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BIM4Ren: Barriers to BIM Implementation in Renovation Processes in the Italian Market

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Abstract: As a part of BIM4REN (Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings) H2020 project, an analysis of the barriers of the renovation process, the potential of digitalization to overcome those barriers, and the requirements to ensure a successful digital workflow. This paper focuses on the Italian market where surveys, interviews, and a workshop were conducted, and then a diagnosis was made on the results obtained. Results show that technological innovation on BIM tools cannot be a stand-alone action to reach a full digitalization of the renovation sector, but it shall be supported by a major awareness of the actors involved, improved skills, and competences, as well as an important change of approach in the current construction practice.

Keywords: BIM; Renovation; Digitalization; H2020; Barriers; Stakeholders

1. Introduction

While the EU climate plan aims to achieve the 40 – 27 – 27 target, energy retrofitting represents one of the main means to achieve it [1] as buildings represent 40% of overall energy consumption and 36% of generated greenhouse gases [2]. Given that 70% of existing buildings were built before the '70s., to achieve the European target the retrofitting rate needs to reach the 3% threshold versus the current 1.2% [3].

Therefore, this scenario leads to strongly promote the renovation rate in Europe. This statement implies to boost the re-use of the buildings rather than demolition, enhance the Energy Efficiency of the building stock, and consequently, fulfil the sustainability policies.

On the other hand, although currently the European Directives drives the Energy Retrofitting, it is foreseen that in a not so distant future, the drivers will be the energy savings for the building owners. Nevertheless, the renovation processes are still complex, not cost-effective, uncertain, and disturbing for the tenants, which involve some reluctance to the renovation from the building owners.

Thus, in order to ensure the acceptance of the refurbishment culture within the AEC sector, significant progresses are necessary: improve the quality of the renovation, reduce the time of phases and between phases (planning, design, construction, operation, and maintenance), minimize the impact on tenants, and finally guarantee that cost/benefits targets are accomplished. Moreover, coordination among stakeholders during all phases is fundamental to ensure tight deadlines and overcome the common fragmentation of the AEC sector. The coordination is key when it comes to the residents, which are strongly affected by the discomfort and intrusiveness caused by the renovation.

In this context, digitalization is the key challenge to support the renovation interventions since it may contribute to collaboration, cost efficiency, and time savings. At the same time, it guarantees process quality along with all the renovation phases, solving some of the hindrances due to the uncertainty of the process. Particularly, the use of Building Models allows to store and share the information about the existing building through Building Information Modelling (BIM). This is a crucial point to avoid uncertainties, since the models are fed and checked by all stakeholders.

Furthermore, the need for digitalization must be adopted by the whole process chain to achieve its full potential. Thus, it must start with the identification of the current barriers of renovation and BIM implementation from all the insights and in all phases, namely, considering all the stakeholders involved. Only this holistic perspective may lead to a successful implementation of BIM in the complex universe of renovation.

The assessment of barriers and BIM use potential in the renovation process is done based on a literature review in combination with empirical data collection in the form of findings from questionnaires, interviews, and validation techniques.

Taking all the aspects into account, this paper identifies the constraints and requirements of the stakeholders to find out the potential of BIM to overcome the barriers of the renovation process and consequently to optimize the overall process.

This objective is addressed in order to reach the project's target of improving the renovation rate through the enhancement of the whole process. It will be achieved by means of the development of new products and efficient manufacturing and installation procedures supported by digital tools.

The following secondary targets also addressed in the report are:

- Harmonize the terminology about the renovation process in terms of stakeholders and phases based on standards used on new construction.
- Gather information from stakeholders around Europe about current practices in renovation and BIM, as well as barriers for its implementation.
- Particularize the analysis of constraints and requirements with closest agents participating in the Pilots, enabling them to tackle together the diagnosis from different perspectives.
- Set the requirements for the implementation of BIM in renovation through the BIM4Ren digital ecosystem environment and the collaborative platform.

1.1. Building Information Models (BIM) in the Renovation Process

Building Information Models (BIMs) are used to store and share the existing building information data, which helps to avoid the uncertainties and support the decision-making process. According to a recent report by the World Economic Forum, full-scale digitalization in non-residential construction would, within 10 years, lead to an annual global cost savings of $0.7–1.2 trillion (13–21%) on engineering and construction (E&C) and $0.3–0.5 trillion (10–17%) in the Operations phase [4].

According to EUROCONSTRUCT [5], the total construction output grew from 2015 to 2018 by 9.6%, mainly supported by new construction which rose by nearly 14%. Civil engineering works recorded in the same period a rise of 6.8% but slightly contributed to the resurgence of the total market, whilst the total building market (residential and non-residential) boosted by 11% over the same period.

As the number of buildings is not meant to expand indefinitely, the part of new construction should decrease to hand over to renovation in the short/mid-term. The split between new construction (60%) and renovation (40%) before the financial crisis in 2007 was unsustainable and benefiting from situational conditions, that are not in sight on the horizon.

As for residential construction, it is currently accounting for almost half of the European construction market. Residential renovation accounts itself for 26% of the total construction output and is forecasted at 410 billion euros in 2018, making it the largest sector in construction in Europe. The new residential insight behind renovation in terms of market size with a foreseen value of 333 billion euros for this year. Figure 1 below showing the construction market by subsectors.

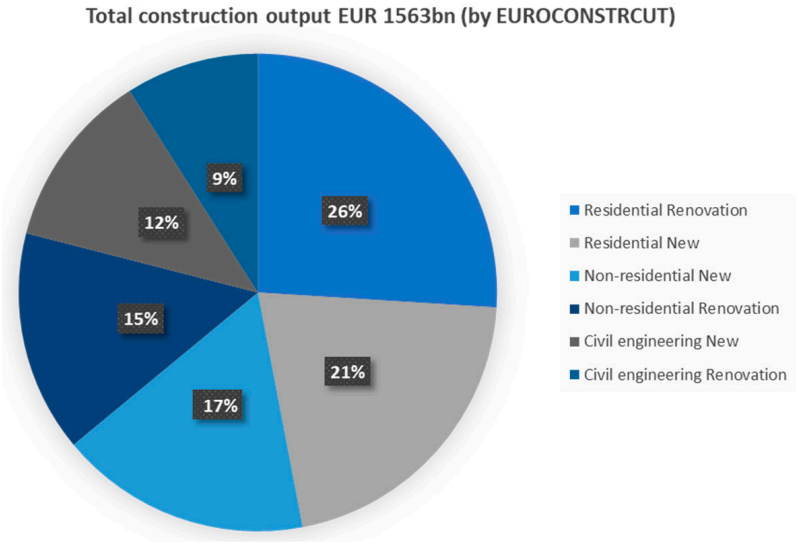

Figure 1. Construction market by sub-sectors according to EUROCONSTRUCT (November 2018).

Furthermore, productivity, defined as the value added by construction workers (output in terms of structures created minus purchased materials) per hour of work and its growth over time, when adjusted for inflation, is low in some field of construction sector [6].

Contractors involved in industrial infrastructure have on average, the highest productivity at 124 per cent of the figure for the industry, followed by civil construction players at 119 per cent and large-scale building constructor at 104 per cent. Trades subcontractors, which are responsible for a large share of value in small real estate and refurbishment projects, are typically relatively small; their productivity is about 20% lower than the sector average. The higher productivity large-scale half of the industry is not immune to the low productivity of the other half.

Therefore, any actions to boost sector productivity needs to be applicable to the entire supply chain as well as to the two major markets in the building industry: new and renovation.

On the other hand, Digitalization – the development and deployment of digital technologies and processes – is central to the required transformation of the construction industry to improve productivity [6]. Such innovations enable new functionalities along the entire value chain, from the early design phase to the end of an asset's life cycle at the demolition phase.

The core technologies enabling this transformation are listed in the following Figure 2.

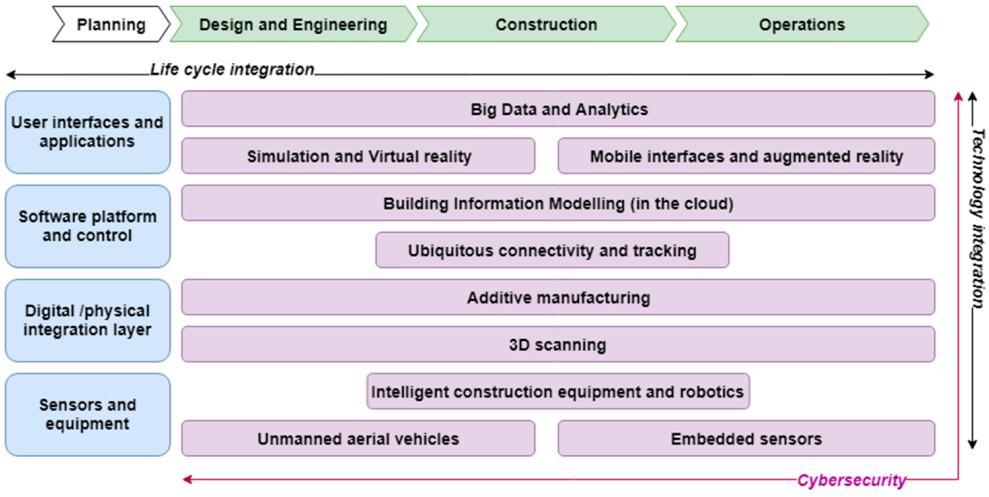

Figure 2. Digital Technologies Applied in the E&C Value Chain (Source: BSG Analysis).

Collecting data through the design, construction, and operational phases would allow for further analysis of these data, generating new insights and simulations to identify clashes and interdependencies, moreover, creating new methods of data visualization using visual and mixed reality, which improves communication and provide on-site information.

First, the use of big data and analytics: algorithms generate new insights from the huge data pools created both during construction projects and the operations phase of existing assets. New methods of simulation and virtual reality help to identify interdependencies and clashes (clash detection) during the design and engineering stages and enable a virtual experience of the building even in the early design phase. This clashes often occur between different design disciplines such as architecture, MEP engineering, etc. By exploiting mobile connectivity and augmented reality, companies can engage in real-time communication and provide workers with additional on-site information.

Working culture in the renovation sector is one of the most important barriers to BIM application to the entire building cycle.

Fragmentation, tendencies toward low innovation, hesitation to spend on new technologies, and low- cost bid mentality slows down the transition from standard design and information management approach to the digitized building information modelling or BIM.

BIM may play an important role in renovation too, helping for instance:

- Simulating HVAC systems layout, avoiding as far as possible incongruencies between services improvement and existing structural elements and helping in clash detection,
- Information management, during the whole building cycle and towards maintenance,
- Anticipating construction site decisions concerning planning and cost overruns

The way that BIM improves efficiency and reduces costs and the time of intervention when applied in renovation depends on typologies of renovation works, the dimension of the construction site and the number of stakeholders involved.

However, the benefits of using BIM for renovation works are strongly dependent on the typologies of intervention, the dimension of the construction site, and the number of stakeholders involved.

1.2. The Barriers in the Renovation Process and Potential of Building Information Modelling (BIM) to Overcome Them

The construction sector is perceived as the poorest performer in Europe in terms of productivity [7], this is partly explained by the difficulties of the construction sector to embrace digital innovations that could help improve both productivity and profitability [6].

Although the importance of digitalization, the implementation of BIM among European industry players remains limited [4]. In Europe, 29% of construction companies use BIM 3D; while 61% have never used it, while only 6% of companies are implementing BIM 4D. Companies use BIM mainly for activities relating to spatial coordination to reduce conflicts in the field, and visualization for stakeholder engagement and preparation of the preliminary schematic design. The industry identifies the reduction of errors, greater cost predictability, and better understanding of the project, moreover, much better life cycle management, as the main BIM benefits (in the case of transport infrastructures). BIM is commonly applied for large-scale residential construction projects, and for transport and water infrastructures.

The BIM implementation is fragmented along the value chain, with BIM being mostly used in the design and construction phases, rather than the operations and maintenance phase. Therefore, mainly architects and general contractors (rather than engineers or trade contractors) use BIM.

BIM implementation is also affected by the market structure and the size of companies, which is led by large companies, while SMEs across the value chain have limited BIM experience. Some other barriers are often related to interoperability, matching the user's requirements, changing work processes, legal issues and training, and creation of new roles and responsibilities.

In the report by the management consulting firm Oliver Wyman [5], digitalization is in a process of reinventing the construction industry, triggering an overall added-value migration from the central construction part of the value chain up to the engineering and design function, and down to facility management and operations' services. A huge and valuable amount of data will be generated throughout the construction process. In addition, cost baselines are quickly evolving, making the competition even more intense in an environment with traditionally low margins. To position oneself in this rapidly evolving landscape alignment with the accelerating marketplace is needed. It is also essential to take advantage of the opportunities and avoid future setbacks in the long run.

Several researchers have highlighted that renovation projects carry several risks and uncertainties which are different from those in new construction and which influence renovation, project performance. Moreover, the lack of demand from projects' owners can be mainly explained by the lack of awareness around BIM benefits (rather than a lack of acceptance), especially at the construction and operations and maintenance stages.

Laser scanning technology can be used to capture dense 3D measurements of a facility's as-built condition, and the resulting point cloud can be processed to create an "as-built" BIM. Its advantage has enabled assessing construction quality, progress control, faster and more accurate real-estate services in building surveys, etc. [8]. Nevertheless, the as-built BIM creation process by using laser scanning is largely a manual procedure, which is a time-consuming, subjective, and error-prone process [9]. A general procedure of creating BIM model based on point cloud data from 3D laser scanner consists of three steps: (1) Data collection - multiple scans are captured from different scanning stations; (2) Data registration - data from multiple scanning stations are stitched together by dedicated software and (3) BIM modelling – CAD/BIM software can be used to author object models while referencing the point cloud. Given these routine processes, current techniques and developed algorithms mainly focus on the BIM modelling stage that involves significant manual work in geometric modelling.

Moreover, there are some studies providing interesting insights about BIM in the renovation as the mentioned ones in the following paragraphs.

According to Ata Gökgür [10] the most significant difference between renovation and new construction projects are the unforeseen nature of ultimate design choices. The design tasks need to be carried out with active communication during the demolition, site activities, and rebuilding for renovation projects. For this reason, continuously changing on-site status on renovation sites makes it difficult to have design solutions fully presented in CAD format.

According to Volk et al. [11], BIM was initially intended to support design and construction and a plethora of BIM compliant tools are currently readily available, including open-source server solutions. However, BIM could be a cost-effective catalyzer to retrofit projects, as it is already for other facility management operations. The creation of an as-built BIM of an existing building is often a challenging process due to the insufficiency of non-digital documentation and/or the absence of computable data. Besides, it is set that when compared to new buildings, many existing buildings are lacking complete, updated, or fragmented building information. These shortcomings might result from insufficient project management, uncertainties in phases, time losses, or increases in cost in retrofit or refurbishment processes. Since existing buildings often suffer from lack of building documentation or other information due to limited updating processes, limitations of BIM use and barriers to BIM implementation are only to be expected.

2. Methodology

The project BIM4REN adopts an open innovation approach, focused on the concept of Living Labs, focused on real application case studies that enable feedback from the pilots' agents, key stakeholders, and targeted beneficiaries throughout the project duration to optimize all project developments and fit them to their real needs and requirements of digital tools users. In this way, the requirements for the BIM tools will be driven through the active end user's participation and involvement in the Living Labs.

The paper reports the results of the starting activities of Living Labs, aimed at defining the major barriers to the use of BIM technologies for building renovation. Because BIM4REN project aims at exploiting BIM potential along all the construction value chain, developing ready to use tools and technologies for the fast and efficient renovation of residential buildings, suitable for all market actors, the first part of the project was dedicated to defining the specific requirements that energy renovation works demand to BIM tools. The results reported in this paper specifically aimed at identifying agreed barriers on the use of BIM for building renovation according to the angle of the several stakeholders involved in the process and therefore translating these barriers into requirements for the BIM tools that will be developed in BIM4REN project. The analysis was carried out in three steps to gather, test, and validate information, respectively, by surveys, interviews, and workshops. General information about the BIM use at national level are collected from documentation reviews, then the three steps process was carried out to analyze barriers and needs for the development of BIM tools for building renovation.

The first step was an online survey, distributed across Europe to collect quantitative and qualitative data from a vast range of construction agents; the second step consisted in detailed interviews with closest stakeholders linked to the renovation field, the early adopters of BIM technologies; and finally, workshops validated results in group discussions with stakeholders concerned with the project Pilot sites, but not necessarily BIM users.

Despite the fact that the full analysis was carried out in three countries, France, Italy, and Spain, in this paper the authors refer to Italy only, planning to extend the analysis to the European context in further work.

2.1. Online Questionnaire

The first stage of the consultation was carried out by an extensive online survey to gather information about the common practices and the main concerns of the stakeholders involved in the whole renovation value chain. It was subdivided into three main parts:

1. General information about the responding organisation
2. Identification of the barriers in the renovation process
3. Potential to overcome the barriers in renovation process through digital tools

The survey was designed to reach different agents of the construction sector, with varying levels of expertise in Digital Technologies (or even any expertise) and varied links with renovation process. The target group of the BIM4Ren questionnaire are the members of the AEC sector, working on Large, Medium, and Small enterprises and self-employees. Referring to the classification of the project stakeholder's community, the survey was able to reach the BIM4Ren Pilots Stakeholders, Early Adopters, and the BIM4Ren Extended Community. In Europe, a total of 311 surveys have been answered, encompassing more than 20 countries, with companies of different sizes and expertise in the construction field and representing the main roles in the construction sector (Architect/Designer, Contractor or subcontractor, Building owner or resident, Public administration as regulator entity, or Industrial). The questionnaire was designed through the open-source software, Lime Survey. https://www.limesurvey.org/ and it was active from 20th December 2018 to 19th February 2019.

2.2. Interviews

The main goal of the interviews was to collect direct and specific information from key stakeholders with a relevant role in one (or more) renovation typology (use case). Interviewees were selected through a manifestation of interest on the project among the membership of Green Building Council Italia, an association that represents the value chain of sustainable construction in Italy, and among contacts of the other Italian partners involved in the project. Prerequisite was to work in building renovation with or without experience on the BIM approach. The choice of the type of stakeholders was dictated by the local characteristic of the construction services supply market. In Italy, the authors tried to represent the variability of the construction firms: from renovation works led by large design studio and contractors,

to medium size companies that carried out design and building phases, to individual businesses that accompanied the client from the early concept to the supervision of construction works carried out by small building firms. Each interview analyzed a renovation action, planned ongoing or delivered, to describe: (1) the sequence of actions, (2) the actors involved, and (3) the type of information exchanged. Existing case studies were chosen regardless of BIM use during the process, but the role of digital tools, as well as constraints and opportunities that they would bring, were discussed. The purpose was to get as much information as possible in relation to the renovation typology that each case study represented, by the description of the construction process in the form of a workflow. The renovation process was subdivided into phases based on the RIBA classification, although updated to the singularities of the renovation. A guideline spreadsheet was created to make the interview process uniform for all interviewers, as a reference or baseline to collect structured information.

The interviews had two main objectives:

1. Identify the preliminary workflows of the selected renovation use case, according to the defined typologies and the role of the stakeholder interviewee. This workflow included the agents involved in each process and sub-process as well as the exchanged information in those stages. This workflow and related data and information exchange were useful to identify typical renovation processes across Europe, to which the digital tools developed by BIM4REN project will be customized. Each workflow was then translated into a BPMN diagram to relate all data in a single view and inform the following stages of BIM4REN project.
2. Discussing with front-runner stakeholders general trends, barriers, and difficulties in the renovation process, to identify which is the market demand for BIM tools and which is the level of expectation from the end-users about the suitability of the digital technologies for a non-standardized process as the building renovation works are.

The interviews have been performed with selected bodies linked to the construction sector. Several requests were made to large and small construction businesses as well as to individual professionals. Nine interviews were completed. The interviewees are stakeholders of the construction sector, some of them particularly connected to the renovation process: project manager from a large technical design team, contractors, and free-lance architects. They have been selected among the pilots' stakeholders, Early Adopters of the projects, and other key agents, all of them taking part in the BIM4Ren extended community.

2.3. Workshops

The last step consists in the validation of the preliminary results achieved from surveys and interviews through discussions in national workshops around the pilot sites. Findings are validated by the agents involved in the pilots, Early Adopters, and other key stakeholders of the renovation process linked to the project partners. Workshops enabled to receive feedback from the end-users and targeted beneficiaries. They will be repeated along with the duration of the project which is a continuous consultation aligned with open innovation and living lab approach.

Two main topics are tackled in the workshops:

1. Barriers in the renovation process, requirements of the stakeholders, and potential of BIM
2. Workflows of different renovation use cases, renovation typologies, including the main activities developed by stakeholders, and the information exchanged.

The discussion between project partners directly related to a pilot, and other experts, with different roles in the value chain and called to provide their informed opinion, allowed the integration of different insights about unique use cases.

In Italy, the workshop was held to the pilot site of the University Dormitory at Complesso Santa Marta, in Venice, on the 1st of April 2019. The activities were subdivided into 2 main parts: an initial session of presentations and the second session of visit, demonstration, and discussion around the Italian pilot site.

To the purpose of the paper, the round table post-it session about barriers and opportunities in the use of digital technologies in the specific Italian pilot case was highly relevant. The construction process of the pilot did not include the use of digital tools and it was highly relevant hearing diverging opinions on the suitability and usefulness of BIM for the specific renovation works.

Barriers were analyzed per typology of stakeholder addressing them. Six types of stakeholders were represented: public clients or owners, private clients or owners, site supervisor, contractor, industrial contractors, suppliers, and architectural/engineering firms. Results of the group discussion are presented in the paper.

3. Results

3.1. Results from the Surveys about the Italian Market

The on-line survey has been shared to the Pilots Stakeholders, Early Adopters, Extended Community, through the members of the Consortium, social networks, associations, and digital means. A total number of 143 surveys have been answered in the Italian market, 76 of them were completed.

3.1.1. Section 1: General Information, Profile, and Digitalization Level of the Respondents

In this section, the objective is to identify the profile of the respondents and their relationship with the level of digitalization.

The first question was about the core business of the organization, resulting in a survey with answers from all the agents of the value chain of the renovation sector. The participation in the survey was not homogenous with two stakeholders represented most of the profiles of respondents (Architects and contractors), 69% of the total 116 answers.

In relation with the number of employees in the organizations of those answering the survey, the situation has been quite balanced with a good representation of companies with different sizes, small, medium, and large enterprises. The major number of respondents belong to small companies. This fact reinforces the value of the answers in terms of the purpose of the BIM4Ren project since the SME in the construction sector is the main recipients of the project's findings. (116 answers).

Regarding the importance of BIM as the frontrunner for digitalization, most answers, the 50%, state that they have participated in a project with a BIM collaborative process, while only 20% are software users (in a total of 46 answers). However, 80% of organizations are willing to invest in the BIM implementation whether as training or software or hardware or all (75 answers).

According to the different profiles of respondents, in the next section, the experience of each one with the renovation sector is analyzed and the main barriers they identify are highlighted.

3.1.2. Section 2: Identification of the Barriers in the Renovation Process

The objective of this section is to map different use cases in the renovation process in relation with different phases, stakeholders involved, typology of work, and the main barriers detected in the process, according to the role in the value chain of the respondent. Also, it is aimed at assessing the factors in a renovation process which has more relevance to the stakeholders according to the role in the value chain in a renovation process.

Although the results of the survey reveal a relatively high percentage of respondents who have used BIM in renovation (79%), within the BIM users, this finding may be questioned considering the lack of specific tools for renovation. Nevertheless, taking into account the comments, it is likely that some of the respondents have had any link with the data gathering phase which may be considered as a stage of the renovation process (61 answers).

For those who have declared not to use BIM in the renovation, the most probable reason of not using BIM is the lack of communication between the stakeholders involved in the project (24%), followed by the changes of the specifications done by the customer along with the project (14%) (17 answers).

About the typology of the renovation work (22%) are in interventions in the envelope, while (18%) is in internal refurbishment (143 answers).

About the phases of the renovation process which face more difficulties are construction work (23%), followed by the renovation technical project (20 %) and Diagnosis (15%) (100 answers).

Additionally, the most negative effects on the success of a renovation project, identified by the respondents, are directly related to construction work: difficulty of management of the legal aspects (13%), followed by lack of communication between the stakeholders involved in the project (12%) Additionally, the changes of the specifications done by the customer along the project (11%) (126 answers).

Finally, the principal issues which can lead to inefficiencies in the renovation process, causing time and economic losses are: lack of knowledge about the existing building which lead to unforeseen issues, lack of accuracy in the data gathering of the existing building, inaccurate data from modelling of existing conditions, and difficulties of collaboration between stakeholders. The following chart illustrates these results. (126 answers). Figure 3 below summaries these answers.

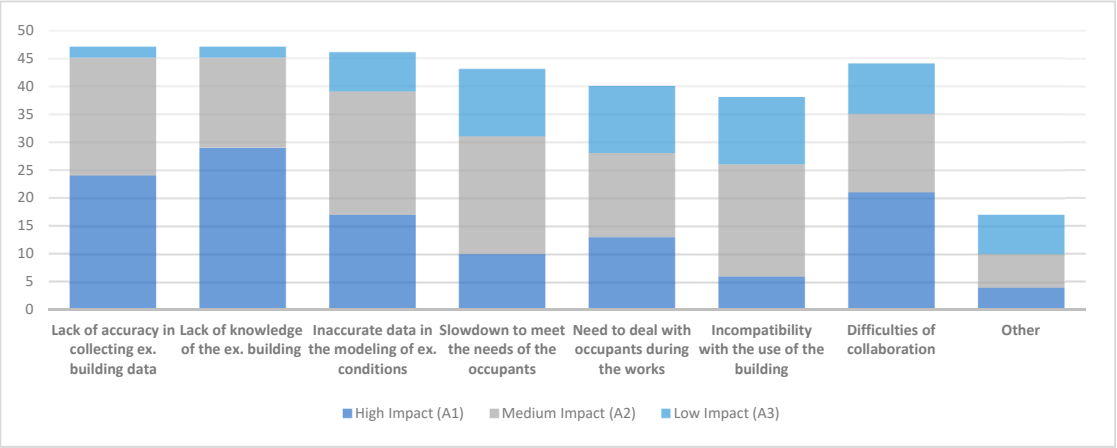

Figure 3. Principal inefficiencies of the renovation process causing time and economic losses.

Summarizing, the phase where more difficulties arisen is the construction work phase. Several problems related mainly to this phase, as the delay in supplying of materials or the material bad organization on-site represent a negative impact on the renovation project, according to the answers.

At the same time, the lack of knowledge about the existing building and the lack of accuracy in gathering data about the building, cause important inefficiency in construction work, which is also caused by an unsatisfactory definition and accuracy of the renovation project.

3.1.3. Section 3: Potential to Overcome the Barriers in Renovation Process through Digital Tools

As mentioned in above sections, digitalization of the construction sector is increasingly recognized as a potential trend, which could contribute significantly to sustainable development. In this sense, the construction industry has gradually adopted digital innovations, with BIM as a frontrunner.

Within this framework, the objective of this section is to analyze the level of digitalization by the different agents in the value chain of the renovation sector, the extension of BIM in companies and how digitalization can help to overcome those barriers in main processes. Also, the requirements that digital technology must have will be defined, to meet the requirements of the respondent as a part of the renovation process.

In relation to the technologies that are highly adopted by different companies, these are mainly: smartphone or tablet, followed by the laser scanner and thermography cameras. (130 answers).

Moreover, the opinion of respondents in relation to the importance of the use of technologies, according to the time or cost savings, has also been extracted. Most of the surveyed agreed that

visualization is the one with higher impact in time savings and costs, followed by collaborative tools, 3D graphic design, document management systems, and clash detection. (130 answers).

Nowadays, although it is supposed that BIM should be known by most of them, a lot of people do not really know its meaning. In this way, the survey also shows the key definitions that are related to BIM according to the respondents are the collaborative work, the information management, workflow, and processes, as well as the generation of a 3D model for visualization. This shows, therefore, that the collaborative process is even more important than the tools themselves. (79 answers).

According to the findings of the survey, the use of digital tools provide benefits to the business of companies inquired, highlighting the most relevant: the mistakes detection (21%), the integration of the information in a unique model (18%), and the improvement in the communication of stakeholders (18%), it is remarkable that the benefits lie mainly in communication issues for ownership and contractor. In addition, the owner considers the integration of the information as a high benefit for its business. (68 answers).

Furthermore, the survey also shows some advantages provided by BIM which could give value to the business, according to the impact on it. For example, the principal value of BIM, which is expected by the companies is the accuracy of the data gathering of the existing building, easy visualization of the solution, reduction of project development time and the construction work time, cost reduction, and information management.

When it comes to renovation, it is known that the works usually have added hinders in comparison with new construction works due to the need of integrating the requirements of the existing building. Nevertheless, BIM can become a solution to overcome some of the specific problems in the renovation, as it has been confirmed in the survey. BIM has a high potential to overcome the most common barriers in the renovation. According to the respondents, the barriers that can be more easily overcome by BIM are firstly the lack of accuracy of the information of the existing building (29%), followed by the imprecise data from modelling of the existing conditions (24%) and the difficulty in the collaboration between stakeholders (17%) (59 answers).

Nevertheless, despite these advantages, BIM is not used in the renovation project because of the lack of specialized human resources and lack of time for training, as surveyors have answered.

Finally, it is important to know what features of a digital tool or platform can be more relevant in renovation works. When it comes to these features, the respondents look for interoperable tools (23%), encompassing the whole renovation process (15%) (66 answers).

To sum up, we can say that the digitalization and the BIM as a frontrunner in this field is an opportunity for improving the renovation sector, which is currently hardly implemented and limited mainly to the data-gathering phase. The use of platforms and digital interoperable tools with others in a BIM environment could help to overcome some key barriers in renovation works. These problems are specially related to the data gathering and the accuracy of the information on the existing building, as well as the unforeseen actions due to acknowledge of the building. It results in a critical factor for the renovation project and for construction work. If the initial information is accurate and complete and can be entirely integrated in the BIM model of the project, it will avoid unforeseen actions during the construction works, which are more expensive as far as the phases of the project progress. Table 1 below summaries the survey results in the Italian market.

Table 1. Summary of the survey results.

Survey Sections	Question	Answer	Total No of Answers
Section 1: General information, profile and digitalization level of the respondents	Stakeholder participated in the survey	(69%) Architects and contractors	116
	The number of employees in the organizations	Small companies less than 50	116
	The importance of BIM as frontrunner for digitalization	(80%) have participated in a project with a BIM collaborative process while (20%) are a software user	75
Section 2: Identification of the barriers in the renovation process	Using BIM in the renovation process	(79%) has been using BIM in the renovation	61
	How BIM has been used in the renovation process	Data Gathering	61
	The reason not using BIM	the lack of communication between the stakeholders involved in the project (24%), followed by the changes of the specifications done by the customer along the project (14%).	17
	The typology of renovation work	(22%) is in interventions in the envelope, while (18%) is in internal refurbishment	143
	The phases of the renovation process which face more difficulties	construction work (23%), followed by the renovation technical project (20 %) and Diagnosis (15%)	100
	The most negative effects on the success of a renovation project	difficulty of management of the legal aspects (13%), followed by lack of communication between the stakeholders involved in the project (12%)	126
	The principal issues which can lead to inefficiencies in the renovation process	Lack of knowledge about the existing building and lack of accuracy in the data gathering of the existing building	126
Section 3: Potential to overcome the barriers in renovation process through digital tools	The technologies that are highly adopted by different companies	smartphone or tablet	130
	The importance of the use of technologies	visualization is the one with higher impact in time savings and costs	130
	The key definitions that are related to BIM	the collaborative work, the information management, workflow and processes, as well as the generation of 3D model for visualization	79
	The use of digital tools provides benefits to the business	the mistakes detection (21%), the integration of the information in a unique model (18%)	68
	The barriers that can be more easily overcome by BIM	the lack of accuracy of the information of the existing building (29%), followed by the imprecise data from modelling of the existing conditions (24%)	59
	Which features of a digital tool or platform can be more relevant in renovation works	interoperable tools (23%), encompassing the whole renovation process (15%)	66

3.2. Analysis of the Interviews Outcomes about Barriers, Requirements and Building Information Modelling (BIM) Potential in Renovation

The Table 2 summarizes the main information about the interviewees and the type of building work chosen as a case study for the interviews. The building process, specific for each case, was described in terms of data collected, documentation produced, and phase of the renovation works where the interviewees intervened. A second part of the talk was dedicated to the analysis of issues that compromised the use of BIM technologies or those that limited it, in case a BIM process was adopted.

Table 2. The main information about the interviewees and the type of building work chosen as a case study for the interviews.

Role of the Interviewee	Size of Work	Type of Building	Type of Work	Building Information Modelling (BIM) Use
Designer + site supervisor	200 sqm	single-family villa from the 50s	Deep structural and energy renovation	NO
Designer + site supervisor	250 mq	single-family villa from the 60s	Deep structural and energy renovation	NO
Contractor	360 mq	Small multi-family building	Energy renovation	NO
Coordinator of the executive design team and BIM manager	29000 mq	tower building from the 60s + new development	Deep energy renovation and adaptation of the building to new function	YES

Overall the interviews led to the definition of several barriers that were classified by the author according to the area of interest and are reported in the following paragraphs.

3.2.1. Limitation of Financial Resources

Small offices and small building firms do not have specialized personnel dedicated to BIM process management. Given the small number of employees, normally the organization of daily work does not leave enough free time to follow training courses and tests platforms and tools to reach the level of expertise needed to face a construction process with the support of digital tools. In fact, it is perceived that for a professional use of BIM software, at least one year of practice is normally needed to reach the desired level of expertise.

On the other hand, hiring a BIM expert is also a cost that small enterprises cannot afford and cannot charge on the project.

Moreover, the same setting up of the digital platform it is something that should be done after the signature of the contract with the client, otherwise, the personnel cost spent on this task cannot be included in the reward, and the effort results in being too expensive for the project.

3.2.2. Lack of Skills and Knowledge

In Italy, the use of BIM is increasing from time to time, but companies that are able to manage the whole process are few and always meet some actors of the process that are not able to integrate information in the model.

If the engineering and architectural design services sector is growing its knowledge on the use of digital tools, thanks to the capacity building actions made by universities, professional councils, and private companies and associations concerned with advancement of professional training, builders and manufacturers cannot benefit from this support, as well as subcontractors and suppliers. Therefore, at some point in the process, a lack of input to integrate or update the model is met. The second drawback is the fact the information flow is interrupted, and traditional slow communication modes shall be chosen instead, neglecting the immediacy of digital communication.

Moreover, the same lack of expertise characterizes the public sector, that is supposed to require the use of digital tools for public works according to the decree n. 560/2017 and to review projects developed in BIM environments.

Finally, the interviewees stated that there is a need to distinguish between the use of BIM processes and tools by an expert on construction technology and the one by digital experts that do not have experience in technical design and supervision of building sites. The informed user of BIM tools represents in the digital environment what he/she has something that is technically correct, the same is not always true for those who have just expertise on digital skills.

3.2.3. Building Information Modelling (BIM) Software Limitation

Data and information exchange among different users over the same BIM platform is not always as smooth as expected. Limitations are found in the exchange of information between plug-ins and the main model and among software from different brands that export data in common environments.

For instance, objects of the same model are not always recognized.

Some interviewees highlighted that not all information can be easily uploaded or downloaded from the model (for instance: material and cost bill, structural calculations).

Often the deconstruction phase reserves the largest part of unexpected information, therefore the survey should be updated regularly as well as the models, which change continuously over time, and sometime BIM users are not prepared enough to keep the model updated at the speed of changes on site.

3.2.4. Renovation Process Practice

Many companies, even in large renovation works, are accustomed to use old fashioned ways of design and resist using BIM methodology. In the current practice, it may happen that companies work on 2D drawings and subcontract the update of the compulsory BIM model for compliance to the final submission.

Some small building firms perceive the use of digital technologies as an increase of control over the effort and cost declared. In fact, gross estimates are frequent where small works do not allow a proper calculation of resources and time dedicated to the tasks. Also, the human factor in a small building site is critical to take decisions as issues arise and are not easily to record on the model in real time.

It is not easy to reduce the complexity of the site to a flow of events on a standard diagram.

3.2.5. Type and Scale of Work

The general opinion is that the effort and cost of setting up a BIM process is worth only on large building works and mainly for new construction.

On existing buildings undergoing renovation works, from the early survey stages along all deconstruction and rebuild works, there is a high probability of finding unexpected input that modify the initial or ongoing work and that can sensitively change the amount of time and effort to dedicate to the update of the model too.

On new construction, the BIM model can be integrated from the early design phase and there is no or few data about existing construction that has to be recorded and updated. Thus, the amount of information to collect at the beginning of the process is reduced if compared to renovation works.

3.3. Results of the Discussion Led during the Workshop at the Italian Pilot Site

At the workshop held at the Pilot site of BIM4REN project in Venice, 26 attendees were involved in a group discussion in which they were asked to express the barriers referred to the use of the BIM process for renovation works according to the experience of their professional practice and share their point of view with the group. The profile of experts varied from designers (engineers and architects), contractors, suppliers, consultants, building firms, and BIM experts. The exercise was led by the author to drive the group in analyzing the barriers to the use of BIM process for renovation works from the point of view of each stakeholder involved in the Venice pilot site. Attendees were invited to suggest potential solutions to overcome the barriers presented and to discuss them around the table. The following paragraphs report the main results of the discussion expressed from the angle of each stakeholder involved in the renovation project.

3.3.1. Public/Private Clients + Owner

Public clients/owners show a small level of knowledge about the BIM process, but the expectations of the building sector are high. In fact, private clients/owners shall comply with the requirements of the Italian law on the use of BIM (DM 560/2017). Educational activities are needed for technical update and capacity building of public officers for defining appropriate tenders that include BIM.

Public owners seem to be concerned with the use of BIM only to comply with the law but do not seem to appreciate the long-term benefits of these processes (e.g., better management of the building).

Sharing the model on a common platform may open privacy issues related to data of public buildings and users.

There is a lack of understanding of the amount of time and resources required to set up a BIM process, and often tenders show that the client underestimates the effort needed.

3.3.2. Private Clients/Owners

The knowledge level is quite good, but expectations are high. For private clients, the use of BIM is generally dictated by urgent works and lack of 2D drawings and previous projects.

For large scale projects there is a lack of understanding of priority requirements: sometimes private clients/owners ask for a bill of materials and management of the platform, but they do not specify the phase at which the BIM is needed (design phase, as built, maintenance?). A dialogue phase is needed at the moment of issuing the contract with professionals/building firms, with the aim of better defining the requirements of the BIM process and its use. If initial data are enough and consistent, it will be easier to develop the following phases.

Normally, the visual impact of BIM model on the clients is high and the 3D visualization impresses people.

Nevertheless, the impact of digitalization of the design and construction process is not really appreciated, because the model remain in the ends of the designer and the client cannot really use it. Simplified BIM tools that allow a fast visualization of the project and of potential variations and to roughly calculate related costs of installation and maintenance, would help in understanding benefits related to the technological shift, generally limited by decisions driven by low budget and shortage of time.

3.3.3. Site Supervisor

On average, the level of knowledge on BIM processes is quite low as well as the level of expectation from the other stakeholders. The site supervisor should coordinate the BIM process, the model should be designed by the design team and integrated by the building firm.

Protocols of implementation of the BIM model that define the type of information and data to exchange and rules of use among stakeholders is missing. The public authority should define the guidelines.

The UNI EN ISO 19650:2019 (UNI EN ISO 19650:2019 Organizzazione e digitalizzazione delle informazioni relative all'edilizia e alle opere di ingegneria civile, incluso il Building Information Modelling (BIM) – Gestione informativa mediante il Building Information Modelling – Parte 1: Concetti e principi – Parte 2: Fase di consegna dei cespiti immobili) adopted ISO 19650-1 e EN ISO 19650-2, on the organization of information for developing and managing a BIM process.

The site supervisor is the less keen actor to use the BIM process because it is seen as an increase of complexity on information and data flow, and it is time consuming during setting up and in the continuous update. The lack of experts in the use of BIM make it non-useful for the management of the building site.

3.3.4. Main Contractor

The main question highlighted was whether there is a benefit for the contractor to use BIM.

It is noticed that there is a difference in the level of digitalization according to the size of enterprises: small-medium construction firms have low experience with BIM processes, big firms have a good level of knowledge.

BIM software are designed for the design phase and less attention is dedicated to the construction and to the information that the building firm needs to collect and transfer to the model (few characteristics for the objects: products, materials, etc.). A BIM family should be developed for several stakeholders.

The economic value of the BIM process is not recognized: it is time-consuming and generally it is difficult to update the model according to the progress of the works in real-time. There is a need to recognize a value to the BIM as a percentage of the work cost. 4D (timing) 5D (individual choices) should be integrated in the process, above all as how to combine BIM management and financial reporting and how to combine different works on the building site.

Normally contractors do not have an in-house BIM manager, and the investment for training internal personnel is quite expensive.

Interoperability among BIM platforms and other software is quite critical to support the dialogue with other firms or suppliers that may use different ones. The use of data and technologies to speed up the survey of the existing building is also relevant.

3.3.5. Industrial Contractors (Subcontractors)

They are updating their processes to align their offer to the market demand. They need specific information to feed the model and specialized professionals able to manage BIM platforms. Their major difficulty is the continuous update of the model according to the decisions taken on site.

3.3.6. Suppliers

They need specific legal agreements to share data on BIM platform and guidelines to define the information to describe objects in the BIM families. It was highlighted that systems to support BIM procedures do not have the needed maturity for a widespread use.

3.3.7. Architectural and Engineering Firms

The construction market requires a transition from standard design methods to BIM processes. Therefore, professionals need to update and train to offer BIM services, in order not to be cut out from the demand. However, training and education is expensive and time-consuming, so it is not easy to start using BIM.

There is a problem of acknowledgment of BIM roles, not only for the BIM manager. The process requires an initial coordination phase to manage the interaction between data, software, and disciplines.

Awareness raising of clients on the potential and benefits of the use of BIM for design, construction, and management of buildings should be encouraged for a wider application of the process.

4. Conclusions

The paper reports the results of the wide consultation work carried-out by the authors in the early stages of the BIM4REN project, funded by the European Commission under the Horizon 2020 Framework program for research and development.

Aim of the consultation is understanding the barriers that limit the use of digital tools and software in the renovation sector and highlighting improvements that BIM can provide to traditional building processes to shape the requirements for the BIM4REN platform implementation. Understanding barriers provide specific inputs for a more tailored design of BIM tools for building renovation able to respond to stakeholders' needs across the whole value chain.

Three main tools were adopted to run the consultation: a web survey, one to one interview, and a workshop for a total of 153 people involved, only in Italy.

It is worth noting that the approach and answers provided differ significantly depending on the level of expertise: some interviewees were BIM experts and some others were not. The BIM concept

itself is under discussion. This generates the situation where some have different opinions about what BIM can do and what it cannot. However, and even if BIM will not always be the answer to all problems, there are situations where such a methodology could indirectly contribute to improve the situation.

In respect to the full analysis, comprehensive of other countries' responses, answers and discussions results are quite aligned. There could be slight differences in the competences of people interviewed depending on their role, nevertheless, the information collected is comparable among countries. However, the view from each stakeholder is relevant as their work is uniquely related to the use of BIM and digital tools.

Overall, three major categories of barriers are perceived: lack of awareness, lack of skills and competences as well as financial resources to get them, and technical limitation of the existing BIM tools.

Some of the actors, previous generations of designers, and mainly SME, show a lack of awareness on the benefits deriving from moving from a traditional approach to a digitized one in terms of time and cost savings, in terms of safety of workers and control of the construction products and in terms of a better management of the construction site at first and of the building at last. This is true for private and public owners/clients that do not require the BIM from the early stages if not for compliance with the national decree. However, it is also proper of site supervisors and contractors that see the use of BIM just as an increase of complexity in the management work.

Other actors cannot properly contribute to the BIM process because they do not have skills and competences for integrating and they work in a digital environment. Some designers and contractors of the old generation and some construction SME show this problem as well as subcontractors and suppliers that are not normally involved in a collaboration process, being just concerned with the supply of products and materials. This lack of skill from several actors in the value chain discourages clients, site supervisors, and designers from adopting the BIM process from the early design phases.

The lack of competence often goes hand in hand with the lack of resources to reach a level of expertise to properly compete on the market. This is the case of small design offices as well as construction SME that, given personnel and cost restrictions, cannot afford to train an internal employee on BIM and on the other hand do not have enough resources to hire a BIM expert. The same actors normally cannot afford licenses or specific tools that would speed up and make easy the application of the BIM process.

Among the technical limitations of BIM tools, most of the respondents perceived the BIM approach as appropriate only for new construction and large renovation works because the complexity of the tools and the time dedicated to set up the model are not justified for small renovation activities. Finally, the limitation of the BIM technology itself such as safety of data sharing, interoperability, and exchange of information among several software and plug-in, time consuming modelling and transfer of information from the survey to the 3d model, are common to all the stakeholders.

Generally speaking, about renovation works, the major risks identified for building renovation are the lack of accuracy of the information about the existing building as well as the lack of collaboration among the actors during the construction process. Actually, these are exactly the kind of issues that a BIM process can support the most. Therefore, to enhance the use of BIM for renovation, it is key to tailoring the BIM process and tools to the specificity of the refurbishment works as BIM4REN project aims to do.

In fact, the digitalization and BIM approach specifically represent an opportunity for upgrading the renovation sector as a whole. If technological development can solve technical limitation on data gathering and safe exchange of information and major collaboration among all the actors of the value chain, actors of the construction sector will ask for time to adapt their normal practice to the novel approach.

As reflected by the report from the World Economic Forum [4], the analysis of barriers performed in the first stage of the Italian living Lab in BIM4REN project highlights that as for every innovation, digitalization require some development stages: an intensive awareness raising activity should set the motivation to adapt normal practice to new digital approaches, a review of the processes should make

easy the exchange of information and collaboration among the actors of the value chain, and finally the enablement phase shall incentivize the development of skills and competences to align the normal practice for all the actors of the value chain.

As future development of the work the three-step process of survey, interview, and workshop should be repeated at the end of the BIM4REN project when the tools will be optimized for renovation works. Similar stakeholders of the value chain should be asked whether the projects tools will have been able to overcome the barriers identified in the current study and what further actions are needed.

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References

1. European Commission. 2030 Climate & Energy Framework. Available online: https://ec.europa.eu/clima/policies/strategies/2030_en (accessed on 1 May 2019).
2. European Commission. 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. *Off. J. Eur. Union* **2018**, *L156*, 75.
3. Buildings Performance Institute Europe (BPIE). Future-proof buildings for all Europeans—A guide to implement the Energy Performance of Buildings Directive. Available online: http://bpie.eu/wp-content/uploads/2019/04/Implementing-the-EPBD_BPIE_2019.pdf (accessed on 1 May 2019).
4. World Economic Forum Group with the Boston Consulting. *Shaping the Future of Construction. A Breakthrough in Mindset and Technology*; World Economic Forum Group: Geneva, Switzerland, 2016.
5. European Construction. Market trends until 2021, summary report. In Proceedings of the 86th Euroconstruct Conference, Paris, France, 22–23 November 2018.
6. Mckinsey Global Institute. *Reinventing Construction: A Route to Higher Productivity*; Mckinsey Global Institute: Kazhakkoottam, India, 2017.
7. European Construction Sector Observatory. Building Information Modelling in the EU construction sector. Trend Paper Series. Available online: https://segm.gr/wp-content/uploads/2019/03/ECSO-TP-BIM-in-construction-March-2019.pdf (accessed on 1 May 2019).
8. Anil, E.B.; Tang, P.; Akinci, B.; Huber, D. Deviation analysis method for the assessment of the quality of the as-is Building Information models generated from point cloud data. *Autom. Constr.* **2013**, *35*, 507–516. [CrossRef]
9. Tang, P.; Huber, D.; Akinci, B.; Lipman, R.; Lytle, A. Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. *Autom. Constr.* **2010**, *19*, 829–843. [CrossRef]
10. Gökgür, A. Current and Future Use of BIM in Renovation Projects. Master's Thesis, Chalmers University of Technology, Gothenburg, Sweden, 2015.
11. Volk, R.; Stengel, J.; Schultmann, F. Corrigendum to "Building Information Modeling (BIM) for existing buildings—Literature review and future needs". *Autom. Constr.* **2014**, *43*, 204. [CrossRef]