process, are markedly more needed during phase 5.



(**a**) (**b**)

Figure 1. Overview of the main required (**a**) INPUTS and (**b**) OUTPUTS per phase according to the respondents' mentions. Low/medium/high relative mentions per phase are shown with colours (the darker the colour, the higher the number of mentions per phase).

Figure 1b follows the same pattern, showing the iterative process behind retrofitting design scenarios until the final design is set, and the energy use reports especially at the beginning and the end, to diagnose problems and later evaluate the solution, also considering comfort assessments. When it comes to the construction phase, the main declared outputs refer to guidelines for installation and assembly, logistics and planning, and budget estimations and cash-flow information.

3.3. Main Perceived Bottlenecks

The respondents were asked to mention the main bottlenecks they perceived based on their own experience, which would need to be solved to increase the efficiency of the overall renovation process. This was conducted through a set of questions aimed at each phase separately, targeting the experts that had previously declared to have personal experience at each phase. Seven main categories for the bottlenecks were identified, as follows: (1) lack of information; (2) unclear definitions; (3) normative and compliance; (4) coordination and communication; (5) responsibilities and guarantees; (6) unreliable assessments (7); and technical challenges.

The responses were then re-assessed and categorised based on the list of main types of bottlenecks, with the result being shown in Figure 2. There, it is possible to see that most of the mentioned bottlenecks clearly refer to lack of information, and coordination and communication issues, followed by normative and compliance aspects throughout the process.

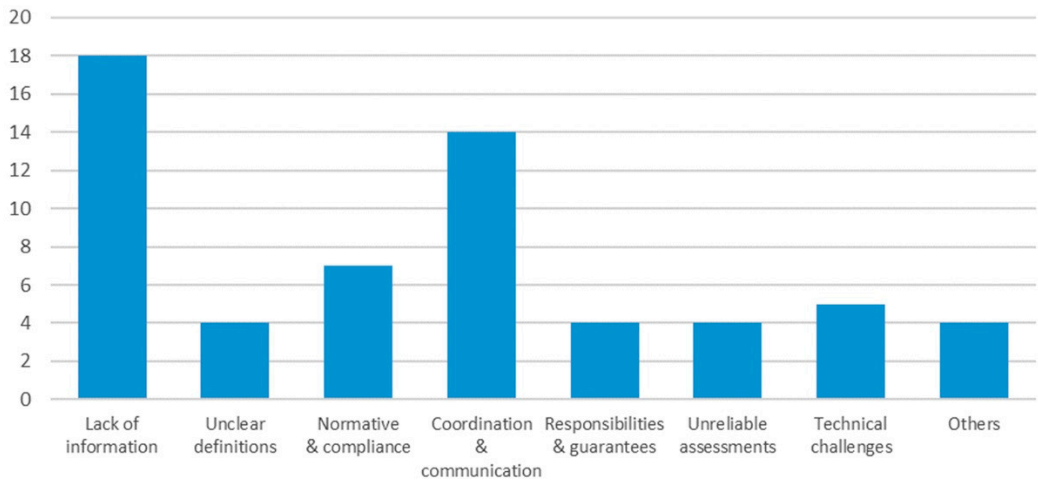


Figure 2. Main types of bottlenecks identified from the responses and frequency of their mentions.

4. Discussion

Further elaboration centred around the most recurrent bottlenecks: (1) lack of information, and (2) coordination and communication. Regarding the lack of information, it was mentioned that it is important to establish clear responsibilities for gathering the information needed at each phase. Moreover, to support this, it was agreed that having a comprehensive building data checklist is necessary, considering the level of detail for said information at every step of the process. Nevertheless, even if responsibilities and data gathering activities are clearly defined, there is a relevant information gap at the early design stages, especially related to technical information that could otherwise serve as valuable input for the concept design.

Regarding coordination and communication issues, in general, it was perceived as crucial to clearly define the responsibilities of all stakeholders throughout the process. Likewise, it was stated as central to have a clear definition of the requirements and key performance indicators used to evaluate the project. Thus, it is paramount to consider clear communication channels between the design team and the client team from early on, with timely and comprehensive information. Establishing a communication protocol for clear and direct interaction among the stakeholders could help reduce time throughout the process, besides supporting faster decisions in the face of changes and unforeseen events, especially during the execution phase where on-site events are bound to happen, and delays may have a sizable impact on the budget and on-site logistics.

The outcomes of the study can serve as the basis of a framework to provide stakeholders with a clear structure and access to a wide range of technologies for the deep renovation of buildings. Those results can be used in the development of communication tools to facilitate the renovation workflow, resulting in more efficient renovation of the building stock.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: More information on the data presented in this study is available on request from the corresponding author. The data are not publicly available due to restrictions regarding the privacy of the participants and the restrictions of the project.

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