Chapter 1
Information Requirements for an Efficient Renovation Process

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Abstract When a renovation process takes place, different stakeholders are responsible of several activities and their interaction occurs at different stages of the building process. Therefore, a deep analysis of possible activities for different stakeholders in each different stage of the life cycle helps outlining how to optimize their interaction, thanks to the use of BIM-based tools that can smooth collaboration and data gathering. As it is commonly agreed that information losses, data lacks or redundancies are one of the main causes of time delay and cost increase, a flowchart representing the building process in case of renovation has been developed and then used to design a BIM management system (BIMMS) to allow every stakeholder along the life cycle of a building (and built asset) finding required information and share existing or new datasets in a straightforward and conflict-free manner. A particular attention has been paid in individualising differences between the public and private sectors, to be successfully applied to the renovation process in both the sectors.

Keywords Renovation processes · Stakeholders · Information requirements

1.1 The Information Workflow in a Renovation Process

When a renovation process takes place, different stakeholders are responsible of several activities. For mapping a renovation process, first of all, a list of involved stakeholders has been produced considering also the literature review (CCC 2006;

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GBPN 2013; RIBA 2013). Furthermore, stages of building processes have been defined, according to (EN 16310:2013), (ISO 6707-1:2020) and (ISO 6707-2:2017).

The process of renovation needs a methodology that takes into consideration several parameters such as the cost of the renovation measures, the targeted performance (Key Performance Indicators like indoor thermal comfort levels, CO_2-emissions, energy, safety), national building regulations, building specific information and the end user needs. Also, the process must be adjusted to allow some iterations, because the planning and the implementation of the renovation measures and the conditions surveys during the process might bring up some hidden deterioration of the building components having an effect either positively or negatively on the targeted performance of the renovation actions.

By listing all the possible actors involved along a renovation process, information workflow can be defined to be considered when developing the BIM Management system to assure a proper definition of ontologies and interoperable exchange formats.

The output of this deed analysis is a flowchart representing actors and actions where:

- actions are represented by rectangular shapes,
- dotted lines are used for actions that are used for actions that are not common to all analysed countries,
- lilac rectangles represent the actions made only in public works,
- decision gates are represented by diamond shapes.

These activities are the starting point for mapping outputs of such activities (that could be mapped in a traditional process and in BIM-based processes) and for estimating times spent for carrying activities and achieving defined outputs. The synoptic flowchart will be used to outline how ICT and BIM can support the rationalisation of information flows (BIM4EEB D2.1, 2019) (Fig. 1.1).

1.2 Definition of Designers' Needs and Requirements for BIM-Assisted Decision Support for Performance-Based Refurbishment

The previous paragraph presents the renovation process described in the project from the general point of view. When the BIM4EEB project proceeded further, that process was updated from the designers' point of view related to the new activities and roles found. A general view of the designer requirements and the concept of performance-based decision making with a specific use case of the BIM-assisted scenario simulator is shown.

The model and energy calculation gradually refine in the energy performance design from a simple monthly calculation with basic information into a dynamic simulation with an accurate building information model (BIM) and detailed information about technical building systems. Figure 1.2 illustrates the scope of the work.

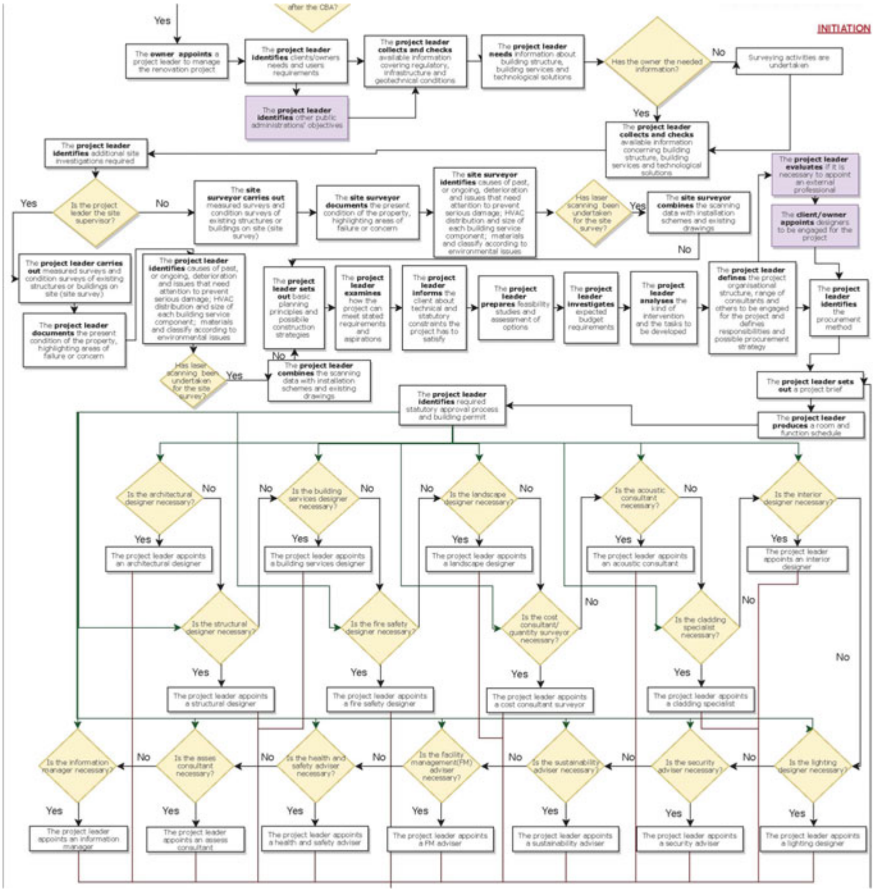

Fig. 1.1 Extract of the developed flowchart for a renovation process

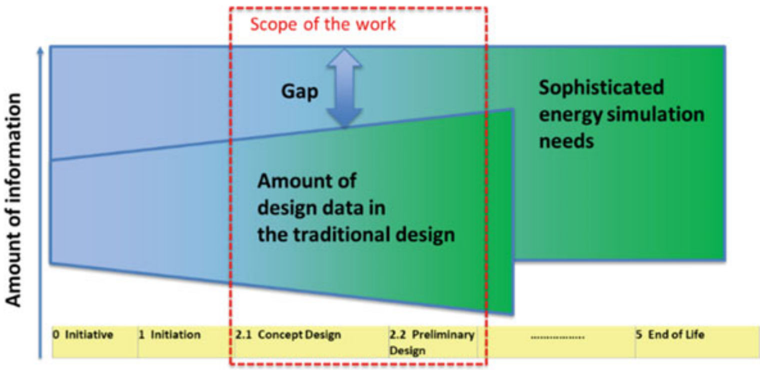

Fig. 1.2 The information gap between the early-stage information need

In this task in the BIM4EEB project the requirements for the data regarding successful performance-based design were studied. This chapter is based on the project deliverable (BIM4EEB D2.2, 2019), which is available in the project website https://www.bim4eeb-project.eu/.

Building Energy simulation (BES) tools are used for analysing energy need and expected indoor environmental quality in the buildings under different retrofitting plans. It essential to analyse not only the energy, but also the value for which the energy is used. We are not interested to just conserving energy, but also optimising the comfort and productivity in the buildings. Typically, BES can calculate performance indicators such as CO_2 emissions, LCC, LCA, occupant's satisfaction and indoor environment quality.

On a general level, the input data to BES are the weather, building envelope, geometry and orientation, HVAC system and the occupant's behaviour. The heating and cooling set-points and the air ventilation rates are the most influential parameters on the building's energy consumption. Besides, in cold weathers, main effects on the heating load come from the building envelope parameters of the window U-value, window g-value and wall conductivity. In hot weathers, the cooling load is mainly affected by the solar-heat gains, the internal heat gains from the occupant's behaviour, and the heaviness of the structures. In addition to its influence on the output results of BES, occupant's behaviour related to people existence and use of appliances and lighting is one major factor that can cause discrepancies between simulation prediction and the real energy use.

A first use case in the project is to model the building as it is before the renovations. This is called an As-is model. The accurate acquisition of data for the As-is models of the buildings that are subjected to retrofitting is the first challenge for BIM-based energy simulations. Old buildings normally lack complete and updated documentation of all data that are required by energy simulation. Appropriate equipment and methods are needed to monitor, collect, and manage the data and the tools developed in the project are expected to fit the need.

In addition to its completeness and updated information, the BIM data should also be interoperable with BES in an easy and automatic manner without a need for the repetition of the exhaustive input data. BIM4EEB tools and methods were developed to also fulfil this need, which is not always possible with the existing tools. There is often a need for different levels of manual interventions.

The model for the BIM Assisted Scenario Simulator tool, called BIMeaser, is presented and the workflow of its use is defined. The most important finding related to the renovation process is the importance of the need for the performance-based building design in the early design phases, where the most important decisions are made according to costs and performance as shown in Fig. 1.3.

The data definitions related to the commercial energy simulation tool IDA Indoor Climate and Energy (IDA-ICE) by the Swedish company Equa Simulation AB open a landscape of huge set of details to be defined. This huge set (more than 1000 parameters) was narrowed according to the findings listing the most important input variables related to the impact on the indoor climate and energy, but still was a big challenge in the project.

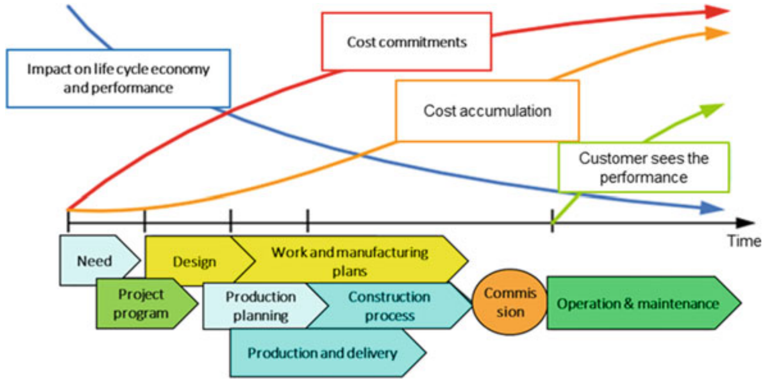

Fig. 1.3 Committed costs and possibilities related to energy performance decay, adapted from (Pietiläinen et al. 2007)

The second finding derived from tool definition was the need for the enhanced collaborative design work. The indoor climate and energy design is a multi-domain challenge, and it should always be considered as a teamwork. All tools around the future building renovation design should comply and support this approach. The performance-based building design process assumes that design selections are validated against the Owners Project Requirements (OPRs) in each design stage before moving to a following design stage. The design team will handle the detailed technical selections affecting to the OPRs using the tool. The management of the consistency of the detailed technical parameters against the OPRs has traditionally been handled manually between design domains resulting to the design errors or time-consuming updates, whenever the technical detail has changed. The BIM Assisted Scenario Simulator will tackle the complexity of the energy and indoor climate design by:

1. speeding up the decision making
2. enhancing the collaboration between the design domains
3. enabling the cross-domain transparency of the technical details in the design team
4. resulting better indoor climate and energy selections in the renovation.

The implemented BIM Assisted Scenario Simulator, called BIMeaser, is presented in Sect. 5.2.

1.3 Information Requirements for Construction Companies in Renovation Interventions

In the last years some studies have been developed regarding the application of BIM in the construction enterprises, but research on BIM adoption in small and medium-sized enterprises (SMEs) have remained an under-represented area (Hosseini et al., 2016; Li et al., 2019). The research on SMEs it is of fundamental importance because SMEs have greatly contributed to the economic development of regions or countries and, currently, guidance to assist SMEs to make an informed decision about BIM adoption are lacking (Lam et al., 2017). It is necessary to understand the main challenges delaying the adoption of BIM in SMEs and to consider corresponding strategies that can be applied to obtain further understanding of BIM in SMEs (Li et al., 2019).

Focusing on the small and medium enterprises, the main barriers derived from the risks associated with an uncertain Return On Investment (ROI) for BIM implementation. The findings of (Hosseini et al., 2016) show that currently around 42% of Australian SMEs use BIM in Level 1 and Level 2 with only around 5% that have tried Level 3. According to (Lam et al., 2017) there is evidence to suggest that small and medium sized enterprises are currently losing out in winning publicly funded projects. (Hosseini et al., 2016) affirm that the findings of their study show that around 42% of SMEs have been engaged in BIM, instead of the 25% provided by the study by (Gerrard et al., 2010). This gap indicates how fast-moving BIM is within the Australian construction industry, but the findings also indicate that the immaturity of BIM implementation is still a problem within Australian market because only the 5% of SMEs had used Level 3 and 8% had utilized Level 2 BIM on their projects. According to (Li et al., 2019), based on previous studies and interviews, in SMEs six challenges exist: (1) SMEs are short on resources, (2) collaboration challenges, (3) lack of BIM awareness, (4) legal disputes and uncertainties in policies, (5) difficulties in meeting SMEs' needs, and (6) concerns about data and information. (Bosch-Sijtsema et al., 2017) assert that the results from their study on SMEs indicated that more than half of medium-sized contractors in the sample used BIM in some projects and the main obstacles for BIM implementation is related to the lack of normative pressure. (Tranchant et al., 2017) carried out an immersive 3D projection for the simulation of the Ajaccio hospital in France. According to (Tranchant et al. 2017), the heart of the economy of France is that of SMEs, which represents 96% of companies. As a result, the innovation of the BIM is becoming a necessity for SMEs, even if they do not practice public contracts. (Malacarne et al., 2018) affirm that the BIM Pitch concept that they developed in their research is unsuitability for SMEs since it is highly time consuming to develop as additional model, as consequence further study are required.

The framework on the recent studies on SMEs underlines that they are limited to few countries. As consequence, additional research is needed to understand the needs of the industry and existing barriers in digitalization and BIM use in AECOO sector.

The exchange of information between the three main parties of a project is a common problem in construction sector.

1. Communication and information exchange between the client and the contractor (under the word "client" are also considered the design teams)
2. Information exchange from the contractor to the supplier (under the word "supplier" is also considered the subcontractor)

3. Information exchange from the supplier to the contractor

The traditional information exchange is done by paper or digital format, using graphics, pictures, documents, and static media documents. This type of exchange of information has several limitations that can be improved utilizing a more digitization method such as BIM.

The BIM method includes the use of information models to replace documents that can be digitalized, and it optimizes the transmission of data, promoting interoperability between the parties involved in the project.

However, the geometric representation is not the only purpose of a BIM model; in fact, this type of approach is used with the addition of data and information characterizing the model itself. From the informative model, it is possible to extrapolate, in addition to the geometric visualization, also data of an informative nature and the latter can be contained in documents linked to the model, such as quantities estimation, specifications or reports, or within the objects constituting the model itself.

Commonly, information exchange issues are related to three main parties involved in a project, namely client, contractors and supply chain as following explained based on (Franchini, 2018).

1.3.1 From the Client to the Company

At the base of the process, there is the need of the client to have the work carried out. The client, therefore, represents the main Fig of every transaction. To this end, the company should clearly understand what the client's objectives are.

To clarify these intentions, the client trusts the elaboration of the project to a team that draws up part of the documents that must be supplied to the companies.

In a frequent scenario, once they have received the material, they must analyse the information and data received from the design team and verify the completeness. If the papers are inadequate, the responsibility of filling these gaps will nevertheless remain with the company, to draw up a complete construction project.

Often, for example, the executive project is incomplete, leading to a loss of time and resources for the company.

At the end of the process, the company should deliver to the client the complete As Built, including all the information useful for the maintenance of the work. Currently many companies have an ERP system (such as SAP), where part of the As-Built information is collected. However, many documents remain stored in other location in the company there is the need to transfer all this inputs to the client and the end of the project.

1.3.2 From the Company to the Supplier

This exchange of information happens to present an offer.

The traditional exchange of information between the company and the supplier happens by paper or digital support, exploiting the use of graphic, documentary, and static multimedia documents. This type of information exchange is usually successful but has several limitations, including:

- The documents or files exchanged are not self-explanatory. Therefore, the meaning of the message may be subject to personal interpretation.
- The exchange of information through this type of support forces the subjects involved to operate in a non-optimal way.

This way often leads to the loss of time and valuable information, and the waste of a large amount of paper.

Even the world of construction companies is getting closer to a more complete digitization; an act that regards information exchange very closely. However, it is important to emphasize that this step forward by companies lies not only in the digitization of their process, but in the use of information models to replace the documents which can be either digital or not. All this makes it possible to optimize the transmission of data, promoting interoperability between subjects, limited by having to know how to use the tool.

If the company was digitized, in the BIM sense, the transfer of information to suppliers would be difficult, if not impossible. The supplier would not be able to open and exploit the information models received, because he is used to using antiquated methods (paper) and/or non-standardised practices. In fact, a supplier may deliver products to hundreds of companies and each of them may have different practices.

1.3.3 From the Supplier to the Company

This exchange of information happens to allow the company to present an offer; to realize the as built, and the maintenance documentation.

This passage of information is significant at different stages of the process starting from the pure design phase, in which the company must take care to carry out the constructive translation of the client's requests, up to the preparation of the maintenance plan that will be used by the final users.

The necessary inputs can be multiple, such as:

1. the date of installation of a material or the date of installation of a product,
2. information in relation to the acceptance of the material,
3. the possibility of replacing a product,
4. the supplier not digitized in the BIM sense, in the same way as in the previous case, will not be able to respond to the needs and requests of the company due to the lack of knowledge of the information method adopted.

There are two possibilities to solve this issue:

1. translating the informative models back into elaborates so that the supplier can analyse the documentation and work on this to respond to the business needs,
2. developing an intelligent method so that the supplier, despite not knowing the BIM platforms and software, is able to exploit these intuitive and practical methods to meet the needs of the company, together with those of the client.

The first point is feasible but would lead to a waste of time and resources that could instead be addressed elsewhere. It is necessary to carry out an accurate investigation to try to better understand the needs of the companies, in such a way as to be able to obtain results that are practically exploitable and standardized.

1.3.4 Attributes and Requirements

To explore solutions related to the above-mentioned information exchange issues, it is necessary to know some information regarding the companies, such as:

- What information does the supplier need to provide for the preparation of an offer?
- Which documents are useful for the preparation of an offer besides the specifications and the calculation?
- What are the necessary inputs to the model for the preparation of an As Built or a maintenance plan?
- Which of this information is essential to be digitized in order to optimize the process?
- Which of this information should be given exclusively by the supplier or site manager?
- What are the attributes that are needed to characterize an object?

To find out what are the attributes three types of objects are considered, representing the category to which they belong, such as:

- A construction work characterized by geometry without the use of industrial products.
- An industrial product without geometry in BIM (e.g., brick) with geometry defined by the construction work (e.g., wall).
- An industrial product geometry both in BIM and in the real world (e.g., air handler).

The first step is to create a basic list of attributes, useful for the company to characterize the object.

It is important that this list can be implemented to be able to add both specific needs and attributes, expressly requested by the client or designer, and new attributes considered essential by the supplier (Table 1.1).

- Is each proposed attribute necessary?

- Is it essential to identify others, and if so, which ones?
- Which of these are needed in the offer phase, such as for the preparation of an As Built, and what for a maintenance plan?
- Which of these attributes is essential to be digitized to optimize the process?
- Which of these attributes should be given exclusively by the supplier or by the site manager?

1.4 Definition of Owner and Inhabitants' Needs and Requirements in Renovation Interventions

An important and difficult step in designing a software product is determining what the end-user expectations of the software will be, such as what activities the user will be able to perform once the platform is operational. This is because the users (especially non expert's users) are often not able to communicate entirely their needs, or the information they provide may be incomplete, inaccurate and/or self-conflicting. On the other hand, nowadays there is the increasing need of the active enrolment of end users towards the provision of personalized services to the potential customers.

The scope of this document is to blueprint a methodological approach and a user requirements extraction process for the building owners' and inhabitants' as main stakeholders in a building renovation and management project. In general, by engaging the owners and inhabitants of a building, enables them to participate as active players in the renovation process, which in turn increases their awareness about their influence on the way a building function. As such, their input during the whole process ensures that their requirements and needs in relation to the renovation's outcome are considered; additionally, it increases the chances of a successful renovation design outcome achieved.

Towards this direction, a detailed methodology is established at the early phase to ensure the proper extraction of end-user's feedback. The definition of the target groups is a primary step along with the definition of the main use cases associated with the roles. Then, to extract the relevant requirements, dedicated to the building owners and inhabitants' questionnaires are structured, while semi-structured interviews (to be addressed by the building representative) were defined, towards co-creating a shared value and directly addressing the owners and inhabitants needs. More details about the methodological framework as well as the results from the analysis are presented in the following.

As shown in figure below, the proposed methodology is composed by three steps through which the requirements coming from the building owners and inhabitants can be captured.

The different steps shown in Fig. 1.4 are detailed in the following text.

Table 1.1 Description of informative attributes

Attribute	Description
Accessibility	Accessibility performance (ability to solve problems in this sense)
Type	Flexibility of the object
Category	Coding indicating their classification (e.g., Uniclass2015)
Code performance	Category requirements
Colour	Primary colour or characterizing the product
Component	Optional components (parts, characteristics, and finishes)
Description	Description of the object that clarifies the design intent
Useful life	Life expectancy of the object (typically indicated in years)
Use	Typical service use
Characteristics	Other essential features related to product specifications
Finish	Main finish
Category	Standard category
Manufacturer	Useful manufacturer's contact
Material	Main material
Serial Number	The code assigned to the object by the manufacturer
Name of the model	Name of the object used in the model
Name	Alphanumeric code that uniquely identifies the object (the code must first report the type of product)
Nominal height	Size typically measured vertically
Nominal length	Size typically measured horizontally
Nominal weight	Object weight
Cost of replacement	Indicative cost for replacement
Form	Main or characteristic form
Dimension	Main or characteristic dimension
Sustainability	Description of sustainability requirements
Warranty	Warranty description and possible exclusions
Duration of warranty (installation)	An indication of the duration of warranty of the installation
Duration of warranty (components)	An indication of the duration of warranty of the components
Duration of warranty (object)	Duration of warranty of the object (normally in years)
Guarantor warranty	Contact details of the guarantor for the installation

(continued)

Table 1.1 (continued)

Attribute	Description
Guarantor of the guarantee (component)	Contact details of the guarantor for the components
Specific identification	Identification of a specific activity to distinguish it from the others
Bar code	Bar code or RFID for unique identification of the object
Date of installation	Date the object was installed
Serial number	An indication of the serial number
Tag	Tag indication
Warranty start date	Date the warranty begins

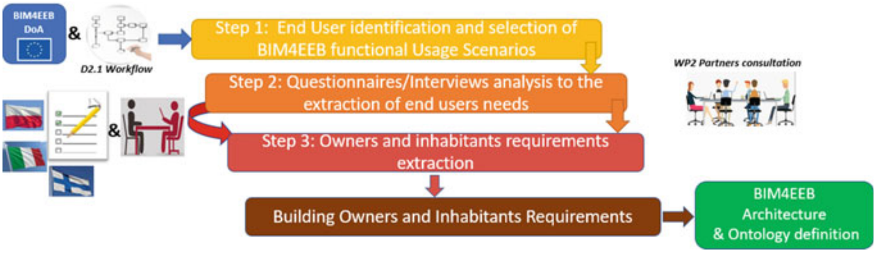

Fig. 1.4 Steps of the followed workflow

Step 1: Selection of end users usage scenarios

The starting point for this analysis, is the identification of the end-users (namely the building owners and inhabitants) business needs and priorities, following consultation with building occupants. A non-exhaustive list of usage scenarios is defined for analysis in the project:

- US-01: Establishment of a comfort and IAQ preserving framework for inhabitants during/post renovation period.
- US-02: A continuous interaction framework for comfort status monitoring and report for inhabitants
- US-03: An alerts and notification framework during the renovation process for owners and inhabitants.
- US-04: Management and control of renovation interventions for owners.
- US-05: Control of working times and economic sustainability for owners - tracking tool for renovation operations for owners

The definition of the different Usage Scenarios highlights the key differentiation among the stakeholders (owners versus. inhabitants).

Step 2: Questionnaires/Interviews analysis to the extraction of the end-users needs

Following the definition of the Usage Scenarios, a set of questionnaires were prepared to address the needs of the building owners and inhabitants (as end-users of the project). The scope was to engage these end-users in the project's activities and further retrieve their valuable feedback towards the extraction of their needs and requirements related to building renovation and management activities. The intended type of information to be gathered from the end users is classified into the following groups:

- Profile information: such as profile data, household composition and building characteristics. This information is useful for segmentation and statistical analysis.
- General knowledge and familiarity with concepts such as BIM (Building Information Modelling), BACS (Building Automation and Control systems), etc., and questions trying to capture the current knowledge of the Owners and Inhabitants, regarding how their building/premises operates.
- Owners & Inhabitants required tools and attitude towards participation in the usage scenarios. This is the targeted information aiming to extract the priorities of the users related to the different usage scenarios defined.

Further to the use of questionnaires for extracting the owners' and inhabitants' needs and requirements, the building site representative partners were also engaged in semi-structured interviews to extract further pilot specific requirements. The use of these semi-structured interviews allowed new ideas/concepts to be examined, as well as further technical requirements to be identified regarding ethical/legal barriers imposed at the different pilot sites. More specifically, the goal of these semi-structured interviews was threefold:

- To shape the final list of Usage Scenarios addressing the owners and inhabitants needs.
- To cross check the results from questionnaire analysis towards the extraction of the final list of owners and inhabitants' requirements.
- To gather any regulatory and legal requirements as part of the overall requirements definition phase at the different pilot sites.

A total number of 102 questionnaires were responded by building owners and inhabitants—45 for building owners & 57 for building inhabitants. Also, a limited number of semi-structured interviews was answered by the pilot representatives (Italy, Poland, and Finland) to express their needs and main expectations from the project.

Step 3: Owners and Inhabitants requirements extraction

Finally, in step 3 we consider the questionnaires/interviews analysis results which are transformed to building owners and inhabitants requirements. A total number of 97 end-user's requirements were extracted incorporating also some technical constrains. The list of the extracted requirements derived from the active participation of the pilot sites. These are further complemented by additional requirements mainly related to ethical and any legislation constrains imposed at the pilot regions of the project.

In total, 30 pilot specific requirements are to be considered at the instantiation/configuration of the framework at the different pilot sites. Further to the above work and the elicitation of the non-exhaustive list the requirements, we categorized them considering the hierarchy and the project's objectives. The prioritization of the end-user's requirements is also a critical task performed to elucidate the requirements to be considered on the analysis. The different layers of priority are:

- High: Requirements in this category as defined are a key innovation of the project. These requirements are essential to achieve the goals of the project and fulfil the end-users' needs.
- Medium: These requirements are necessary or very helpful to set the application prototypes, but not crucial one for the whole system operation.
- Low: Requirements in this class are not necessary for the BIM4EEB system. However, they may be considering as important for the fine-tuned operation of the system examined.

Overall, the outcome of the work is (a) the definition of the relevant for the building owners/inhabitant's usage scenarios to further enable the (b) extraction of the user specific requirements for this target group of the BIM4EEB project. The extraction of the requirements will further facilitate the design and development of the different software implementations targeting building occupants: inhabitants and owners.

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