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Stakeholder requirements for the BIMERR system

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** The beneficiaries GU and EXE left the BIMERR consortium during the finalisation of this deliverable.*

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2.0	UOP	05.07.2020	Submission to the EC

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Definitions and Abbreviations

AEC	Architecture, Engineering and Construction
AR	Augmented Reality
BEMS	Building Energy Management System
BEPS	Building Energy Performance Simulation
BICA	Building Information Collection Application
BIF	BIMERR Interoperability Framework
BIM	Building Information Model
BS	Business Scenario
DoA	Description of Action
DGN	DesiGN
EPC	Energy Performance Contracting
FEM	Finite Element Method
H&S	Health and Safety
HMD	Head-Mounted Display
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IoT	Internet of Things
KPI	Key Performance Indicator
LBMS	Location-based Management System
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LoD	Level of Detail
LTI	Lost Time Injury
MEP	Mechanical, Electrical and Plumbing
O&M	Operation and Maintenance
OPEX	OPerating EXpense
PPE	Personal Protective Equipment
PRUBS	Profiling Resident Usage of Building System
PWMA	Process & Workflow Modelling & Automation
RES	Renewable Energy Systems
RoI	Return of Investment
UC	Use Case
UI	User Interface
VOC	Volatile Organic Compounds

EXECUTIVE SUMMARY

This deliverable presents the analysis of the **end-user requirements** in order to create the necessary inputs for defining the different components of the BIMERR platform and hence, setting the skeleton for the BIMERR framework. The list of the produced requirements is derived through the active end users participation and involvement in the BIMERR Living Lab, i.e. it engages end-users from the early stages cultivating motivation to share and discuss experiences as well as requirements.

The specification of **business scenarios and use-cases definition** at the very early phase of the work, drives the whole requirement definition process so as to allow end-users to easily grasp the intention, functionality and use of the BIMERR platform. Suitable **end-user questionnaires** specifically prepared for this reason, capture the views and requirements of all BIMERR system stakeholders, ranging from architects and project managers, to workers.

The results of these activities, which are presented here, form the basis for the design and development of the project work packages. Therefore, this document lies at the core for the whole project, setting the guidelines for the development of the BIMERR platform. The use cases and requirements definition enable the definition of the BIMERR reference architecture and further guide the development and evaluation phase of the project at the pilot premises.

Instead of the originally proposed time limited requirements phase [1], an extended iterative methodological approach is adopted to increase the quality and validity of the produced results. The first iteration of this approach was reported in the first version of this deliverable submitted on M06, while the second and third iteration results for the user requirements are reported in this final version of the deliverable.

1. OBJECTIVES OF THE REPORT

The objectives of this deliverable are first to present the main stakeholders of BIMERR along with the definition of business scenarios and use cases for the BIMERR pilots, and then to collect, analyze and propose user requirements that map the different steps and roles in the renovation process.

Hence, this deliverable presents the documentation of BIMERR end-user requirements, analyzes the iterative process that was followed, presents the findings and finally reports the user requirements of the project. Note that this second version of deliverable D3.1 was decided by the consortium [2] in order:

- for an iterative requirements elicitation process to be adopted, and
- to have enough time to capture the user requirements for the Occupant user group after the finalization of the pilot buildings

1.1 BIMERR BRIEF BACKGROUND

Building Information Model (BIM) methodologies and tools offer large advantages for the construction/ renovation sector such as:

i. reduction of critical mistakes and omissions
ii. improvement of collaboration between stakeholders

These benefits can lead subsequently to:

i. Lower costs, through rework reduction and efficiency increase by avoiding miscommunications.
ii. Higher speed, since design and documentation can now be done concurrently instead of serially, as well as easier adaptation of the original model to onsite changes.
iii. Higher quality: due to enhanced flexibility in project development without interrupting the development team, since close control for technical issues and detailed decisions regarding project implementation can be achieved.

Other benefits of BIM for renovation projects include reduction of uncertainties regarding the post-renovation performance, early visualization of renovation impact to get consensus from building owners, improved collaboration between Architecture, Engineering and Construction (AEC) stakeholders leading to fewer conflicts, mistakes and re-works on site.

Nevertheless, BIM methods and tools are gaining acceptance in the AEC industry, but not with the anticipated pace. This is due to a number of key factors, such as the requirement for the entire construction value chain to use consistent BIM tools in order for any party to reap benefits, the investment in time required as a learning curve on behalf of AEC companies and professionals, the size and complexity of BIM models that are very heavy for CAD tools, etc. One of the major challenges is the use of BIM not only as a tool in the design process, but also as

the interface for information exchange between the different parties involved in construction/renovation projects.

As presented in greater detail in the DoA, BIMERR introduces an ICT-enabled Renovation 4.0 framework to address these challenges and support the renovation of existing buildings by providing key enablers in the most critical steps of the process:

- Creation of enhanced digital models of existing buildings with information that includes building equipment, energy usage, resident-dependent building operation, urban topology, etc. This will be achieved via improving existing scanning-based tools as well as introducing innovative solutions through the use of smartphone apps and Augmented Reality (AR) technologies either by residents or AEC professionals.
- Renovation design and planning will be aided by an innovative Renovation Decision Support System that enables design and planning stakeholders to quantitatively evaluate the available options across several key target metrics (e.g. economic and energy usage that account for resident behaviour as well as building information, sustainability/ environmental metrics for the solution that best meets the short- and long-term renovation targets).
- Renovation process and workflow management will be a key enabler for several things like process simulation for optimization across project phases in order to identify and leverage opportunities for fine-tuning process steps, work scheduling and planning for improved coordination between the stakeholders, on-the-fly progress reporting and guidance of workers via AR-enabled smart glasses for improved productivity and re-work elimination.

To achieve these goals, BIMERR follows an implementation methodology that comprises several steps. In this concept, end-users and project beneficiaries are collectively placed at the center of all research, innovation, demonstration and communication activities of the BIMERR project through a User-Driven Innovation Approach [1]. The goal is to involve renovation professionals and building occupants throughout all stages of the project lifecycle, as key enablers of the BIMERR innovation process. The User-Driven Innovation Approach is realized by the BIMERR Living Lab that targets the following objectives:

- Widely disseminate the project outcomes towards end-users, beneficiaries and construction/renovation stakeholders so as to generate a broad awareness and engagement/ involvement in the various project activities.
- Create opportunities for further exploitation and replication of the project results after its official completion.

- Facilitate the training activities of AEC professionals during the BIMERR demonstration activities.
- Obtain feedback from the end-users and targeted beneficiaries throughout project duration to optimize all project developments, so as to directly address critical needs of stakeholders involved in the operation of the BIMERR framework.

1.2 SCOPE OF THE DOCUMENT

The scope of this document is to define the user requirements of the project, which are key inputs to the specifications extraction of the BIMERR system architecture (T3.5), as well as to the whole system implementation.

A top down methodological framework is adopted for the requirements elicitation process. It combines the high-level overview of the renovation business scenarios and use case definition together with the extraction of the list of requirements that come from the end users. In order to capture the views of the users, we developed appropriate research tools such as questionnaires that either form the basis for moderating discussions in workshop focus groups and semi-structured interviews, or are used directly for online feedback from targeted users.

2. METHODOLOGICAL FRAMEWORK

In order to meet the BIMERR objectives, user requirements that form the basis for the definition of the BIMERR tool architecture, are produced. Several tools such as templates and questionnaires have been produced in coordination with the consortium partners, and subsequently used either by the pilot partners in the context of the Living Labs for moderating discussions with the targeted user groups during especially organized focus workshops, or for online feedback from user groups. Details about the employed methodology are provided in the next section.

2.1 METHODOLOGY

The BIMERR solution addresses many aspects of the renovation process (see section 3) and at the same time involves many different stakeholders (end-users and main beneficiaries). As described before, the Living Lab approach adopted by BIMERR, engages end-users from the early stages of any new idea cultivating motivation to share and discuss experiences as well as requirements. In this context, building upon the user-driven approach of Living Labs, the first step of the requirements elicitation process was the definition of BIMERR end-users.

After extensive internal discussions with the BIMERR pilot partners [1], the total number of BIMERR tools end-users was identified. The characteristics of this group of end-users were rather diverse and their potential interaction with BIMERR tools differed significantly, indicating the complexity of the requirements' elicitation process. Hence, two of the earlier decisions for targeting the complexity of such a problem, were a) grouping the end-users into main user groups and b) choosing the design thinking method [3] for the early interactions of the Living Lab members in the context of Workshops.

2.1.1 Grouping the end-users into Main User Groups

As will be described in section 4, residential building renovation projects follow a multi-phase, multi-step process where each phase/step involves different roles and professionals (from project managers to construction site crews and building owners), while BIMERR targets each of these roles with a different cluster of tools and applications. Hence, the process of grouping the end-users into Main User Groups was based on the homogeneity of the work challenges as well as work environment of each end-user involved in the building renovation process. Figure 1 outlines the methodology of targeted questions that was adopted for the discussions among the BIMERR consortium partners, and finally led to the specific grouping described in section 5.

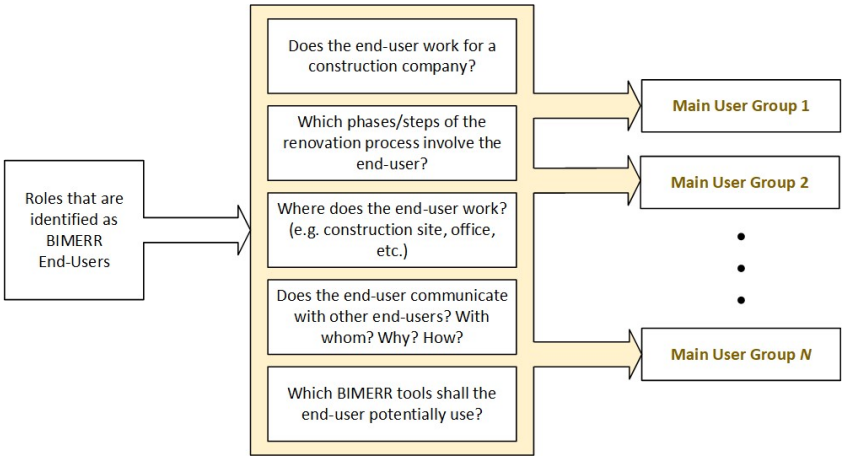


Figure 1: Grouping BIMERR end-users to Main User Groups

2.1.2 The Design Thinking method for the Workshops

This method was chosen to conduct the requirements workshops during the early stages of the project. Design thinking is a five-step method of creative problem solving [4]. Its aim is to create innovative products or services based on a deep understanding of users' problems and needs.

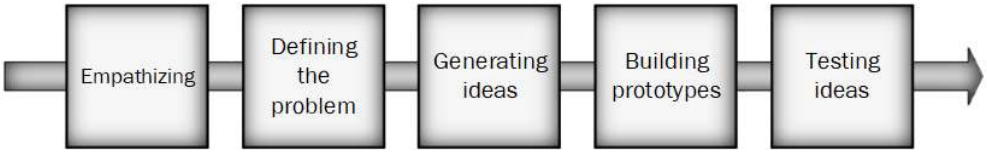


Figure 2: Five steps of Design Thinking method

In the context of BIMERR, specific design thinking exercises (section 6.1.1.1) were created around the BIMERR objectives and end-users' needs. The exercises were designed and conducted by BIMERR consortium pilot partners that had the necessary expertise.

The approach of Design Thinking attempts to step into the shoes of BIMERR tool users and describe each stakeholder involved in the renovation process. In order to achieve this goal, participants create a user archetype and empathy map - social and economic information with demographic characteristics and what encourages him/her to work, as well as more detailed information about thoughts and experiences for benefits and problems related to renovation with BIMERR.

In parallel, extensive discussions with project partners (pilot and technical) drove the elaboration of the high level business scenarios that target the needs of construction companies during renovation projects, and their first analysis into sixteen *use cases* (section 4.3) that outline the high level functionalities offered by the project's ICT-enabled renovation process.

Subsequently, the characteristics, needs and motivations of BIMERR *main user groups* were further analyzed and requirements elicitation techniques were followed as the first step of any requirement engineering approach. Two traditional requirements elicitation techniques [5] were organized:

a) requirements workshops
b) online surveys

Both were supported by carefully structured questionnaires that were derived with the help of the technical partners to reflect their information needs.

2.1.3 Questionnaires

In order to record the needs of the *main user groups*, seven questionnaires were produced, each targeting a different *main user group*.

The methodology for the production of the questionnaires was the following:

- The use cases were analysed to the point that each main user group could be potentially associated with a set of BIMERR tools.
- A template was produced that included the aforementioned mapping information grouped per main user group (see Annex 2). This way, BIMERR consortium partners and especially technical partners, would be able to navigate themselves into the necessary interactions with the specific main user groups, before going to the BIMERR solution development phase.
- The template was circulated to all the technical partners and they produced relevant questions for their tools for each main user group, where applicable.
- All the feedback was processed in order to avoid overlapping questions and produce a homogeneous and coherent list of questions for each main user group.
- Two versions of the questionnaires were produced:
    a. one version with almost all the questions, in order to be used by moderators during requirements workshops [6]
    b. and a second more processed version, in order to be used for online surveying [7]. This version included mainly
        - closed-ended questions, i.e. multiple-choice of either single-answer or multiple-answer type and
        - semi closed-ended questions, i.e. questions that apart from fixed choices offered the option to add personal comments and text.

    This kind of questions were easier to use online; offered faster responses as well as a more structured post-processing. Additionally, many questions were altogether rewritten in a more popular rather than technical manner; this way participants without special technical

knowledge (ICT, construction related, etc.) were also comfortable to answer (see Annex 3 for excerpts of the questionnaires used).

The second version of the questionnaires was used to produce an online-survey available via the official website of BIMERR[1], targeting the BIMERR Living Lab members. Targeting the two pilot countries specifically, the questionnaires were also translated to Polish and Spanish, and the results from all the online questionnaires were statistically processed.

2.1.4 Requirements Workshops

Requirements workshops were organized for collecting additional and detailed information on end-users requirements; the participants were representatives of the main user groups and members of the BIMERR Living Lab. The workshops were organized by the BIMERR pilot partners in the context of the Living Lab activities, and involved:

- introduction to the project concept so the participants could follow the relevant discussions
- semi-structured discussions loosely following the workshop questionnaires [6] driven by moderators
- design thinking exercises
- brain storming sessions where poster charts of the BIMERR concept are placed on walls and participants were able to express themselves with comments on post-it notes (participants of the same *main user group* used post-it notes of the same colour).

It should be pointed out that the workshop questionnaires were translated to both Spanish and Polish in order to help the workshop moderators as well as the participants.

Instead of having a time limited requirements phase for all end-user requirements to be finalized, an iterative methodological approach was adopted to increase the quality and validity of the produced results. During the first iteration (M06) the user requirements were produced based on a workshop organized by the pilot experts in Poland. The next iteration (M11) provided an update and was based on three additional workshops; two were hosted by the pilot partners in Spain and one in Poland. The third and last iteration (M18) reflected the feedback from online questionnaires.

In this context, the feedback from the end-users was gathered at different iterations and this iterative methodology enhanced the credibility of the produced user requirements since it was based on multiple 'space' and 'time' samples, i.e.

[1] https://bimerr.eu/

feedback during different phases of the project, as well as feedback from different participating countries.

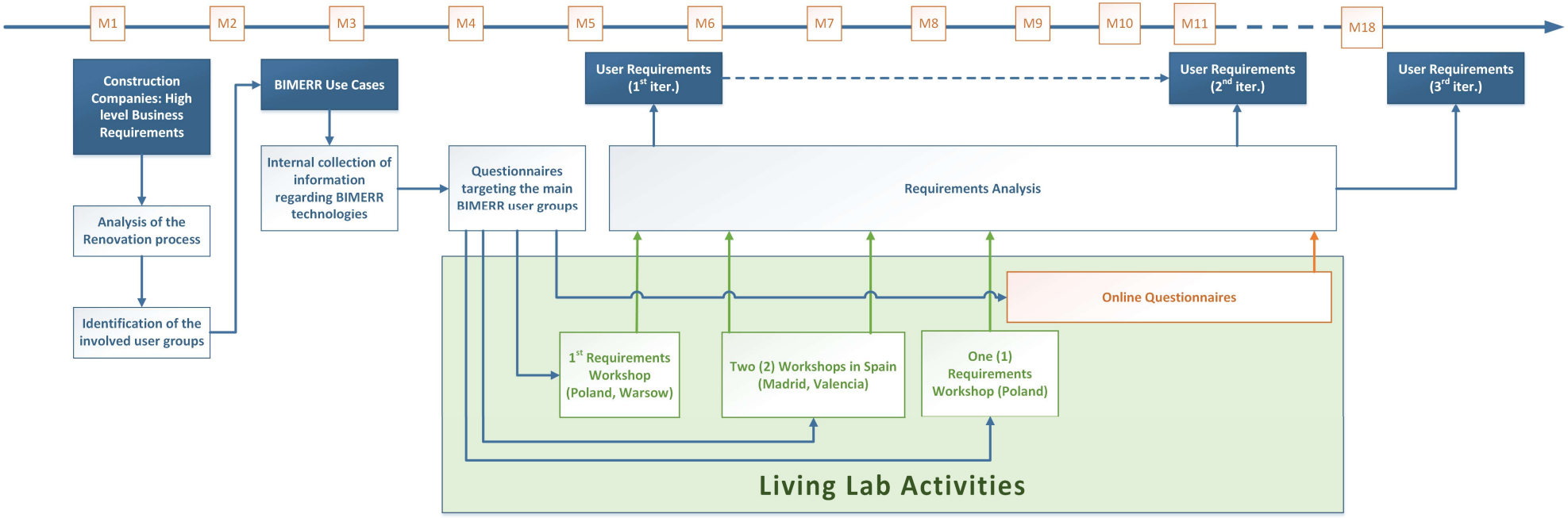


Figure 3: Timeline of the requirements elicitation methodology followed in T3.1

Figure 3 provides the timeline of the overall methodology described so far and is summarized as follows:

- Analysis of the renovation process and the involved stakeholders [8]
  The analysis presents the different steps during a renovation process and describes the corresponding/involved user roles. It is based on the expertise of the construction partners.
- Analysis of Business Scenarios
  The targeted business scenarios are based on the DoA and consultation with the technical partners and the pilot site stakeholders.
- BIMERR Use Cases
  Based on the proposed Business Scenarios, several use cases are identified. The aim is to describe a list of system use cases that highlight the main principles of the BIMERR tools and hence, an appropriate subset can be tested during the pilot trials**.** The use cases are defined after consultation both with the technical and the pilot partners of the project.
- Questionnaires
  After the definition of the Use Cases, a set of questionnaires is prepared, each targeting and trying to capture the needs of the different BIMERR users. This is also part of the goal to engage the different users in the context of the Living Labs, both with workshops in the two pilot countries and online surveys, in order to capture their feedback.
- User requirements
  In this last step, the results from the questionnaires analysis are mapped onto BIMERR user requirements. The prioritization of end users requirements is also produced, setting the initial guidelines for the design and development of the BIMERR platform.

The iterations are mainly performed during the last two steps.

3. RENOVATION PROCESS

The following sections present a description of the steps during a renovation process provided by the expert construction partners. It should be mentioned here that not all steps and phases are present in the different renovation projects.

The renovation process analysis drives the formulation of the use cases, provides a preliminary list of the BIMERR stakeholders and is a starting point for the modeling activities in WP6.

Figure 4 shows an outline for the renovation process, while the respective steps of each phase are presented in the following sections, i.e. sections 3.1-3.7 provide the general outline and a short description of the traditional approach regarding the renovation process as it is currently followed by the consortium pilot partners, while section 3.8 briefly discusses the high level innovations that BIMERR introduces to the renovation process. It should be noted that each pilot country follows a somewhat different process regarding renovation projects. For this reason, Table 1 is provided in order to indicate the applicability of each step to the three pilot countries participating in BIMERR.

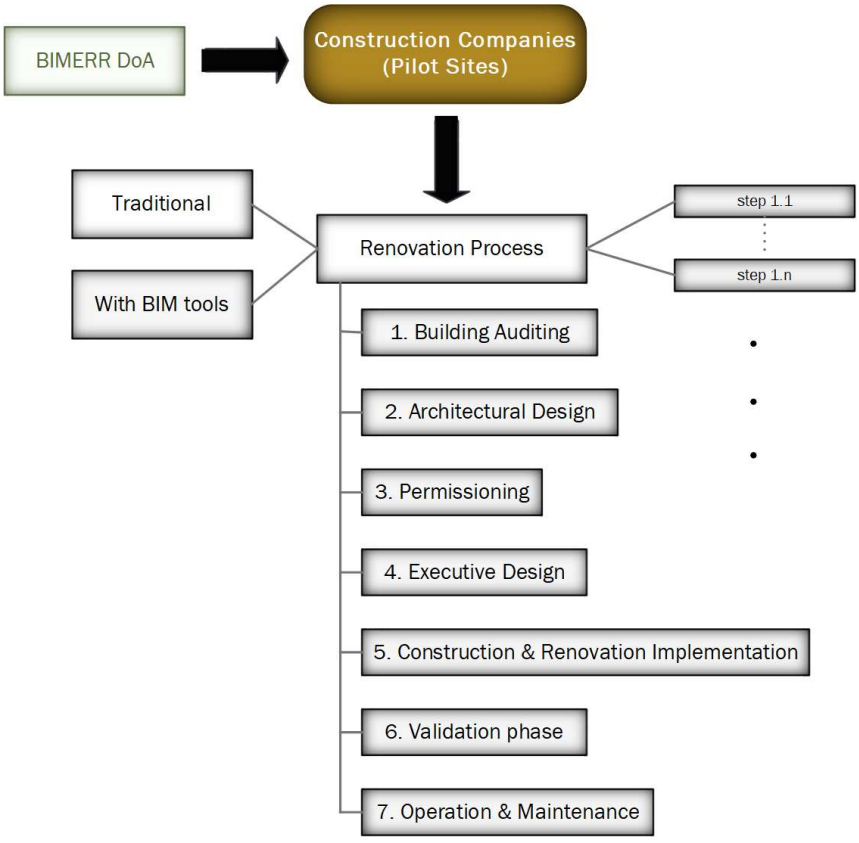


Figure 4: High level analysis of the renovation process into phases

3.1 PHASE 1: BUILDING AUDITING

The first phase of the renovation process involves 6 steps:

Step 1.1: On-site Inspection of the building and surrounding context
During this step the visual inspection of the building conditions is carried out, i.e. inspection of existing materials and components, inspection of the building structure, inspection of heating/cooling systems, electrical, plumbing etc. This process leads to the identifications of building problems and an initial definition of renovation strategies targeting the energy efficiency of the building.

Step 1.2: Legislation and Public Offices
During this step all the restrictions imposed by the Heritage Conservation are identified and the official documentation of the building to be renovated is retrieved.

Step 1.3: Technical survey
This step can be performed in two ways, depending on whether or not BIM-based solutions are available.
In this step the as-is CAD drawings of the building to be renovated are derived. For the conventional way, drawings are based on existing documentation, manual measurements and photogrammetry survey.
If BIM-based solutions are to be used, this step involves defining the Level of Detail (LoD) of the BIM model, the 3D laser scanning of the existing building (indoor/outdoor), the data cleansing process and finally the actual creation of the BIM model with the agreed LoD.
Structural analysis (if required) is also included in this step.

Step 1.4: Technical Specification
This step defines different actions depending on the available BIM-based solutions. The conventional processes include the description of the building structure and materials as well as their technical characteristics. On the other hand, the BIM-based approach involves all the necessary adjustments of the BIM model, along with its enrichment with data regarding materials and components.

Step 1.5: Energy certifications and auditing of the building

Step 1.6: Surveys
In this step a survey targeting the building users (owners, occupants, and facility managers) is held in order to identify their needs and expectations.

3.2 PHASE 2: ARCHITECTURAL DESIGN OF THE RENOVATION

The second phase of the renovation process involves 9 steps.

Step 2.1: Energy efficiency objectives of the renovation

In this step the objectives for the renovation project are defined. Different renovation scenarios are derived along with their budget planning and ROI. The owner (client) approves the renovation strategy that is to be followed.

Step 2.2: Architectural design

This step can again be executed in two ways depending on the available tools. In the conventional method the final architectural project is produced with CAD tools, where the architect incorporates the renovation decisions of previous step, while in the BIM-based approach this step is carried out with the appropriate BIM tools. There is also the option to perform semi-steady or dynamic simulations of the proposed renovation solution in order to verify the predefined energy-efficiency objectives.

Step 2.3: Rehabilitation of existing building structure

If existing building is qualified to perform structural rehabilitation, the structural design (with all needed analysis, simulations and calculations) of the existing building is elaborated. Again, this step execution method depends on the availability of tools (CAD or BIM).

Step 2.4: Preliminary Mechanical, Electrical and Plumbing (MEP) Design

In case of complex renovation of the building there is a need to optimize and improve or replace mechanical, electrical and plumbing systems. The involved engineer needs special building permissions related to different systems. This step produces the preliminary MEP design based on the architectural model.

Step 2.5: Integration of renewable energy solutions

The architectural model is updated to consider (if any) renewable energy solutions.

Step 2.6: Hygrothermal analysis

In this step the hygrothermal analysis of buildings components (walls, roofs, etc.) is performed.

Step 2.7: Thermal bridge analysis

In this step, calculations and corrections of thermal bridges are performed using Finite Element Method (FEM) simulation.

Step 2.8: Energy simulation of the renovation solutions

The renovation solution is examined with respect to energy efficiency, using either semi-steady or dynamic simulations.

Step 2.9: Integration of the design into the BIM model

In this step, the architectural design from Step 2.2 is implemented in BIM model.

3.3 PHASE 3: PERMISSIONING

The permissioning phase of the renovation process is different among the three pilot countries.

In *Poland* permissioning is not required for buildings up to 25 m, when it comes to renovation excluding their partitions and construction elements and the reconstruction that requires arrangements in terms of fire protection; due to this act, things like insulation and window replacement can be provided without permission. In this case it is necessary just to communicate to the Technical Office that renovation works will be carried out.

For buildings higher than 25 m or in buildings where substantial modifications (e.g. building volume extension) will be performed, it is necessary to submit the Renovation project to the Technical Office and obtain building permission. To get the application to building permit there is a need to prepare information about health and safety conditions, When it comes to historical monuments renovation, due to the Act on the Protection and Care of Monuments all works connected with the building and its surroundings must be accepted by Voivodeship Monuments Conservator, before submission and application to construction permission or official information about construction works. There is a need to get a permission to provide works in historical monument as well as in surroundings of the monument.

In *Spain* there is a two-step process: request of authorization and approval.

In *Greece*, any construction work, such as the erection, modification and restructuring of buildings/facilities, requires the prior issue of a building permit and in certain cases specific planning permission. This can be achieved after the inspection from several authorities, including but not limited to: Forest inspection, Archeology inspection, Architectural Committee inspection (specific cases), Aviation Authority / Port Authority inspection (specific cases). Prior to the building permit, the owner should get the Building Certificate. This is a Certificate that gives the owner the right to build according to the terms and conditions that will allow the issuing of a building permit. This Certificate is valid for one year.

Additionally, an Energy Performance Certificate must be issued before commissioning. As far as renovation projects, the Energy Performance Certificate is mandatory after the completion of major renovation of building or building units.

Finally, an Environmental License is also required in the context of Greek legislation. In order for renovation project to be carried out, the impact on the environment should be examined with an environmental impact study that is submitted to authorities for approval.

3.4 PHASE 4: EXECUTIVE DESIGN OF THE RENOVATION

The next step of the renovation process is the executive design. It's a detailed design project based on architectural but extended to construction details and technical solutions used in the architectural project. This phase can be divided into four steps:

Step 4.1: Executive design of the project

It is either carried out with CAD, or with BIM tools. It is important to create a BIM model that it can be used during the construction phase of the renovation process.

Step 4.2: Elaboration of construction details (CAD or BIM)

In this step, the executive design is elaborated by providing detailed specifications of construction elements (for example construction connections, layers connection, detailed information about anchoring, specified reinforcement in concrete, construction cantilevers, etc.)

Step 4.3: Cost estimation of the renovation solution

The cost estimation of the renovation solution is prepared on the basis of executive design. The cost estimation considers quantity take-off, cost of material, machines and working crew. It depends on types of planned work and used materials.

Step 4.4: BIM execution plan

3.5 PHASE 5: CONSTRUCTION AND RENOVATION PROJECT IMPLEMENTATION

The fifth phase of the renovation process is analyzed in 17 steps:

Step 5.1: Site utilization planning

In this step, the decision making process for determining the location of temporary facilities within the boundary of a construction site is performed. It is important to identify spatial relationships and develop the best alternative solutions, so that the efficiency of the construction process is improved over the project life cycle. Examples of temporary facilities associated with construction projects include: laydown areas, unloading areas, material paths, staging areas, personnel paths, storage areas, prefabrication areas, work areas, tool and equipment areas, debris paths, hazard areas, and protected areas.

Step 5.2: Schedule and budget planning

During this step, there is a need to determine scope of the project and then analyze the potential work. It is critical for all stakeholders and decision makers engaged in the process to be aligned on the final design before starting the construction

work. Once there is a sign off, a list of required materials is created. At the end of this step, the budget and timeline is finalized.

Step 5.3: Health and safety planning and assessment

The health and safety protection plan is drawn up by the site manager before the construction begins. The construction manager may also commission the preparation of a plan, but he/she is officially responsible to provide H&S plan.

The H&S plan manager prepares the relevant information, which is part of the construction project. He/She also takes into account the specificity of the building and the conditions for carrying out construction works.

Step 5.4: Maintenance planning of the construction site

Step 5.5: Waste management

The company should have a general waste management plan that includes general and dangerous types of waste. In order to determine the final scheme of the Waste Management Plan for the construction site, an environmental protection specialist determines along with the construction manager what kind of waste is expected to be produced and what are the possible ways of its management permitted by the law. Due to the fact that environmental issues are regulated in the H&S Plan, it has to be approved by a specialist in environmental protection, employed within the construction company.

Step 5.6: Logistics planning

Having ready the work schedule, it is possible to create a logistic plan of the materials delivery and machines works. This plan is revised and adjusted each week during technical meetings with the construction crew, in order to optimize works at the construction site.

The logistics schedule should be prepared immediately after taking over the contract for implementation and should be in line with the schedule of construction works. The logistics schedule specifies the deadlines for submitting an offer, signing contracts with suppliers as well as the deliveries themselves.

Step 5.7: Materials and components orders
According to the Logistic plan of Step 5.6, the materials and components have to be ordered and delivered on site.
Step 5.8: Manufacturing of renovation components

There are two ways, either renovation components can be manufactured on the construction site or can be purchased as prefabricated items.

Step 5.9: Components delivery and storage
According to the Logistic plan of Step 5.6 and in parallel with Step 5.7, the delivery of materials and components will be done according to the schedule of work.
Purchased goods, products and services should be assessed in terms of their compliance with the requirements defined by the investor. There should also be a quantitative quality control, compliance of delivery with the order and receipt of necessary approvals and documents confirming material properties.
A list of persons authorized to order, accept and confirm delivered materials should be prepared.

Step 5.10: Cost control, choice of the subcontractors
Choosing of a subcontractor depends on many aspects such as experience, references and specialization. The company, which has many projects, has the appropriate knowledge and experience to anticipate and avoid risks.
When it comes to cost control, there is a need to revise and control all cost related to the construction site. Cost control is done by:

- monitoring of planned cost in relation to the real one
- analysis of the reasons for deviations of planned outlays (prices, quantities)

Step 5.11: Planning of construction works
Planning of the construction works is done in parallel and it is continuously revised in order to effectively complete the work.

Step 5.12: Construction work execution according to the renovation project
Architectural and structural works, installations, demolition work.

Step 5.13: Inspections during the construction
Quality control, audits, monitoring of construction progress, etc. It should be pointed out that in several cases independent inspections are also required.

Step 5.14: Installation of additional equipment installation
During this step, auxiliary equipment such sensors, IoT devices and meters are installed in the building under renovation.

Step 5.15: Preparatory activities for renovation solution installation
These are additional activities that are not however carried out for every renovation project.

Step 5.16: BIM execution plan monitoring and updating

The BIM model is continuously updated throughout the renovation works, so the as-built model of the renovated building could be properly delivered at the end of the project.

Step 5.17: As-built project
This step is about documentation, i.e. collection of documents which form the so-called as-built project documentation which consists of a building permit accompanied by building permit documentation, a building log book, protocols with acceptance of partial and final works.
The as-built project documentation includes also all the applied changes that were made during the construction works along with geodesic documentation and recorded as-built geodetic measurements and data.

3.6 PHASE 6: VALIDATION PHASE

The sixth phase of the renovation process involves 3 steps. Specifically,

Step 6.1: Testing and commissioning
This step can be carried out both by the construction company and by independent companies.

Step 6.2: Energy Certification
Energy auditing to determine the primary energy demand of the building after performing renovation works.

The obligation to have a property energy performance certificate (commonly an energy certificate, energy passport) results from European law. Obligations of the Member States of the European Union enshrined in Directive 2002/91 / EC.

The basis for preparation of the integrated characteristic is the energy performance of the building, as specified in the construction design.

Energy performance is a collection of data and energy indicators of a building regarding the building's calculated energy demand for central heating, hot water, ventilation and air conditioning, and in the case of a public building also for lighting.

Step 6.3: Additional testing
In this step, more additional testing can be performed such as thermal imaging and blower door test

3.7 PHASE 7: BUILDING OPERATION AND MAINTENANCE

Step 7.1: BIM model – O&M

The Table 1 presents the applicability of all the renovation steps for each pilot country.

Phase	STEP ID	Steps	Pilot Spain	Pilot Poland	Pre-Pilot Greece
1 Building Auditing (Technical and legislation survey)	**1.1**	**On-site Inspection of the building and surrounding context**:	yes	yes	yes
	1.2	**Legislation and Public Offices**	yes	yes	n/a
	1.3	**Technical survey**	n/a	yes	yes
	1.3a	**Technical survey (BIM-based renovation process):**	not common	not common	no
	1.4	**Technical specification**	not common	not common	yes
	1.4a	**BIM Model Refinement and Finalization (BIM-based renovation process)**	not common	not common	yes
	1.5	**Energy certifications and auditing of the building**	yes	yes	no
	1.6	**user surveys (identify what the users need or want)**	not common	not common	no
2 Architectural Design of the Renovation	**2.1**	**Define objectives for the energy efficiency and strategy for the renovation (different scenarios); budget planning and ROI for each scenario. Define with the owner the renovation strategy + validation of the client**	yes	yes	n/a
	2.2	**Architectural Design (with CAD tools)**	yes	yes	yes

Phase	STEP ID	Steps	Pilot Spain	Pilot Poland	Pre-Pilot Greece
	2.2a	**Architectural Design (BIM-based renovation process)**	not common	not common	n/a
	2.3	**Rehabilitation of existing building structure** (if required)	yes	yes	yes
	2.3a	**Rehabilitation of existing building structure** (if required)	not common	not common	n/a
	2.3b	**Rehabilitation of existing building structure** (if required)(BIM-based renovation process)	yes	yes	n/a
	2.4	**Preliminary Mechanical, Electrical and plumbing (MEP) Design** (if changed)	yes	yes	yes
	2.5	**Integration of renewable energy solutions**	yes	not common	n/a
	2.6	**Hygrothermal analysis**	not common	not common	n/a
	2.7	**Thermal bridge analysis**	yes	yes	n/a
	2.8	**Energy Simulation with renovation solution**	not common	not common	yes
	2.9	**Integration of the design into the BIM model**	n/a	n/a	yes
3 Permissioning	**Different processes depending on the pilot country**		yes	yes	yes
4	**3.1**	**Executive design of the project in CAD**	yes	yes	yes

Phase	STEP ID	Steps	Pilot Spain	Pilot Poland	Pre-Pilot Greece
Executive Design of the Renovation	**3.1a**	**Executive design of the project in CAD/BIM (BIM-based renovation process)**	yes	not common	yes
	3.2	**Elaboration of construction details in CAD**	n/a	yes	n/a
	3.2a	**Elaboration of construction details (BIM-based renovation process)**	yes	yes	n/a
	3.3	**Cost estimation of the renovation**	yes	yes	n/a
	3.4	**BIM execution plan**	no	no	yes
5 Construction and Renovation Project Implementation	**5.1**	**Site utilization planning**	n/a	n/a	yes
	5.2	**Schedule and budget planning**	yes	yes	yes
	5.3	**Health and safety planning and assessment**	yes	yes	yes
	5.4	**Maintenance planning of the construction site**	yes	n/a	yes
	5.5	**Waste management**	yes	yes	yes
	5.6	**Logistic planning**	yes	yes	yes
	5.7	**Materials and components orders**	yes	yes	n/a
	5.8	**Manufacturing of renovation components**	yes	yes	yes
	5.9	**Components delivery and storage**	yes	yes	yes
	5.10	**Cost control, choice of the subcontractors**	yes	yes	n/a
	5.11	**Planning of construction works**	yes	yes	n/a

Phase	STEP ID	Steps	Pilot Spain	Pilot Poland	Pre-Pilot Greece
	5.12	**Construction work execution according to the renovation project**	yes	yes	yes
	5.13	**Inspection during the construction (quality control, audits, monitoring of construction progress, etc.)**	yes	yes	n/a
	5.13a	**Independent Inspection**	yes	yes	n/a
	5.14	**Additional Equipment installation (e.g. sensors, IoT equipment, etc.)**	n/a	yes	yes
	5.15	**Preparatory activities for renovation solution installation**	no	no	yes
	5.16	**BIM execution plan monitoring and updating**	no	no	yes
	5.17	**As-built project**	n/a	yes	n/a
6 Validation phase	**6.1**	**1a) Testing and commissioning (by the construction company)**	n/a	yes	yes
	6.1a	**1b)Testing and commissioning (by independent company)**	n/a	yes	n/a
	6.2	**Energy Certification**	n/a	yes	n/a
	6.3	**Testing with Thermal imaging and Blower - Door Test (in case of deep renovation)**	n/a	not common	n/a
7 Building Operation and Maintenance	**7.1**	**BIM Model- O&M**	n/a	n/a	yes

Table 1: Applicability of each step of the renovation process to the pilot countries involved in BIMERR project.

3.8 INNOVATIONS IN RENOVATION PROCESS INTRODUCED BY BIMERR

The following sections highlight the different innovations that will be introduced by BIMERR in the renovation process.

3.8.1 Building auditing

Traditionally, in this step of the renovation process the focus is mainly on capturing the geometry of the building to be renovated. Designs and reports are produced describing building conditions.

BIMERR introduces advanced Scan-to-BIM techniques enabling *reality capture*. Walls, floors, windows, false ceilings, radiators and many more internal and external features of the building to be renovated are to be accurately captured and automatically introduced in an enhanced BIM model.

Furthermore, BIMERR envisages the capturing and representation to the BIM model of many more details concerning the building, such as energy related equipment (e.g. air-conditioners), hidden building components (e.g. pipes behind walls) or even details that only occupants and/or building managers know (e.g. hidden humidity issues).

3.8.2 Architectural/Executive Design of the Renovation

In this phase of the renovation process the energy efficiency objectives of the building set by the owner/real estate manager, are targeted via a set of proposed renovation changes. Traditionally, designers (architects, engineers) use CAD tools to produce architectural designs according to pre-defined objectives following a set of fixed generic renovation solutions.

BIMERR builds upon the enhanced BIM-model of the previous phase and optimizes this one with respect to energy efficiency and cost. BIMERR offers the designer tools that

- access advanced databases with new materials, components and energy systems; all properly modelled and extended to enable the LCA-LCC assessment.
- allow accurate simulations of any post renovation scenario taking into account the actual energy behavioural profiles of the building occupants.

This way, the designer can perform multiple simulations, examine different solutions that finally make a proposal that benefits all the involved parties.

3.8.3 Planning the Renovation Project

The main focus and innovation of BIMERR lies in the planning process of renovation projects. BIMERR offers workflow automation tools that support project manager activities from the initial cost and time estimation of the project at hand, to the automated scheduling and constant updating of all relevant activities (e.g. orders, deliveries, etc.). The planning activities are further facilitated by the automated information (e.g. drawings, site investigations, reports etc.) exchange between the involved parties (local authorities, vendors, subcontractors, etc.) in a transparent and integrated way.

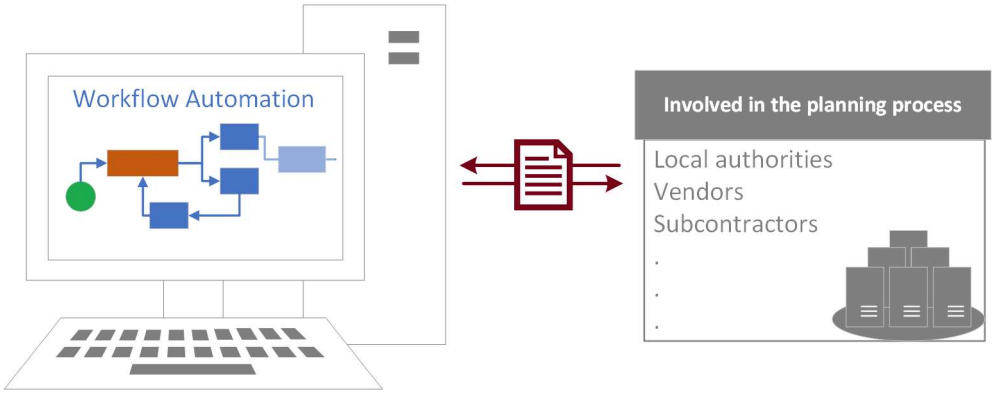


Figure 5: Process/workflow modelling and automation

3.8.4 Construction and Renovation Project Implementation

In this phase construction works take place. BIMERR supports the on-site stakeholders (workers, foremen, site engineers) with tools that expedite work progress monitoring and reporting, enhance collaboration, and increase workforce and occupants' safety during renovation works. The tools include Augmented Reality enabled applications on smart glasses and mobile devices applications for

- display of an interactive 3D building model in Augmented Reality
- task management for execution of construction and repair works
- communication of critical information regarding hazards, component availability, deviations for initial construction plans, work progress, etc.
- context-aware instructions/guidance.

4. BIMERR BUSINESS SCENARIOS AND USE CASES

4.1 BIMERR BUSINESS SCENARIOS

An initial list of Business Scenarios is defined in order to screen the landscape for the BIMERR framework. A list of **five Business Scenarios** is defined after consultation with pilot partners and taking into account the main objectives of the project:

- BS1: Construction companies and/or architectural studios to reduce time and cost of renovation projects design procedures
- BS2: Construction companies to reduce the time and cost of project planning processes (from permissions to materials order) through standards-based communication with all involved stakeholders
- BS3: Construction companies to reduce time and cost during renovation and commissioning works
- BS4: Increase workforce and occupants' safety during renovation works
- BS5: Construction companies and/or architectural studios to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model

These high-level scenarios in conjunction with the pilots further lead us to the definition of the main use cases for the project.

4.2 BIMERR MODULES

Prior to the detailed use case analysis, we provide a list of BIMERR modules as derived from the DoA. This high-level review of the basic modules will further facilitate the presentation of use cases in the following section.

BIMERR modules
1. BIMERR Interoperability Framework (BIF) a. Building Info Query Builder b. Building semantic modelling tool c. Building info secure provision component 2. Digital Building Model Creation Tools a. Scan-to-BIM b. ARIBFA i. BIM 3D Model Registration and Tracking Module ii. Indoor Localization Module iii. Marker-less Feature Recognition Module iv. AR Annotation & Context Aware-Visualization Module c. PRUBS d. Building Information Collection Application (BICA) 3. Renovation support tools a. RenoDSS i. Building Energy Performance Estimation module ii. Building Components and Systems Database iii. Urban Planning module iv. Life Cycle Cost/Life Cycle Assessment module 4. Process & Workflow Modelling & Automation (PWMA) a. Process modelling tools b. Work-flow automation tools & on-site guidance 5. BIMERR middleware

Table 2: BIMERR system components

4.3 USE CASES DESCRIPTION

A detailed description of BIMERR Use Cases is provided focusing mainly on the definition of functionalities. A template has been selected as a tool for the description of the BIMERR Use cases (see Annex 1). Following this common template, the consortium partners contributed in the composition of the final list of use cases.

4.3.1 UC-01: Rapid scanning of the geometry of the building, semantic modeling and accurate representation in a BIM

BIMERR Use Case 1	
UC ID	UC-01
Use Case Name	Rapid scanning of the geometry of the building, semantic modeling and accurate representation in a BIM

Related Business Scenario(s)	BS1: Construction companies and/or architectural studios to reduce time and cost of renovation project design procedures
Description	Surveyors shall be able to rapidly capture information about the building geometry in order for BIM modelers to significantly accelerate the creation of accurate and semantically-rich building models. These models must contain all necessary information for the design team (architects, engineers) to proceed with the design of the energy renovation project. The model delivered by the Scan-to-BIM process should thus contain the building structure, and building components of particular value to effective energy renovation design.
Involved Stakeholders	Surveyor, BIM Modeler
BIMERR components involved	Reality Capture Solution, Scan-to-BIM, BIMERR Interoperability Framework (BIF), BIM Platform
Pre-conditions	Availability of the required equipment (3D laser scanning tools, thermographic cameras) is needed. The methodology for Reality Capture and the algorithms for automatic Scan-to-BIM need to have been identified prior to the use case implementation.
Use Case Path	The surveyor responsible for the building auditing and inspection performs rapid scanning of the geometry of the building. The BIM modeler proceeds with the accurate representation in a BIM-model in order to reduce manual interventions and corrections. The surveyor uses the Scan-to-BIM tool and the Reality Capture Solution, based on laser scanning and thermal/color images to extract geometric data, as well as, identify key building elements and components (e.g. walls, doors, windows, radiators). With the utilization of fine-grained Scan-to-BIM algorithms, the resulting information is transformed into BIM models. The BIM modeler validates the resulting models and through an easy to use User Interface performs the semantic enhancement of the BIM. The semantically enhanced model can be then fed to a BIM management platform for further processing and utilization in

	the frame of alternative functions and steps involved in the renovation process.
Post Condition	The Building Information Model of the building to be renovated is made available in the BIM platform and contains information about the building structure and secondary components relevant to energy analysis and renovation design.
Business Impact	A key stepping stone to the application of BIM-based tools that will contribute to the reduction of time, cost and uncertainty in the renovation process. An automation of the process of taking data by scanning minimizes human error and represents a model with greater fidelity to the current state.
Realization Description	
Leading Partner	UOE
Contributing Partners	FIT, Exergy, Suite5, UBITECH
Priority	High

4.3.2 UC-02: Accelerate the collection of data about the building systems through BIM-based internal audit support tools and interaction with building managers and occupants.

BIMERR Use Case 2	
UC ID	UC-02
Use Case Name	Accelerate the collection of data about the building systems through BIM-based internal audit support tools and interaction with building managers and occupants.
Related Business Scenario(s)	BS1: Construction companies and/or architectural studios to reduce time and cost of renovation projects design procedures
Description	Apart from the geometry and key elements of the building that can be extracted through the application of Scan-to-BIM concepts and approaches, a key prerequisite for obtaining a complete picture of a building (and its energy performance) prior to the launch of the renovation project, is the identification and mapping to the BIM of the main building

	systems (heating/ cooling, ventilation, etc.) and networks (pipes, cables) that may be even hidden behind walls. This information is really critical for a renovation project since it will provide valuable input to workers towards safely and properly performing the renovation works and avoiding either incidents/ damages to the backbone infrastructure of the building or accidents caused (by drilling a gas pipe or cutting an electricity line cable).
Involved Stakeholders	Building surveyor, Building occupant, Building manager
BIMERR components involved	HMD-AR glasses and ARIBFA (BIM 3D Model Registration and Tracking Module, Indoor Localization Module, Marker-less Feature Recognition Module, AR Annotation & Context Aware-Visualization Module), BICA, BIMERR Interoperability Framework (BIF), BIM platform
Pre-conditions	A pre-designed BIM is already available in a BIM management platform either by the pre-existing data of the building or through rapid Scan-to-BIM, as described in UC-01.
Use Case Path	The building surveyor/engineer walks through the building and with the use of appropriate equipment (e.g. **HMD-AR** glasses) and applications, accurately maps and annotates in a (semi)automatic manner, energy related equipment, their characteristics and other related hidden components within the building. In this way the BIM model is updated with the relevant information, while additional areas of failure or concern may be annotated and highlighted and uploaded in the BIM model thereafter. The AR application includes an ***Indoor Localization Module*** which will be responsible to determine the user's indoor location and subsequently locate all the mapped characteristics of the building in their actual position. Moreover, when requested, the occupants of the building and/or the building managers (having better knowledge of their building/premises) will be able to upload supplementary data (photos, notes, etc.) to the BIM model, utilizing the **an easy to use** application/User interface. Hence, further input to the BIM is provided thus reducing the time and cost required for multiple site visits of the building surveyor.

	All gathered information will be used to enrich the pre-designed BIM model, accelerating the overall collection of data required for the initial renovation scenario modeling process.
Post Condition	A complete representation of the building (Building Information Model) and its constituent systems and elements is made available in the BIM platform.
Business Impact	Acceleration of the building data collection during the building auditing/ surveying step will significantly reduce the time and cost of the overall renovation process. Also, identifying the existing key energy components of the building, will provide a sound understanding of the building systems and energy requirements producing a near-complete BIM model, which subsequently can be used in the renovation scenario modeling utilizing the RenoDSS tool. The use of infrared thermography will allow the quick identification of thermal diagnostics for the existing building. The existence of complete information about the building systems, even those that are hidden behind walls, can have a significant impact in the avoidance of damages or accidents during renovation works, thus allowing for further avoidance of critical delays or extra investments.
Realization Description	
Leading Partner	CERTH
Contributing Partners	GU, EXERGY, Suite5
Priority	High

4.3.3 UC-03: Adapt design to the actual building use, including accurate information about occupancy and schedules, comfort requirements/ preferences and energy uses.

BIMERR Use Case 3	
UC ID	UC-03
Use Case Name	Adapt design to the actual building use, including accurate information about occupancy and schedules, comfort requirements/ preferences and energy uses.

Related Business Scenario(s)	BS1: Construction companies and/or architectural studios to reduce time and cost of renovation project design procedures. BS5: Construction companies and/or architectural studios to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model
Description	Beyond the static components of a building that can be extracted and modeled by tools using visual information, renovation for energy efficiency also requires detailed information about the energy consumption of the building – and more importantly, information to understand why and how energy is consumed, so that accurate post-renovation consumption projections can be made. Incorporating the behavioral patterns of the inhabitants and their comfort zones, will enable to adapt the proposed design to the actual building usage. Moreover, it will provide a tool to evaluate the different renovation scenarios and select the best scenario considering both current and intended building usage, occupancy requirements and human-centric features related to well-being and comfort.
Involved Stakeholders	Building occupant, Architect
BIMERR components involved	PRUBS, RenoDSS (Building Energy Performance Estimation module), BIM platform
Pre-conditions	Specification and installation of sensors and meters and processing of the gathered data from the installed smart equipment, responsible for the real-time monitoring of different comfort related parameters (e.g. IAQ, Temperature) need to be available. Parameters involved in the evaluation methodology need to be considered. Access of real-time - device level - data is needed to obtain quantitative feedback based on sensor and meter readings. The limitations in data availability (limited sensing equipment, not

	adequate number of users involved to extract accurate results etc.) should be accessed.
Use Case Path	Data streams from IoT devices installed in the building to be renovated will be made available to **a profiling tool** which will perform accurate profiling of building use aspects to generate detailed occupancy and behavior profiles of occupants. Such profiles, are subsequently, fed into a building energy performance simulation tool to provide an estimation of expected post renovation building energy performance, on the basis of specific occupancy schedules and profiles, to properly replace the previously used generic occupancy schedules and occupants' behaviors. This way, simulation of building performance will become more accurate and really adapted to actual behaviors and schedules of building occupants, thus offering the architect a representative prediction for the anticipated performance of the building, under each of the renovation scenarios applied.
Post Condition	Accurate profiles of occupants (energy use, comfort, occupancy) within buildings. Building design based on accurate prediction of post-renovation energy performance and execution of alternative design scenarios (simulation-based). Accurate predictions of the post-renovation energy performance of buildings.
Business Impact	Inaccurate representation of the actual building use is the root cause for the creation of a huge gap between predicted and actual energy performance of renovated buildings. The reason behind the gap creation is the inability of current energy performance simulation tools to address the real schedules and energy use preferences of building occupants (occupancy and behavior) and are mainly based on generic schedules for different types of buildings. The reduction of this gap may have a significant impact in the viability and further penetration of Energy Performance Contracting (EPC) in renovation projects, allowing construction companies to accurately estimate the anticipated post-renovation energy performance of a renovated building and get involved in profitable EPCs that are built on the principle that Construction

	Companies fund themselves the implementation of the renovation project and are getting paid back through the savings achieved in post-renovation operation. Increased accuracy of predictions reduces any uncertainty and risk that are created by the existing gap created by the use of generic schedules in Building Energy Performance Simulation tools (affecting significantly energy savings and respective cash flows) and will enable the realization of highly attractive payback periods and business cases.
Realization Description	
Leading Partner	HYPERTECH
Contributing Partners	Suite5, XYLEM
Priority	High

4.3.4 UC-04: Consider new materials and technologies in any design and simulation activity through appropriately configured BIM-compliant models residing in relevant open repositories (with accurate specification of their impact in energy performance of buildings).

BIMERR Use Case 4	
UC ID	UC-04
Use Case Name	Consider new materials and technologies in any design and simulation activity through appropriately configured BIM-compliant models residing in relevant open repositories (with accurate specification of their impact in energy performance of buildings).
Related Business Scenario(s)	BS1: Construction companies and/or architectural studios to reduce time and cost of renovation projects design procedures. BS5: Construction companies and/or architectural studios to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model

Description	Construction materials have come a long way over the years. From the use of timber and concrete to cigarette butts and cardboard, builders are looking for newer and more effective materials for their projects. Builders are taking advantage of innovative solutions that will reduce the time and cost of designing new structures. To keep up with the trend it is really important that such new materials are introduced in any design and simulation tool to enable the accurate representation of the building and the communication of accurate information to all involved stakeholders (from materials vendors to workers). Such materials need to be modeled in a standardized format to enable their inclusion in design and simulation toolkits and allow these to perform their business functions. Moreover, models need to be enhanced with LCA-LCC attributes to enable the holistic assessment of relevant renovation projects considering the whole lifecycle of a building
Involved Stakeholders	BIM expert, Architect
BIMERR components involved	RenoDSS (Building Components and Systems Database)
Pre-conditions	Detailed specifications on the modeling of new materials (based on existing standards) should be available. LCA-LCC attributes availability for materials should also be available. Building performance simulation tools need to adapt to comply with modeling standards and be able to assess building performance from an LCA-LCC perspective.
Use Case Path	During the configuration of the **Energy Performance Simulation tool**, the Renovation Designer accesses the Building Components Database to ensure that envisaged materials, components and energy systems are available, properly modeled and extended to enable the LCA-LCC assessment needs for the renovation project. In case of absence of a specific component, he/she launches the process for the addition of the missing component through

	a user-friendly and customizable interface (available in the BEPS), which enables the introduction of new "stereotypes" in a standardized format, that can, later on, be "understood" by the BEPS. Such new "stereotypes models" need to reflect the impact of the specific component, as part of an orchestrated operation of the building, in the energy performance assessment performed through simulation, considering, also, an LCA-LCC perspective. Search for such, appropriately modeled, materials is performed over a comprehensive database maintained by BIM experts. In case such a material is not available, a relevant request shall be placed in a friendly UI of the database for its inclusion.
Post Condition	Enlargement of materials and components database that enhance the optimization capabilities of the DSS and accurate representation of the renovation project (design), without any risky assumptions or utilization of materials (models) with similar characteristics.
Business Impact	More accurate representation of a renovation project that can be directly communicated to other stakeholders for the continuation of the renovation process, without any asterisks or notes indicating that some parts of the design are not correct. More accurate prediction of energy performance by avoiding risky assumptions or replacements of non-existing materials with others (that have a similar performance) and could irreversibly affect the simulation result and lead to significant energy performance gaps at post-renovation phase.
Realization Description	
Leading Partner	EXERGY
Contributing Partners	HYPERTECH, XYLEM
Priority	Medium

4.3.5 UC-05: Accurate scheduling of activities and assessment of their efficiency through simulation and verification.

BIMERR Use Case 5	
UC ID	UC-05
Use Case Name	Accurate scheduling of activities and assessment of their efficiency through simulation and verification.
Related Business Scenario(s)	BS2: Construction companies to reduce the time and cost of project planning processes (from permissions to materials order) through standards-based communication with all involved stakeholders.
Description	Optimizing the efficiency of the renovation process in terms of time and cost relies on optimally planning and coordinating the execution of all intermediate steps following the design phase. In this sense, construction companies are in need of optimal tools for re-engineering the business processes linked to a renovation project and assess their efficiency in an evident manner, through modeling and simulation. By optimizing the process they are able to introduce it in workflow automation tools to enable the sequential activation of respective process steps for optimal coordination between all involved stakeholders.
Involved Stakeholders	Project manager
BIMERR components involved	PWMA
Pre-conditions	The architect has selected the best scenario considering both current and intended building usage (UC-03) and the involved activities. Re-engineered process, specially adapted to local constraints. The cost and time constraints should be provided to the project manager by a) occupants, b) building owners, c) construction company.
Use Case Path	Having in hand all existing information for the building (to be renovated) and the final design, the project manager launches the planning of the project activities, aiming at resource and time efficiency.

	He/She imports all the activities in a project management scheduler and receives an initial estimation of anticipated time and costs (simulation-based). Cost and time outliers are highlighted allowing the project manager to re-consider and devise specific parts of the schedule to further optimize the overall efficiency of the project.
Post Condition	An optimized project plan in terms of cost and time efficiency, introducing increased flexibility for addressing unexpected deviations.
Business Impact	The simulation of the construction process will help to visualize the constructive processes and study the solutions in the relevant or difficult points before beginning the work, and hence, it will result in the reduction of cost. The cost of unforeseen works increases as renovation progresses, so the anticipation of such problems leads to a clear reduction of cost and time. The effective simulation of the construction process will reduce the potential problems with neighbors.
Realization Description	
Leading Partner	NOVITECH
Contributing Partners	BOC
Priority	Medium

4.3.6 UC-06: Process automation and execution on a workflow-based approach (exchange of information and documentation on a BIM-based approach) with a sequential initiation of sub-processes, once specific activities have been completed.

BIMERR Use Case 6	
UC ID	UC-06
Use Case Name	Process automation and execution on a workflow-based approach (exchange of information and documentation on a BIM-based approach) with a sequential initiation of sub-processes, once specific activities have been completed.

Related Business Scenario(s)	BS2: Construction companies to reduce the time and cost of project planning processes (from permissions to materials order) through standards-based communication with all involved stakeholders.
Description	Workflow management is key to ensuring the efficiency of renovation project implementation processes, that are characterized by increased complexity and a variety of stakeholders involved. To avoid unnecessary delays, renovation processes need to be supported by appropriate tools that allow for the automatic activation of sequential steps and the communication of the relevant information to each stakeholder for timely performing their assigned tasks.
Involved Stakeholders	Project manager
BIMERR components involved	PWMA
Pre-conditions	Business process and accompanying workflow route needs to have been defined in detail.
Use Case Path	Once project scheduling has been performed, the project manager approves the optimal schedule and introduces it in a Workflow Management and Automation application which will assist her/him to follow the different steps in an automated manner, while monitoring the relevant cost and time indicators. Once the process is initiated in the workflow tool, the whole process and schedule is followed in an automated manner (sending appropriate requests for information to different stakeholders, putting orders for the purchase of materials, delivery of materials on site, sending accompanying documentation for the material specifications, receiving updates, etc.). Moreover, the project manager receives specific alerts for issues that could lead to re-scheduling of the project or the workflow execution and decides ad-hoc on the optimal route for the project implementation.

Post Condition	Automated execution and thorough monitoring of the renovation process to identify inefficiencies, unexpected delays and devise the renovation implementation for increasing its efficiency.
Business Impact	Improve control of the construction process and project delivery efficiency (time and cost).
Realization Description	
Leading Partner	NOVITECH
Contributing Partners	BOC
Priority	Medium

4.3.7 UC-07: Stakeholders' systems exchange appropriate and "understandable" data between each other.

BIMERR Use Case 7	
UC ID	UC-07
Use Case Name	Stakeholders' systems exchange appropriate and "understandable" data between each other.
Related Business Scenario(s)	BS2: Construction companies to reduce the time and cost of project planning processes (from permissions to materials order) through standards-based communication with all involved stakeholders.
Description	Typically, once the executive design is completed, the project management team provides all the information (drawings, site investigations, engineering reports, time plan etc.) to local authorities (local administration – technical office) in order to acquire the building permit for the project (depending on the scale of the works/building). Once the permit is granted, this information is transformed into the tender offer, upon which the subcontractors will provide their quote for undertaking the works, adhering also to the permit's specifications. Vendors will also provide their quotes for services/materials based on the same information. During the actual renovation phase, the above-mentioned information pack is transformed into engineering drawings and passed to

	the site manager and foreman who in turn has to communicate the information to the working crews.
Involved Stakeholders	Project manager, Subcontractor, Vendor/Supplier, Site managers, Foreman, Worker, Architect, Consultant, Material manufacturer
BIMERR components involved	PWMA, BIMERR Interoperability Framework (BIF), BIMERR Middleware
Pre-conditions	The interested stakeholders need to integrate their legacy systems to the standardized interface provided by the BIF. Training of stakeholders.
Use Case Path	The information routing to all stakeholders needs to be facilitated by the **Workflow management tool**, which will implement the different steps of the renovation project process and plan and will automatically provide the appropriate BIM-based information to stakeholders that have "connected" themselves to a "centralized" interoperability platform. Connection to the interoperability platform requires the interested stakeholders to integrate their legacy systems through standardized interfaces that will allow them to receive the required information on the basis of BIM-based semantically interoperable mechanisms. As part of this semantic integration, the platform needs to provide appropriate and user-friendly UIs to the interested stakeholders that will enable them to perform the semantic mapping between their information models and the reference BIM that is utilized in the platform. Once such integration is performed, the renovation stakeholders (AEC professionals), will be able to access (through their legacy systems) appropriate information querying mechanisms to create data queries over the BIM model of the building and retrieve properties that are of interest to the step they are involved. Through secure information provisioning mechanisms**,** being responsible for cross-linking and integrating the different building data/documentation on the common building information model, stakeholders will be granted with access to

	the building information required to produce their input in the project. Coordination of the information exchange between the different stakeholders needs to be coordinated by the workflow management tool that will enable automated transmission of notifications/ baseline information and assign actions to the appropriate stakeholders.
Post Condition	A centralized platform enabling the integration with external legacy systems and ensuring interoperable and secure information exchange among renovation stakeholders.
Business Impact	Processes simplification and avoidance of unnecessary paperwork due to standardized interfaces for information exchange and hence, significant reduction of time required for information exchange and avoidance of events where information is lost or not properly communicated.
Realization Description	
Leading Partner	Suite5
Contributing Partners	UBITECH, All application developers
Priority	High

4.3.8 UC-08: *Daily renovation activity schedules are automatically generated (based on accurate project scheduling) and individual guidelines are provided to the workforce responsible through ambient interfaces and apps.*

BIMERR Use Case 8	
UC ID	UC-08
Use Case Name	Daily renovation activity schedules are automatically generated (based on accurate project scheduling) and individual guidelines are provided to the workforce responsible through ambient interfaces and apps.
Related Business Scenario(s)	BS3: Construction companies to reduce time and cost of renovation works, increase labor productivity and improve logistic of renovation works.

Description	A key inefficiency issue of most construction and renovation projects relates to the poor guidance provided to individual workers regarding the installation of materials and systems, the materials and quantities to be used, exact location where the works need to be performed specifications for installing new technologies/ materials, etc. Detailed information need to provide to workers during their actual work, in an innovative manner, to avoid critical errors that may irreversibly affect the efficiency of the whole process.
Involved Stakeholders	Site manager, Worker
BIMERR components involved	PWMA, ARIBFA
Pre-conditions	The program that will be used to schedule the project, e.g. Project, Primavera or others needs to be defined. The master schedule needs to be imported to PWMA toolkit, which considers Location-based Management System (LBMS) requirements. BIM model has to consider requirements of the construction phase. The on-site guidance application needs to identify the construction locations. The context-aware information should be adapted to the targeting stakeholder.
Use Case Path	The site manager has created the project scheduling, through the use of a workflow management tool to organize activities and schedule their implementation while assigning specific responsibilities to each worker for the implementation of scheduled tasks in specific locations of the construction site. The workflow is assigned to a specific crew. Workers receive notification about assigned tasks to them. The scheduled workflow needs to be displayed in real-time in smart equipment (e.g. smart glasses, tablets, smart phones) utilizing augmented reality-driven on-site guidance. Ideally the guidance application shall run on

	smart glasses, which are worn by worker/foreman. The head-mounted device will recognize semi-automatically or automatically, the worker's location of the construction project and it will provide worker with a list of scheduled tasks with respective workflows created by the site manager. Due to H&S risks the applications might be limited to scenarios where the worker will be standing and not moving. Using the AR application (workflow automation and on-site guidance application) the worker will receive context-aware information in real-time and will be able to display job instructions, information on materials, drawings, BIM model, etc. The worker is able to select contents, which are superimposed on real world in AR. Displayed contents are correlated to BIM model and pre-defined locations of the construction project. Moreover, worker at the end of work could fill out a quick and simple checklist to verify if the work has been done according to the specification.
Post Condition	An intuitive app for smart glasses, augmenting the real construction site with relevant BIM-based information and properly assisting workers to perform their daily tasks will be developed.
Business Impact	The detailed task scheduling enhances project monitoring, which results in better decision making with greater anticipation before scheduling deviations occur. Scheduling deviations lead to cost and time increases of the construction project. Moreover, workers equipped with devices that provide use-friendly instructions for work that has to be performed, will enhance the project quality, since the possibility for errors during work execution, is reduced. Context-aware information can be helpful for low-skilled workers or foreign workers, who are not familiarized with the language of native construction crew. Simple check lists filled in by workers will help the construction company to have a record of the work projection.

Realization Description	
Leading Partner	CERTH
Contributing Partners	GU, NOVITECH
Priority	High

4.3.9 UC-09: Continuous monitoring and updates of renovation activity schedules (based on reporting from the workforce and monitoring of process execution) towards effective devising and avoidance of delays (bi-directional communication through ambient interfaces)

BIMERR Use Case 09	
UC ID	UC-09
Use Case Name	Continuous monitoring and updates of renovation activity schedules (based on reporting from the workforce and monitoring of process execution) towards effective devising and avoidance of delays (bi-directional communication through ambient interfaces)
Related Business Scenario(s)	BS3: Construction companies to reduce time and cost of renovation works, increase labor productivity and improve logistic of renovation works.
Description	Renovation projects are characterized by their dynamic nature, meaning that several unexpected events may occur during project implementation that may affect the overall cost and time of the project. Such events happen at a daily basis and may be of critical importance or not. In any case, all such information need to be transparently communicated to the project manager who keeps track of the project progress, time and costs and is responsible for addressing them in updated project schedules that aim at optimizing the efficiency of the project.
Involved Stakeholders	Foreman, Site manager, Worker
BIMERR components involved	PWMA, ARIBFA
Pre-conditions	Project schedule and assignments should be communicated to the involved actors.

	Clear guidance on the way issues are reported. An application and the associated UI for reporting ad-hoc events during project implementation should be available.
Use Case Path	Scheduled and assigned workflows to the crew are monitored by a foreman using the workflow management tool. Based on daily work status provided by the foreman at the end of the day, scheduling needs to be updated and adapted. For example, if a crew was not able to complete the assigned activities scheduled for that day, the foreman indicates e.g. the percentage of work completion and a reason for non-completion. The workflow management tool then calculates the remaining work and allows/ guides the foreman to adjust scheduling accordingly. Moreover, input data on work status will be used to calculate the relevant KPIs on project progress and performance, which will be displayed on the dashboard. On the dashboard, all renovation tasks can be followed in real-time with a daily update. Moreover, the project progress can be displayed on BIM model in AR, while the site manager is walking through the constructions site. Additional data about work status and events occurring in the construction site needs to be continuously communicated to the foreman to increase his/ her visibility and make him/ her aware of critical issues. This comprises key input for appropriately re-scheduling works to avoid critical delays, especially with regards to activities that need to be stopped for a specific period (e.g. due to mistakes in the ordered quantities of materials, or other failures). Through an intuitive application available on smart glasses to work crews, they will have the opportunity to report progress over specific activities, along with information about unexpected issues (and relevant notes) that need to be considered by the foreman.
Post Condition	A comprehensive dashboard for monitoring the progress of the overall project and specific activities.

	Intuitive interfaces for workers, for continuous reporting of works progress and highlighting of unexpected events.
Business Impact	Cost control and execution time. Anticipation of decision making in relation to "new purchases" or subcontracting due to unforeseen events. Communication with the affected subcontractors quickly which will reduce the response time.
Realization Description	
Leading Partner	NOVITECH
Contributing Partners	CERTH, GU
Priority	High

4.3.10 UC-10: Continuous reporting from workforce and occupants for changes performed over the initial renovation design (location-based on a BIM representation) and automated update of the BIM model (as-built documentation).

BIMERR Use Case 10	
UC ID	UC-10
Use Case Name	Continuous reporting from workforce and occupants for changes performed over the initial renovation design (location-based on a BIM representation) and automated update of the BIM model (as-built documentation).
Related Business Scenario(s)	BS3: Construction companies to reduce time and cost during renovation works.
Description	Construction projects are usually characterized by the fact that slight modifications to the initial construction plan are not reflected in the building documentation, due to lack of communication between workers and site managers, or due to negligence. Appropriate tools are required to ensure that whenever ad-hoc decisions on modifications are taken and executed on-site, these are directly reported to the site manager allowing him/her to update the BIM model and ensure

	the accurate representation of the executed works in the as-built documentation of the building.
Involved Stakeholders	Site manager, Building occupant, Building owner, Worker, Foreman
BIMERR components involved	ARIBFA, BICA, PWMA, BIM platform
Pre-conditions	A decision path has to be defined when a change in the project is created. Appropriate guidelines provided to all involved actors with regards to the reporting process should be available. An application for real-time reporting and update of as-built documentation should be available.
Use Case Path	Workers and occupants/owners are in need of easy-to-use applications to report changes in the renovation project during the construction. Through the use of existing AR-enabled applications workers are able to report changes (e.g. geometrical/material) they plan to perform, since the current situation does not allow them to complete their task according to the project specification. The note can consist of a short text and photos. Based on attached notes to the BIM model, a report with suggested changes is sent to the architect, who will update the model accordingly. In a similar manner occupants will use appropriate tools that will allow them through their smart phone to verify the compliance of the works performed against the original plans and provide feedback on occurred changes. This relates to inspections performed by occupants/ owners during the renovation works. For example, when they notice that the height of knee wall is lower than originally designed, they will be able to report it through a friendly UI. The site manager receives this information and displays the BIM model in order to verify the dimensions. If the dimension is different than in the project designs the site manager creates an issue (by using the workflow management tools) which is linked to the task

	workflow. The foreman receives notifications related to the workflow. The crew reacts immediately and starts adding new layers of bricks. When they finish, the foreman marks the issue as 'resolved'. Moreover, apart from verification they will have the opportunity to introduce slight changes (proposals that need to be approved by the site manager) based, of course, on the flexibility offered by respective project contracts.
Post Condition	Accurate as-built documentation. Continuous verification of executed works and avoidance of issues that could delay the delivery of the project or may require the re-execution of specific activities.
Business Impact	Transparency in the work for the client, that will also provide increased security for the construction team. Reduction of errors as-built, that is normally done at the end of the renovation works and not automatically. Reliable documentation of the work that reduces the cost in post-sales work (due to errors or lack of quality.)
Realization Description	
Leading Partner	CERTH
Contributing Partners	GU, Suite5, NOVITECH, EXERGY
Priority	High

4.3.11 UC-11: Identification of threats and dangers and provision of alerts to workforce and occupants through BIM-based apps and Uis

BIMERR Use Case 11	
UC ID	UC-11
	Identification of threats and dangers and provision of alerts to workforce and occupants through BIM-based apps and UIs
Related Business Scenario(s)	BS4: Increase workforce and occupants' safety during renovation works
Description	The avoidance of accidents on-site and the preservation of workforce (along with occupants) health and security are

	critical issues linked to any construction/ renovation project, not only for efficiency but also for other legally-related reasons. Any relevant issue that may have a negative impact to in situ H&S needs to be promptly reported, documented and transparently communicated to all involved actors, to increase their awareness and cautiousness when on-site and prepare proper actions to tackle it.
Involved Stakeholders	Site manager, Worker, Foreman, Building occupant, Building owner
BIMERR components involved	ARIFBA, BICA, BIM platform
Pre-conditions	To identify the risks and provide relevant guidance and tools for reporting and documenting.
Use Case Path	A site manager prepares health and safety (H&S) instructions for workers and occupants/owners (who are visiting the construction site) as well as H&S training material for new workers as part of the induction. He/She uploads everything to **the BIM model and thus makes the relevant information available to all applications provided for actors operating on-site**. Before starting the working day, workers receive a H&S report (through the smart glass-enabled app) with current risks at the construction site, as well as notification about changes done on the site. The site manager has a quick meeting with workers to inform them about potential risks that may occur. The report is based on the continuous reporting described in UC-12. In the opposite side of the building, workers are installing scaffoldings. The site manager has attached to the workflow H&S instructions that should be followed by workers during the installation. The foreman is wearing smart glasses displaying instructions that should be seen before starting the scaffolding assembly.

	Occupants/owners plan to visit the construction site. Before entering the construction site, they use an available app to display H&S instructions that should be followed during their visit. Moreover, for visitors and workers, potential risks could be displayed for each floor of the building.
Post Condition	Appropriate guidance to actors operating on-site (and/ or occupants visiting the renovation site) for avoiding on-site accidents and ensuring H&S for both workers and visitors.
Business Impact	Prevention and reduction of work accidents on site. Increased safety and security. Avoidance of delays related to H&S events.
Realization Description	
Leading Partner	CERTH
Contributing Partners	GU, Suite5, EXERGY
Priority	Medium

4.3.12 UC-12: Continuous reporting from workforce and occupants for dangers and threats (location-based on a BIM representation) and automated update of the BIM model.

BIMERR Use Case 12	
UC ID	UC-12
Use Case Name	Continuous reporting from workforce and occupants for dangers and threats (location-based on a BIM representation) and automated update of the BIM model.
Related Business Scenario(s)	BS4: Increase workforce and occupants' safety during renovation work
Description	Apart from possible H&S issues identified and highlighted by the H&S manager, there might be relevant issues that come up during the actual work performed on-site. Such issues may be known only to workers (e.g. exposed electricity cables due to incomplete electrical works) or observed by occupants visiting the renovation site, who shall make this information available to any other actor involved to avoid possible accidents and safety-related incidents.

Involved Stakeholders	Site manager, Worker, H&S Manager, Building occupant
BIMERR components involved	BICA, ARIBFA, BIM platform
Pre-conditions	To establish the risks and to define the necessary collective and individual measures.
Use Case Path	A worker is walking through the construction site and he/she notices that the protection from falling is not fixed properly. He/She creates an H&S issue by using a smart glass-based app, that should be resolved by a H&S manager. The H&S manager receives a notification about the problem and its location, which is highlighted on the BIM model (and respective user interface of a BIM management platform). Once the problem is solved, the H&S manager changes the issue status. A site manager receives the notification for an H&S issue and its status. The site manager creates periodically H&S reports (official document). He/She uses history log of all registered issues and their status, to create automatically the report. An occupant noticed during the visit on the construction site that the edge protection of the stairwell is missing. The occupant creates an H&S issue by using the relevant user interface. The H&S manager receives notification about the problem and its location. Once the problem is solved, the H&S manager changes the issue status.
Post Condition	Accurate and prompt notifications to involved actors for H&S issues to prevent against severe incidents at the construction site.
Business Impact	Prevention and reduction of work accidents on site (Lost Time Injury - LTI).
Realization Description	
Leading Partner	CERTH
Contributing Partners	EXERGY, Suite5, GU
Priority	Medium

4.3.13 UC-13: Perform back-to-back simulations of alternative renovation scenarios to evaluate and select the best energy-performing renovation scenario

BIMERR Use Case 13	
UC ID	UC-13
Use Case Name	Perform back-to-back simulations of alternative renovation scenarios to evaluate and select the best energy-performing renovation scenario
Related Business Scenario(s)	BS5: Construction companies to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model
Description	Renovation is not a one-size-fits-all case. Successful renovation scenarios for a specific building may not be optimal for similar buildings of the same typology. In this sense further optimization is required during the design phase, which needs to be based on iterative simulations of alternative scenarios to select the optimal one from an energy performance and cost perspective.
Involved Stakeholders	Building owner, Building occupant, Architect
BIMERR components involved	PRUBS, RenoDSS (Building Energy Performance Estimation module, Building components and systems database)
Pre-conditions	Alternative renovation scenarios available. Evaluation methodology needs to be available. A rationalization prior to optimization exercise might be required to eliminate nonfunctional scenarios/conditions.
Use Case Path	When it comes to evaluating and selecting the optimum renovation scenario for a building, the architect needs to be equipped with a powerful decision-making tool that allows for the comprehensive and comparative analysis of alternative renovation scenarios and their simulation results in terms of energy performance and cost (mainly). The architect uses this tool to estimate the impact of several possible design options provided by the different building properties (size, geometry) and energy components (HVAC, etc.).

	The tool will utilize valuable information regarding energy behavior of the building occupants, together with cost elements for different materials extracted from a complete database that is integrated with the building energy performance simulation module. Through multiple simulation cycles the architect aims to optimize (i) the two main sources of energy efficiency improvement in a building, namely the *improvement of the thermal inertia of the building*, as well as the *modified energy consumption patterns* due to the replacement of heating/cooling system and (ii) the overall cost of the project, related both to materials and energy costs at post-renovation operation.
Post Condition	Optimized renovation scenarios based on the collective (and comparative between different scenarios) evaluation of energy and cost-relevant KPIs
Business Impact	Informative decisions regarding renovation scenario adaptation to improve energy efficiency.
Realization Description	
Leading Partner	XYLEM
Contributing Partners	HYPERTECH, EXERGY
Priority	Medium

4.3.14 UC-14: Energy performance assessment to be elevated at a life-cycle perspective including relevant LCA-LCC metrics

BIMERR Use Case 14	
UC ID	UC-14
Use Case Name	Energy performance assessment to be elevated at a life-cycle perspective including relevant LCA-LCC metrics
Related Business Scenario(s)	BS5: Construction companies to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model
Description	A key challenge for the construction/ renovation sector is to enhance the sustainability and environmental performance of

	the building sector, to comply with relevant EU and national directives, while achieving ambitious optimization objectives that refer to the life-cycle of buildings and the materials/ components used.
Involved Stakeholders	Architect
BIMERR components involved	RenoDSS (Building Energy Performance Estimation module, Life Cycle Cost/Life Cycle Assessment module)
Pre-conditions	Material and component database, considering also LCA/LCC parameters should be available.
Use Case Path	Evaluation of energy performance and costs of alternative renovation scenarios needs to be uplifted to a life-cycle level, during the design phase. In this context, the architect will need to go through a Life Cycle Cost/Assessment of the various renovation options to be explored through a powerful Renovation Decision Support tool. The user needs to assess the renovation options taking into account the energy aspects of the implemented components (technologies/materials, systems), as well as other related aspects such as decommissioning and recycling. This can be done through the enhancement of current materials "stereotypes" (models) to be introduced in building performance simulation tools, with LCA/LCC aspects in order to facilitate the assessment of the building performance, also considering a life-cycle perspective.
Post Condition	Optimized (from a sustainability point of view) renovation designs
Business Impact	Realization of ambitious sustainability objectives for the construction/ renovation sector and compliance with relevant regulation. Further improvement of the economic performance of renovation projects considering a life-cycle perspective.
Realization Description	
Leading Partner	XYLEM

Contributing Partners	EXERGY
Priority	Medium

4.3.15 *UC-15: Energy performance simulations to assess not only energy metrics, but also accurately evaluate occupants' comfort and indoor air quality*

BIMERR Use Case 15	
UC ID	UC-15
Use Case Name	Energy performance simulations to assess not only energy metrics, but also accurately evaluate occupants' comfort and indoor air quality
Related Business Scenario(s)	BS5: Construction companies to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model
Description	Current urbanization trends indicate that people spend most of their time in indoor environments, thus wellbeing is a critical factor that needs to be efficiently addressed by the construction sector. Establishment of built environments that can preserve high levels of human comfort and indoor air quality is a key requirement for the renovation industry since they are tightly connected to the real estate value of a building and, thus, directly affect the economics and contractual terms for the implementation of such projects.
Involved Stakeholders	Architect, Building occupant
BIMERR components involved	PRUBS, RenoDSS
Pre-conditions	Installation of sensors and Building Energy Management System (BEMS) with centralization and treatment of the gathered data from the installed smart equipment, responsible for real-time monitoring of different comfort related parameters (IAQ, Temperature, Humidity, VOC, etc.) should be available.

	Access to real-time-device level is needed to obtain quantitative feedback based on sensors and meter readings. Definition of the inhabitants' perception regarding the quality of their indoor environment, and establishment of their comfort zones (accurate behavioral/comfort profiles) through the PRUBS toolkit.
Use Case Path	Introduction of indoor conditions (temperature, humidity, surface temperature) as another metric to evaluate the effectiveness of the renovation scenarios is key to the real estate value enhancement of renovation projects. In this context architects needs to have access to detailed comfort profiles and hygienic/ health requirements of occupants in buildings, which need to be inferred in a non-intrusive manner. Subsequently, such profiles and boundaries need to be introduced in a powerful renovation decision support tool to address both these aspects in any simulation performed and corresponding evaluations. The profiling tool must be in position to collect and correlate ambient information (temperature, humidity, CO2, VOC, luminance) from sensors with control actions (information collected by actuators on HVAC and lighting devices), in order to extract comfort profiles of occupants and occupancy schedules. This information will replace relevant schedules already available in BEPS tools in order to enable the holistic and accurate assessment of alternative renovation designs, not only from an energy, but also from a human-centric perspective.
Post Condition	The extraction of (dis)comfort profiles will further facilitate the design of livable renovated buildings with a high degree of satisfaction among the final building occupants.
Business Impact	Increased building occupants satisfaction, creating cascading effects and impacts in real-estate values, established EPCs and social welfare/ well-being.
Realization Description	
Leading Partner	HYPERTECH
Contributing Partners	XYLEM, Suite5

Priority	Medium

4.3.16 *UC-16: Assessment of energy performance to also address the district aspect and enable the consideration of interactions between buildings, but also between buildings and district systems in a holistic assessment framework incorporated in urban planning applications*

BIMERR Use Case 16	
UC ID	UC-16
Use Case Name	Assessment of energy performance to also address the district aspect and enable the consideration of interactions between buildings, but also between buildings and district systems in a holistic assessment framework incorporated in urban planning applications
Related Business Scenario(s)	BS5: Construction companies to accurately predict the energy performance of renovated buildings and continuously update their predictions based on real data, towards making more attractive the energy performance contracting model
Description	Modern cities are characterized as dynamic ecosystems where different systems and sectors interact with each other for the realization of common and individual sustainability objectives. In this context, buildings play a critical role (considering their huge energy needs) and are key enablers for the realization of city-wide objectives. Optimizing the interaction of buildings with urban systems (electricity, heating, etc.), but also between themselves (in order to achieve increased self-consumption in cases of local generation penetration) are major issues that need to be addressed in urban planning processes and relevant simulation environments. Accurate simulation of both building energy performance and interactions involved in future smart city scenarios, can facilitate informed decision-making and optimal urban planning towards enhanced sustainability and satisfaction of city commitments as documented in relevant SECAPs (Sustainable Energy and Climate Action Plans).
Involved Stakeholders	Architect, Building owner, Urban Planner

BIMERR components involved	RenoDSS (Building Energy Performance Estimation module, Urban Planning module, Life Cycle Cost/Life Cycle Assessment module)
Pre-conditions	Extraction of accurate context-aware energy profiles of building occupants and delivery of associated optimized renovation scenarios. Concrete definition of the involved interactions in a smart city environment and associated algorithms.
Use Case Path	During the design phase, results from the BEPS (reflecting the predicted energy performance of the renovation project) are fed into an Urban Planning module, so as to evaluate the building performance as part of large-scale energy efficiency strategies applied at district level and assess the contribution to the realization of urban development strategies. In this context, the urban planning module (and an overlay decision support tool) needs to ensure that the building itself contributes sufficiently to the realization of district-wide energy efficiency goals (or if not, it shall define specific targets to be achieved), while enabling the assessment of its performance at the district scale by evaluating how the building interacts and takes advantage of district-wide systems (e.g. district-wide renewables, storage, etc.) which may radically alter its performance (e.g. when participating in RES-sharing schemes for self-consumption or taking advantage of local Distributed Energy Resources that may improve its energy and environmental performance). Both the results of the energy performance simulation (addressing also LCA/LCC aspects) and urban planning tools need to be considered in the renovation decision support tool, which performs the holistic evaluation of alternative renovation scenarios and assists the designer in the definition of the optimal design in socio-techno-economic performance terms, but also in close collaboration with urban planners.
Post Condition	Delivery of optimal renovation project design, by introducing the building into an urban context and considering interactions with city-wide systems and actors.

Business Impact	Existence of local generation systems may lead to a further optimization of the energy performance of a building through reducing dependence on grid-delivered electricity and maximizing self-consumption. Better environmental performance of renovated buildings through maximum utilization of local (clean energy) RES Improved urban energy performance. Realization of urban sustainability goals. Urban air quality improvement. Significant reduction of building OPEX.
Realization Description	
Leading Partner	XYLEM
Contributing Partners	HYPERTECH
Priority	Medium

4.4 TAXONOMY OF THE BIMERR BUSINESS SCENARIOS AND USE CASES

Each business scenario is associated with one or more use cases that define the technical perspective of business needs. More specifically, the following figure shows the associations between business scenarios and use cases as well as the association of each use case to planned BIMERR tools. There are four use cases related with BS-01, three with BS-02, three with BS-03, two with BS-04 and six with BS-05 (two are also related with BS-01). Finally, Table 3 provides a summary of each use case in terms of BSs, involved BIMERR user groups, planned tool (or module), leading/contributing partners and priority.

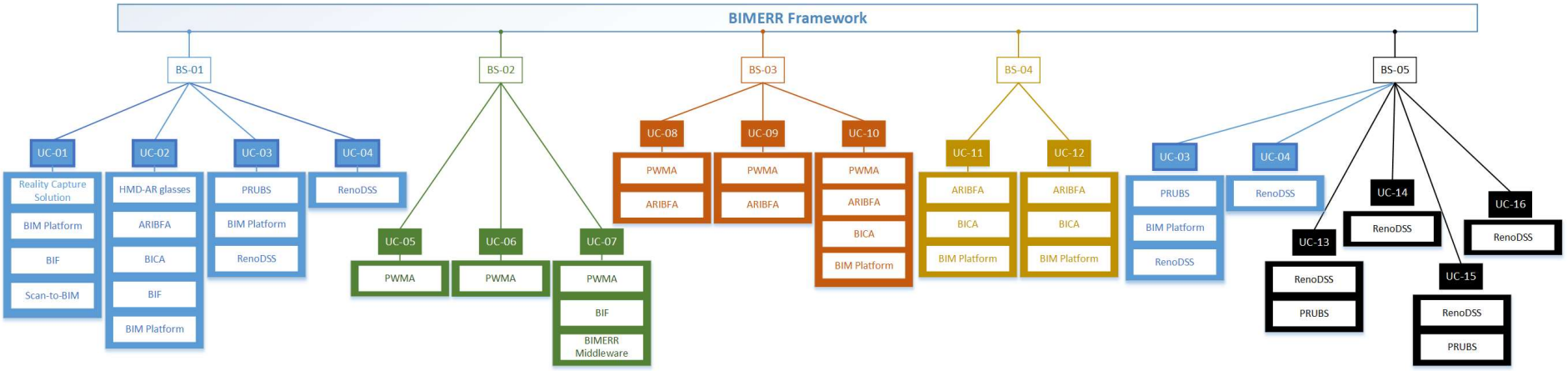


Figure 6: Taxonomy of BIMERR business scenarios and use cases along with the associated tools

As seen from the analysis of the use cases, they target all stages of the Renovation Process by providing:

- accurate and time efficient representation of the building (geometry, components and energy related context) in a BIM, (UC-01, UC-02)
- accurate simulation of the post-renovation energy performance of the building and improved choices for the materials and components database,
  (UC-03, UC-04)
- accurate scheduling/planning of the renovation activities, (UC-05)
- automated communication and information exchanged during planning process, (UC-06, UC-07)
- continuous monitoring of the renovation progress, automated assignment and reporting of daily activities, targeted guidance to working crews, automated issue detection even from clients, (UC-08, UC-09, UC-10)
- more safety during construction works, (UC-11, UC-12)
- optimized renovation scenarios by multiple simulations that consider not only energy performance (UC-13) but also the LCA/LCC of the examined scenarios (UC-14).
- performance evaluation of user comfort and indoor air quality via enhanced simulations, (UC-15)
- building renovation impact assessment in district level, (UC-16)

UC	BS	User Group	BIMERR Component	Partners	Priority
UC01	BS-01	BIM modeler Surveyor	Scan-to-BIM	**UOE** FIT Exergy Suite5 UBITECH	High

UC	BS	User Group	BIMERR Component	Partners	Priority
UC02	BS-01	Building manager Building occupant Surveyor	HMD-AR glasses ARIBFA (BIM 3D Model Registration and Tracking Module, Indoor Localization Module, Marker-less Feature Recognition Module, AR Annotation & Context Aware-Visualization Module) BICA BIF BIM Platform	**CERTH** GU EXERGY Suite5	High
UC03	BS-01 BS-05	Architect Building occupant	PRUBS BIM Platform RenoDSS (Building Energy Performance Estimation module)	**HYPERTECH** Suite5 XYLEM	High
UC04	BS-01 BS-05	Architect BIM expert	RenoDSS (Building Components and Systems Database)	**EXERGY** HYPERTECH XYLEM	Medium
UC05	BS-02	Project manager	PWMA	**NOVITECH** BOC	Medium
UC06	BS-02	Project manager	PWMA	**NOVITECH** BOC	Medium
UC07	BS-02	Project manager Subcontractor Vendor/Supplier Site manager Foreman Worker Architect Consultant Material manufacturer	PWMA BIF BIMERR Middleware	**Suite5** UBITECH All application developers	High
UC08	BS-03	Site Manager Worker	PWMA ARIBFA	**CERTH** GU NOVITECH	High

UC	BS	User Group	BIMERR Component	Partners	Priority
UC09	BS-03	Foreman Worker Site manager	PWMA ARIBFA	**NOVITECH** CERTH GU	High
UC10	BS-03	Site manager Building occupant Worker Foreman Building owner	ARIBFA BICA PWMA BIM platform	**CERTH** GU Suite5 NOVITECH EXERGY	High
UC11	BS-04	Site manager Worker Foreman Building occupant Building owner	ARIBFA BICA BIM platform	**CERTH** GU Suite5 EXERGY	Medium
UC12	BS-04	Site manager Worker H&S Manager Building occupant	BICA ARIBFA BIM platform	**CERTH** EXERGY Suite5 GU	Medium
UC13	BS-05	Building owner Building occupant Architect	RenoDSS (Building Components and Systems Database, Building Energy Performance Estimation module) PRUBS	**XYLEM** HYPERTECH EXERGY	Medium
UC14	BS-05	Architect	RenoDSS (Building Energy Performance Estimation module, Life Cycle Cost/Life Cycle Assessment module)	**XYLEM** EXERGY	Medium
UC15	BS-05	Architect Building occupant	PRUBS RenoDSS	**HYPERTECH** XYLEM Suite5	Medium
UC16	BS-05	Architect Building owner Urban Planner	RenoDSS (Building Energy Performance Estimation module, Urban Planning module, Life Cycle Cost/Life Cycle Assessment module)	**XYLEM** HYPERTECH	Medium

Table 3: Overview table for each BIMERR Use Case.

5. BIMERR USER GROUPS

5.1 DESCRIPTION OF BIMERR USERS

Table 4 provides a brief general description of the 17 user groups/roles identified in the use cases and are involved in the renovation process.

No	BIMERR	Description
1	BIM modeler	A BIM modeler is engaged in the process of generating digital models of the construction/renovation place. She/He develops the construction drawings and imports data to a BIM platform.
2	Building surveyor	The building surveyor is responsible for making sure that buildings are safe, energy efficient and livable. He/She interacts with other professionals such as engineers, architects and builders to ensure that buildings are designed and constructed to comply with building regulations.
3	Architect-Designer/ Engineer	An architect/engineer prepares construction drawings and specifications. He/She could lodge the planning application and building warrants. He/She leads the design team to meet the client's design requirements and hence, defines the client requirements, arranges site investigations, establishes the preferred solution, develops the design, prepares room data sheets, offers advice on material selection, etc. An architect/engineer also monitors the construction of the project to ensure it is done according to the plans and specifications.
4	BIM expert	A BIM expert is engaged with the process of generating and managing digital building information models. He/She is a member of the BIM team; however, different terminology is used in the AEC Industry to define the roles in a BIM team. A BIM manager is usually someone who manages the team. A BIM modeler builds the BIM virtually and ensures that the model aligns with the goals set by the BIM manager. A BIM technician is someone who develops the construction drawings and extracts data on a BIM platform.

No	BIMERR	Description
5	Urban planner	Urban planning deals with the development and design of land use and the built environment, including air, water, and infrastructure such as transportation, communications, and distribution networks. It deals with the physical layout of human settlements. The primary concern is public safety, including efficiency, sanitation, protection and use of the environment issues. It is interdisciplinary and includes social, engineering and design sciences.
6	Building manager	A building manager is mainly involved in the development of master plans for properties as well as budget estimation for proposed projects. He/She could serve as lease manager for the owner's rental properties and be the contact with the tenants. He/She may be responsible for space planning, and space inventory and allocations. Also, a building manager might be in charge of minor projects such as contracted work and services.
7	Building occupant	The occupant is the final customer. Since one of the objectives of the BIMERR project is to establish an energy efficient environment fully preserving end users' needs and preferences, tools and applications will be available to address the high level need for establishing a sustainable environment.
8	Building owner	The person who owns the building and has full authority to control the renovation project. Generally, the owner is mainly involved in the financial issues of the construction project and makes sure that the necessary financial resources are available timely. He/She has to work together with the architect and other consultants to achieve the goals set for the construction project.
9	Consultant	Construction consultants help clients prepare for their projects and ensure that contractors complete the project on cost. They provide cost estimates and budgets, select contractors, administer construction

No	BIMERR	Description
		contracts, and resolve differences between contractors and project owners.
10	Health & Safety manager	His/Her roles and responsibilities include monitoring health and safety risks at the workplace and advising employees how to avoid them. He/She ensures compliance with all health and safety legislation, works with and trains employees to improve the health and safety standards in the workplace, assists with the creation and management of health and safety monitoring systems and policies in the workplace, as well as manages emergency procedures (such as fire alarm drills).
11	Material manufacturer	Building materials manufacturers produce a variety of materials used for construction. This is an established industry and the use of the materials is typically segmented into specific specialty trades, such as carpentry, insulation, plumbing, roofing work, etc.
12	Project manager	Project manager monitors and controls all the aspects of a project and makes sure that the people involved achieve the objectives on time and to cost, performance and quality. He/She also directs the Design Team and ensures that appropriate information and understanding exists to effectively execute the project.
13	Subcontractor	A subcontractor is hired by a general contractor to perform a specific job within a construction project. As such, plumbers, painters, electricians and other specialists may be considered construction subcontractors.
14	Vendor/Supplier	Nowadays a supplier is not only an organization contracted to provide physical supplies such as goods, materials, plant, etc. but also any provider of services and goods, either directly to the employer or to another supplier in a supply chain.

No	BIMERR	Description
15	Foreman	Foreman is usually a senior worker in charge of a construction crew.
16	Site manager	A site manager or sometimes construction manager, oversees site operations on a day-to-day basis, and ensures that work is done safely, on time, within budget and to the right quality standards.
17	Worker	A construction worker is a tradesperson, laborer, or professional employed in the physical construction of the built environment and its infrastructure.

Table 4: The user groups identified in BIMERR Use Cases.

The 17 user groups identified in the use cases are grouped to 7 main user groups according to their role in the use cases and the BIMERR component (tool) they will use. The remaining user groups are allocated to (or represented by) one of the seven main user groups since their role is considered either complementary or derivative for the use cases. Figure 7 depicts the users' classification to main and secondary user groups while Table 5 provides the users' involvement in the BIMERR use cases.

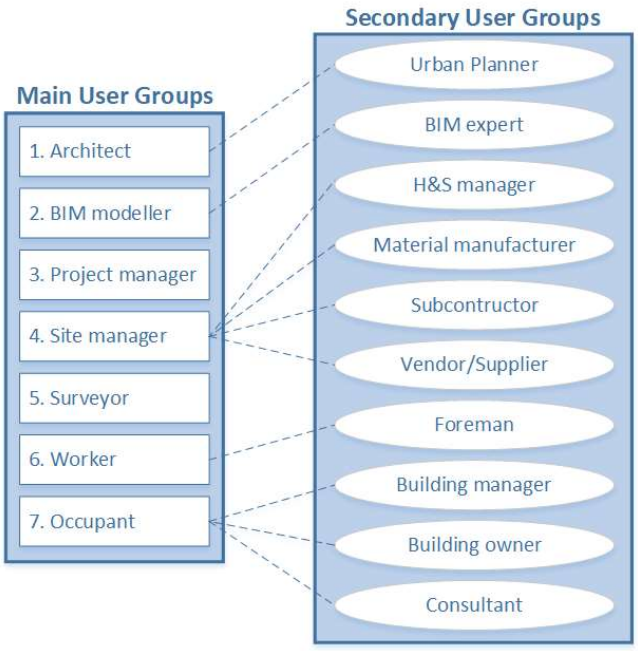


Figure 7: User groups and categorization to main and secondary groups according to their importance for the BIMERR use cases

User Group	Use cases involved	Main User Group
Architect	UC03, UC04, UC07, UC13, UC14, UC15, UC16	1
Urban planner	UC16	
BIM modeler	UC01	2
BIM expert	UC04	
Project manager	UC05, UC06, UC07	3
Site manager	UC07, UC08, UC09, UC10, UC11, UC12	4
H&S manager	UC12	
Material manufacturer	UC07	
Subcontractor	UC07	
Vendor/Supplier	UC07	
Building surveyor	UC01, UC02	5
Worker	UC07, UC08, UC09, UC10, UC11, UC12	6
Foreman	UC07, UC09, UC10, UC11	
Building occupant	UC02, UC03, UC10, UC11, UC12, UC13, UC15	7
Building manager	UC02	
Building owner	UC10, UC11, UC13, UC16	
Consultant	UC07	

Table 5: BIMERR end users (involvement in use cases and allocation to main user groups)

6. REQUIREMENTS WORKSHOPS

The standard approach in user centered design is that qualitative research is done first to identify a list of problems and needs from the stakeholders, without regard to how important each problem or need is and what percentage of stakeholders it affects. For this kind of research, 5-7 users is the "sweet spot" of knowledge gained versus cost of gaining that knowledge (i.e. cost of workshop, organisation overhead, etc.[2]). As a consequence, the workshops organised under the living labs umbrella in this task, focused on qualitative user research, therefore 5-7 participants was a sufficient targeted number.

In the next two sections general information (location, date, number of participants, organization strategy) about the Polish and Spanish workshops are provided.

6.1 REQUIREMENTS WORKSHOPS IN POLAND

Budimex, the Polish pilot partner, conducted two requirements workshops in Poland, one on month M05 in Warsaw, and one on M08 in Rother's Mills. Table 6 summarizes information about these two workshops.

Date	Location	Number of Participants	BIMERR user groups
31.05.2019	Warsaw/Poland	10	Architect - BIM Expert - Project manager Site manager - Building Surveyor - Worker
20.08.2019	Rother's Mills/Poland	7	Project Manager - Site Manager - Worker

Table 6: Summary information for the Polish workshops

Prior to the discussions for BIMERR technology and concept, participants were asked five questions regarding their gender, age, educational background, years of experience and their level of familiarity with BIM technology in general (see Annex 4). The aggregate results are shown in Annex 5. Fifteen out of seventeen participants held a Master's Degree and two of them a Bachelor.

6.1.1 Organization of the Polish workshops

The two workshops included participants from all the main user groups apart from occupants, as it was explained before. The first part of the workshops included an introduction to the BIMERR project and the Design Thinking Methodology that was followed during the workshops. The second part was about moderating discussions

2 https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/

with the participants from the different user groups for the questions in the provided questionnaires. Finally, design thinking exercises were conducted at the third part of the workshop. During the exercises the participants (see Figure 8) described tools and technologies currently available for renovations such as laser scanning, thermal imagining and building leak tests. They also engaged in discussions on possible process modifications that could make them feel more satisfied with their work. The participants mentioned the need for easier and faster decision-making processes along with a more structured building certification process.

Additionally, the participants provided feedback for the planned BIMERR tools that were presented to them. Specifically, they described what is useful, and what will make these tools more effective for their work. Participants expressed concerns about safety issues related to using smart glasses, tablets and smartphones at the construction site. They really liked the way how the planned BIMERR tools make surveying and decision making process easier and detailed.

More detailed descriptions can be found in the workshop reports [9]-[10] provided by the pilot partner that organized the workshops. For the purposes of this deliverable, sections 6.1.1.2-6.1.1.7 provide a brief overview of the exercises held during the workshops, while the subsequent feedback analysis has led to the user requirements listing, as it is provided in section 8.2.

Figure 8: The 1st requirements workshop in Warsaw, Poland

6.1.1.1 Design Thinking Exercises

The third and last part of the workshop included the use of creative thinking - Design Thinking, in order to get feedback from the project stakeholders, and their opinions on the tools and solutions proposed by BIMERR. It started with a short description of the BIMERR tools and then six design thinking exercises were carried out:

6.1.1.2 Exercise 1 – Value map for the present situation in the renovation process

The participants described the current thermo-modernization process; they described tools and technologies available for renovation including for example laser scanning, thermal imagining and building leak tests.
The exercise focused also on what makes the participants satisfied related to the renovation process. The key target of this exercise was to determine what could potentially make them work better.

6.1.1.3 Exercise 2 – Feedback matrix

During the second exercise two groups were asked to share their opinions on BIMERR tools. They discussed about what it would be useful, what will make these tools more effective during their work, as well as concerns and questions about the proposed solutions.

6.1.1.4 Exercise 3 – Client/User archetype

In this exercise, participants described one of the stakeholders involved in the renovation process. They provided general information, social, economic and demographic characteristics as well as what motivates them to work. Since BIMERR targets stakeholders involved in the construction site as well as stakeholders in office environments, the role of *site manager* which bears characteristics of both was chosen.

6.1.1.5 Exercise 4 – Empathy map

This exercise was an extension of the previous one. Participants discussed further the characteristics of *site manager* (chosen during exercise 3). Specifically, what does the *site manager* think, what kind of discussions does he/she have with coworkers (critics, complains, etc.), what are the advantages working as a *site manager* (high salary, compliments) and finally what are the challenges a *site manager* faces at work (deadlines, budget cuts, lack of staff).

6.1.1.6 Exercise 5 – Client/User map

This exercise was an extension of previous ones but now the participants considered the scenario of a *site manager* using BIMERR tools.

Participants discussed the advantages resulting from using BIMERR tools, such as more efficient scheduling and task planning, but they also noted possible risks such as cost of application and people's unwillingness to learn another software.

6.1.1.7 Exercise 6 – Single brainwriting for BIMERR tools

During this exercise, participants considered themselves as users of the BIMERR tools and wrote down the advantages that they would have; advantages such as time-saving, improved working conditions, easy way to notate collisions and mistakes, better and faster information transferring, automation of important work aspects (e.g. material ordering, overall planning) and risk prevention.

6.2 REQUIREMENTS WORKSHOPS IN SPAIN

Ferrovial, the Spanish pilot partner, conducted two requirements workshops, one in month M06 in Madrid, and one in M07 in Valencia. Table 7 summarizes information about these two workshops while Annex 6 presents the demographic analysis of the participants.

Date	Location	Number of Participants	BIMERR user groups
19.06.2019	Madrid/Spain	6	Architect - BIM Expert - Project manager Site manager - Building Surveyor
12.07.2019	Valencia/Spain	11	Architect - BIM Expert - Project manager Site manager - Building Surveyor - Worker

Table 7: Summary information of Spanish workshops

The figures provided in Annex 6 summarize information about the participants' gender, age, years of experience and level of familiarity with BIM method. Also, regarding the educational background of the Spanish workshops participants, fifteen of them are holding a master's degree and one of them has a doctorate.

6.2.1 Organization of Spanish Workshops

The workshops in Spain were carried out in a similar way to those in Poland, i.e. first a quick introduction for BIMERR and the Design Thinking Methodology, then moderation of collaborative and dynamic discussions with the participants from the different user groups based on the provided questionnaires that were translated into Spanish, and finally, synthesis of the canvas through design thinking exercises (see the following figures from the workshops and details in the reports provided by the organizer, [11] and [12]).

It should be mentioned that in particular the workshop held in Valencia was an opportunity to share information with some partners that are also working on another BIM-related EU project, BIMplement.

Figure 9: Photo from the 1st requirements workshop in Madrid, Spain

Figure 10: Photo from the 2nd requirements workshop in Valencia, Spain

7. ONLINE SURVEY

The online survey was conducted with seven questionnaires in four different languages, each targeting a different BIMERR user group. The online questionnaires were made available to BIMERR living lab members via the project official page during a period of seven months spanning from M11 to M18 (November 2019 to June 2020).

Note that the requirements elicitation process for the Occupants was based entirely on the online survey since due to the Covid-19 world health crisis, physical meetings were not allowed for most of this period.

Table 8 summarizes the total number of completed questionnaires for each user group and supported language. Note that participants could fill in the questionnaires at their preferred language.

	Architect	BIM Expert	Building Surveyor	Occupant	Project Manager	Site Manager	Worker	**Completed Questionnaires**
EN	4	3	2	2	8	0	0	**19**
ES	18	6	8	18	1	6	10	**67**
GR	0	0	0	5	1	1	0	**7**
PL	2	5	0	3	0	3	0	**13**
Total	**24**	**14**	**10**	**28**	**10**	**10**	**10**	**106**

Table 8: Completed online questionnaires

Again, as for the workshops, before getting to the requirements related questions, participants were asked to reply to five demographic questions (see Annex 4). The results per user group are shown in Annex 7.

Furthermore, sample responses from the online survey are provided in Annex 8.

8. BIMERR USER REQUIREMENTS

In this section, the BIMERR end-user requirements are defined. The requirements have been derived following the use cases identification, the produced questionnaires and the subsequent findings from the Workshops and online survey as described in Sections 6 - 7.

8.1 BIMERR REQUIREMENTS EXTRACTION METHODOLOGICAL FRAMEWORK

Requirements elicitation is the iterative process of discovering, clarifying and refining the needs, capabilities, conditions, and constraints that BIMERR must satisfy in order to deliver a tool that meets the end users' needs. As with most common requirements elicitation methods, the people who are going to use the system are directly involved. BIMERR user requirements elicitation process is based on three iterations.

In the first iteration we considered the results from the workshop held in Warsaw and further analyzed the different viewpoints of the stakeholders in order to produce a non-exhaustive list of end users requirements. The results of the first iteration were included in D3.1 submitted in M06.

The second iteration took place on M11 and the results of the three additional workshops described earlier were considered. Workshops provided the opportunity to have face-to-face interviews with representatives of six out of seven BIMERR main user groups. Moderators used the workshop questionnaires [6] to conduct a semi-structured discussion with the participants allowing also brainstorming sessions. During the second iteration the total number of requirements reached 148, adding 38 new requirements to the list. Note that at this stage 11 requirements were revised in order to better reflect the outcome of all the workshops and 2 requirements were omitted because they were conflicting with conclusions that derived from the other workshops. The complete list of requirements derived during the second iteration is available since M11 on the project official repository [13], while the specific changes (additions, revisions, rejections) to BIMERR user requirements of the first iteration are listed herein in section 8.2 per user group.

The third iteration was based on the results of the online survey. It was carried out in order: (a) to verify the requirements for the six BIMERR user groups, and (b) to produce the user requirements for the seventh user group, the occupants, (as mentioned in section 7, there were no physical meetings with the occupants due to safety precautions against Covid-19).

For the verification process, requirements can either be verified, revised in terms of their priority, or omitted. Specifically, a requirement previously created during workshops, can be

- rejected, only if the participants' responses to the relevant online questions, lead to a different contradicting requirement.
- revised in terms of its priority, if the participants' responses verify the requirement, but other options could also apply. This scenario is mainly the case when multiple responses receive close preference percentages.

It should be pointed out that in this process, questions that received less than ten responses were not considered.

An important part of the entire process involved the provision of a hierarchy on requirements and their prioritization. In this context, different types of priority /importance were considered:

- High: These requirements are essential in order to achieve the goals of the project since they define the core aspects of the system
- Medium: They are necessary or very helpful but not crucial for the whole system operation
- Low: They are not required for the BIMERR tool, however, they can be considered as important for additional features that could bring added value

The final list consists of 151 user requirements, and it is presented in section 8.2, along with the changes between the second and third iteration for each user group.

8.2 BIMERR End Users and Business Requirements

The template for the requirements presentation is shown in Table 9.

BIMERR Requirements Template	
ID:	'BMRR-'<number>
Description:	Short description of the Requirement
Originator:	The stakeholder who raised the requirement
Type:	Functional, Performance, Design constraint, Operational, Legal,
Priority:	Low, Medium, High (to achieve the goals of the project)
Comments:	Supporting info to the Description

Table 9: Requirements template

Although most of the fields in this template are straightforward [14], the 'type' field is further explained:

- Functional: System functionalities that the users require
- Performance: Requirements that relate to "how well" a system function should be performed (e.g. level of accuracy)
- Design Constraint: Requirements that limit the options of the system developers since they impose constraints that need to be considered

- Operational: Requirements that relate to the specific environment of system deployment.
- Legal: Requirements concerning access and privacy aspects of the system
- Process: Requirements describing events that should be triggered by other events
- Pilot Specific: Requirements that derive from users at specific pilot deployments

In the followings, for each BIMERR user group the user requirements along with the changes that occurred between iterations are presented in separate sections. An additional subsection to each user group summarizes interesting comments and observations made by the workshops' participants that were not however used for the requirements list.

8.2.1 Architects' (designers) requirements

In the first iteration 34 user requirements targeting the Architect were derived.
In the second iteration the Architect user requirements were 47. Specifically, requirements:

- BMRR-001, BMRR-002, BMRR-004 and BMRR-029 were revised
- BMRR-113, BMRR-114, BMRR-115, BMRR-116, BMRR-117, BMRR-118, BMRR-119, BMRR-120, BMRR-121, BMRR-122, BMRR-123 and BMRR-124 were added

In the third and final iteration, 47 requirements were compiled for the Architects, 6 of them were changed, 2 were deleted and 25 were verified. The final list includes 45 requirements (see Table 10) targeting the Architect. The following bullet list summarizes the changes of the third iteration:

- BMRR-029 and BMRR-061 were deleted
- BMRR-001 was modified not to include the DGN format
- BMRR-017, BMRR-027 and BMRR-028 had their priority changed from High to Medium
- BMRR-120 had its priority changed from Low to Medium
- BMRR-018 had its priority changed from High to Low
- BMRR-002, BMRR-003, BMRR-004, BMRR-005, BMRR-006, BMRR-007, BMRR-008, BMRR-009, BMRR-010, BMRR-011, BMRR-012, BMRR-013, BMRR-014, BMRR-015, BMRR-016, BMRR-025, BMRR-026, BMRR-113, BMRR-114, BMRR-116, BMRR-117, BMRR-118, BMRR-121, BMRR-122, BMRR-123 and BMRR-124 were verified.

Req ID	Description	Type	Priority
BMRR-001	Architect shall be able to import data to the design software he uses in specific data formats. - Import in DWG format - Import in PDF format	Design Constraint/Polish Pilot	High

BMRR-002	Architect shall be able to export data from the design software she uses in specific data formats. - Export in DWG format - Export in PDF format	Design Constraint/Polish Pilot	High
BMRR-003	Architect shall be able to import BIM models to her design software in IFC format	Design Constraint	High
BMRR-004	Architect shall be able to export BIM models from the design software he uses in DWG or IFC format	Design Constraint	High
BMRR-005	Architect shall be able to exchange information with site manager	Functional	High
BMRR-006	Architect shall be able to exchange information with investor	Functional	High
BMRR-007	Architect shall be able to exchange drawings with other stakeholders	Functional	High
BMRR-008	Architect shall be able to exchange documents with other stakeholders	Functional	High
BMRR-009	Architect should exchange annotated photos with other stakeholders	Functional	Medium
BMRR-010	Architects shall be able to get Building log book in order to complete their work	Functional	High
BMRR-011	Architects shall be able to get material specifications (coefficients and properties) in order to complete their work	Functional	High
BMRR-012	Architect shall be able to have an up-to-date representation of the building to be renovated	Functional	High
BMRR-013	Architect shall be able to use current survey results for construction representation	Functional	High
BMRR-014	Architect should be able to use BIM model in order to check geometrical properties of the building.	Functional	Low
BMRR-015	Architects shall be able to retrieve building information as PDF files	Functional	High
BMRR-016	Architects shall be able to retrieve building information as AutoCAD files	Functional	High
BMRR-017	Architects shall be able to retrieve building information as Images	Functional	Medium
BMRR-018	Architects shall be able to retrieve building information as Spreadsheets	Functional	Low
BMRR-019	Access to building information shall be restricted only to specific stakeholders	Legal	High
BMRR-020	Architects in Poland shall be able to use the following online database for design materials selection: http://www.e-bistyp.pl/	Operational Pilot specific	Medium
BMRR-021	Architects in Poland shall be able to use the following online database for design materials selection: http://alatea.pl/pliki/programy/kosztorysowanie/intercenbud.htm	Operational Pilot specific	Medium
BMRR-022	Architect shall be able to optimize the design material selection by standard calculations	Functional	High
BMRR-023	When the renovation project has to use specific technology/materials, architects will produce only one renovation scenario	Performance	Low
BMRR-024	Renovation scenarios proposals should be reported to the client via a written report	Functional	High
BMRR-025	Architect shall be able to consider insulation as an energy saving measure to the renovation design	Functional	High

BMRR-026	Architect shall be able to consider heating system as an energy saving measure to the renovation design	Functional	High
BMRR-027	Architect shall be able to consider cooling systems as an energy saving measure to the renovation design	Functional	High
BMRR-028	Architect shall be able to consider hot water production systems as an energy saving measure to the renovation design	Functional	Medium
BMRR-030	Climate data should be considered for life cycle cost calculations	Functional	High
BMRR-031	Architect shall be able to provide cost estimation for renovation projects	Functional	High
BMRR-032	Occupants' energy bills should be available in order for operational energy data to be considered.	Operational	High
BMRR-033	Occupants' comfort should be monitored with IoT solutions	Functional	High
BMRR-034	Energy consumption should be monitored with IoT solutions	Functional	High
BMRR-113	Architect shall be able to import data to the design software he uses in specific data formats. - Import in IFC format - Import in DWX format - Import in XML format	Design Constraint/Spanish Pilot	High
BMRR-114	Architect shall be able to export data from the design software she uses in specific data formats. - Export in DWG format - Export in PDF format	Design Constraint/Spanish Pilot	High
BMRR-115	Architects will calculate three (3) alternative scenarios per project	Operational Pilot specific	Medium
BMRR-116	Architect will use smartphones or tablets using Android	Design Constraint	Medium
BMRR-117	Architect's software tools can support files for import functionality	Functional	High
BMRR-118	Architect's software tools can support files for export functionality	Functional	High
BMRR-119	Architect stores building information in CAD, xml, pdf and doc files	Design Constraint	Medium
BMRR-120	Architect will use email to exchange information with other stakeholders	Design Constraint	Medium
BMRR-121	Architect will exchange information up to two times per day with other stakeholders	Operational	Low
BMRR-122	Architects will exchange information with site managers	Operational	High
BMRR-123	Architects will exchange information with clients (investors)	Operational	High
BMRR-124	Architects should be able to post-evaluate the energy performance of a building based on actual operational data	Functional	Low

Table 10: User requirements for Architects

8.2.1.1 Comments regarding the Architects user group

Discussions during the workshops produced a list of comments regarding Architects' work that cannot be considered as requirements but are listed here since they are useful observations.

- Poland
  - Architects use AutoCAD[3] and Revit[4] in their everyday job
  - They use BIM models. The main information that they take/add to BIM models are material parameters and properties
  - Architects exchange information with other stakeholders in many ways: email, cloud content management platforms, file serving service, printed documents
  - The frequency of information exchange varies; generally, at least once a week
  - Documents and drawings are the most common type of exchanged information, but annotated photos are also used when details are required
  - Sometimes data is not available electronically in architects' information systems. In such cases, architects request the data from other stakeholders, or access the official project documents.
  - Architects use ArCADia-TERMOCAD and BuildDesk Energy Audit
  - Architects don't model energy performance
  - Architects don't consider occupants' comfort in their calculations. However, they do think that if they had the option to monitor indoor comfort, it would be beneficial to their work.
  - The alternative scenarios are reported to the client and the in-house decision maker
- Spain
  - The information they take/add to BIM models are type of material for the facade, roof and sill, window and terrace enclosures as well as type of thermal installations.
  - Architects don't use BIM models for renovation projects, only for new constructions.
  - Sometimes data is not available electronically in architects' information systems. In such cases, architects request the data from other stakeholders, or try to work without it, or they search for it online in Open BIM libraries.

3 https://www.autodesk.com/products/autocad/

4 https://www.autodesk.com/products/revit/

- Architects use CYPETHERM, HEPLUS, Design Builder HULC, ENERGY PLUS, ARQUIMIDES.
- The alternative scenarios are reported to the client and the in-house decision maker

8.2.2 BIM-experts' requirements

In the first iteration, the BIM Experts (or BIM modellers) user group was targeted with 9 requirements. During the second iteration requirement:

- BMRR-042 was omitted. This requirement was a specific design constraint regarding point cloud formats that was suggested by the polish participants of the first workshop, however participants of the three additional workshops of the second iteration, concluded to a more generic preference regarding point cloud formats.
- BMRR-125 was added.

In the third and last iteration 9 requirements were compiled, 1 of them was changed, 1 requirement was deleted and 7 requirements were verified. The final list of requirements includes 8 requirements targeting the BIM expert (see Table 11). The following bullet list summarizes the changes during the third iteration:

- BMRR-125 was dropped
- BMRR-038 had its priority changed from High to Medium
- BMRR-035, BMRR-036, BMRR-037, BMRR-039, BMRR-040, BMRR-041 and BMRR-043 were verified

Req ID	Description	Type	Priority
BMRR-035	BIM experts shall be able to get point clouds in order to generate BIM models	Functional	High
BMRR-036	BIM experts shall be able to get 2D drawings in order to generate BIM models	Functional	High
BMRR-037	BIM experts shall be able to use auxiliary data related to energy refurbishment	Functional	High
BMRR-038	BIM experts shall be able to employ Level of Development specification from BIMForum	Design Constraint	Medium
BMRR-039	BIM experts shall be able to use commercial software for the generation of BIM/S2B process	Operational	High
BMRR-040	Point clouds shall be stored in basic formats	Design Constraint	High
BMRR-041	Point clouds shall be stored in enriched formats	Design Constraint	High
BMRR-043	BIM experts shall be able to produce BIM models in IFC format	Design Constraint	High

Table 11: User requirements for BIM Experts

8.2.2.1 Comments regarding the BIM-experts user group

Discussions during the workshop produced the following interesting observations:

- Poland

- BIM experts deliver BIM models in both proprietary (e.g. RVT) and open formats (e.g. IFC).
- BIM experts don't export/produce BIM models in energy-oriented formats.
- BIM experts are not aware of the existence of E57 open format.
- BIM experts use Navisworks for managing models.

- Spain
  - BIM experts use auxiliary data while producing a BIM model for energy refurbishment projects such as materials information, thermal transmission of the building envelope, thermography, and orientation.
  - The most common software platform used by BIM experts in order to generate the BIM/S2B process is REVIT.
  - BIM experts are not aware of the existence of E57 open format.

8.2.3 Project managers' requirements

In the first iteration the Project Manager user group was targeted with 17 requirements. During the second iteration 11 requirements were added, specifically:

- BMRR-126, BMRR-127, BMRR-128, BMRR-129, BMRR-130, BMRR-131, BMRR-132, BMRR-133, BMRR-134, BMRR-135 and BMRR-136

In the third and last iteration 28 requirements were compiled.

- BMRR-049, BMRR-050 and BMRR-127 were dropped
- BMRR-044 had its priority changed from Medium to High, and a minor change in the wording to make it more specific
- BMRR-053 and BMRR-056 had their priority changed from High to Medium
- BMRR-045, BMRR-051, BMRR-052, BMRR-054, BMRR-055, BMRR-057, BMRR-058, BMRR-059, BMRR-126, BMRR-129, BMRR-130, BMRR-131, BMRR-132, BMRR-133 and BMRR-135 were verified

The final list of requirements includes 25 requirements targeting Project Managers (see Table 12).

Req ID	Description	Type	Priority
BMRR-044	Project managers shall be able to work with mobile devices (Laptops) running Windows	Design Constraint	High
BMRR-045	Project manager shall be able to work with mobile devices running Android	Design Constraint	Medium
BMRR-046	Project manager shall be able to work with internet connection limited to specific IPs	Design Constraint	High
BMRR-047	Project manager shall be able to exchange information with the architect (person who supervise the project design)	Functional	High
BMRR-048	Project manager shall be able to exchange information with the construction manager (person who oversees the workflow on the construction site)	Functional	High
BMRR-051	Project manager shall be able to exchange drawings	Functional	High

BMRR-052	Project manager shall be able to exchange documents	Functional	High
BMRR-053	Project manager shall be able to exchange annotated photos	Functional	Medium
BMRR-054	Project manager shall be able to find construction drawings in order to properly complete his/her work	Functional	High
BMRR-055	Project manager shall be able to retrieve AutoCAD files of the building of the renovation project	Functional	High
BMRR-056	Project manager shall be able to retrieve Spreadsheets with building information of the renovation project	Functional	Medium
BMRR-057	Project manager shall be able to retrieve PDF documents with building information of the renovation project	Functional	High
BMRR-058	Access to building information shall be restricted only to specific stakeholders	Legal	High
BMRR-059	Site managers shall receive notification when planned construction works are rescheduled	Process	High
BMRR-060	Project manager should be able to order materials with an automated process	Functional	Medium
BMRR-126	Project manager shall be able to exchange information with the client	Functional	High
BMRR-128	Project manager shall exchange information in real-time with the site manager	Functional	High
BMRR-129	Project managers will use tools that can support files for import functionality	Design Constraint	High
BMRR-130	Project managers will use tools that can support files for export functionality	Design Constraint	High
BMRR-131	Project managers shall be able to reduce the number of project re-schedules that occur due to poor initial planning of work	Functional	Medium
BMRR-132	Working crews shall receive notification when planned construction works are rescheduled	Process	High
BMRR-133	Occupants shall receive notification when planned construction works are rescheduled	Process	Medium
BMRR-134	The information of project rescheduling should reach all interested stakeholders within days of the project manager's decision	Process	Low
BMRR-135	After the project manager decides on a change in project plan, an automated email notification should follow	Process	Low
BMRR-136	From a process perspective, project manager will exchange the following information: task scheduling, budget, unit cost, changes, drawings, notes	Process	High

Table 12: User requirements for Project Managers

8.2.3.1 Comments regarding the Project Manager user group

Discussions during the workshop produced the following interesting observations:

- Poland
  - Project managers use Microsoft Project in their everyday jobs.
  - the data formats that are supported for importing to/exporting from these tools are: BXF, PDF, XLS, DWG.
- Spain
  - Project managers think that process-wise, material orders should be automated.

- Project managers noticed that when on site, internet connection might be subject to maximum download/upload quota.
- Project managers use Microsoft Project, Revit and AutoCAD in their everyday jobs.
- The data formats that are supported for importing to/exporting from these tools are: PDF, DWG, DOC, XLS, JPG, IFC.

8.2.4 Site managers' requirements

In the first iteration, 15 user requirements were elicited for the Site manager user group. During the second iteration, requirements:

- BMRR-064, BMRR-067 and BMRR-072 were revised
- BMRR-137, BMRR-138, BMRR-139, BMRR-140, BMRR-141, BMRR-142, BMRR-143, BMRR-144, BMRR-145 and BMRR-146 were added

In the third and last iteration 25 requirements were compiled.

- BMRR-064 was dropped
- BMRR-070 had its priority changed from High to Low.
- BMRR-071 had its priority changed from High to Medium.
- BMRR-063, BMRR-065, BMRR-068, BMRR-069, BMRR-073, BMRR-074, BMRR-075, BMRR-076, BMRR-137, BMRR-139, BMRR-140 and BMRR-141 were verified

The final list of requirements includes 24 requirements targeting Site Managers (see Table 13).

Req ID	Description	Type	Priority
BMRR-062	Site manager shall be able to work with internet connection limited to specific IPs.	Design Constraint	High
BMRR-063	Site manager shall be able to work with mobile devices running Android	Design Constraint	Medium
BMRR-065	Site managers should receive pictures reporting changes at the construction site	Functional	High
BMRR-066	Site manager shall be able to exchange information with the architect (person who supervise the project design)	Functional	High
BMRR-067	Site manager shall be able to exchange information with the construction manager (the person who oversees the construction works)	Functional	High
BMRR-068	Site manager shall be able to find construction drawings in order to properly complete his/her work	Functional	High
BMRR-069	Site manager shall be able to retrieve AutoCAD files of the building of the renovation project	Functional	High
BMRR-070	Site manager shall be able to retrieve Spreadsheets with building information of the renovation project	Functional	Low
BMRR-071	Site manager shall be able to retrieve PDF documents with building information of the renovation project	Functional	Medium
BMRR-072	Access to building information shall be restricted only to specific stakeholders	Legal Pilot Specific	High

BMRR-073	Site managers should be able to send out Health and Safety alerts by using a mobile app	Design Constraint	High
BMRR-074	Site managers should be able to send photos with text comments along with the Health and Safety alerts	Functional	High
BMRR-075	If 3D visualizations are available on site, site managers should have access to BIM overlays	Functional	High
BMRR-076	Site managers should be able to send Health and Safety alerts (H&S) when a H&S issue has been identified	Functional	High
BMRR-137	Site manager shall be able to work with lap tops running windows	Design Constraint	High
BMRR-138	Site managers will synchronize their data with the BIM model in a frequency that ranges from once a day to once a week	Design Constraint Pilot Specific	High
BMRR-139	Site managers will use tools that can support files for import functionality	Design Constraint	High
BMRR-140	Site managers will use tools that can support files for export functionality	Design Constraint	High
BMRR-141	Site managers will use email to exchange information with other stakeholders	Design Constraint	Low
BMRR-142	Site managers will continuously exchange information with working crews	Operational	High
BMRR-143	Site managers will exchange information with the architects and project manager at least twice a week real time	Operational	High
BMRR-144	Site managers will exchange information with the client no more than twice a month real time	Operational	High
BMRR-145	Energy efficient materials/equipment should be integrated into the procurement system	Functional Pilot Specific	High
BMRR-146	Site managers should be able to track all changes occurring at the construction site	Functional	High

Table 13: User requirements for the Site Managers

8.2.4.1 Comments regarding the Site managers user group

Discussions during the workshops produced a list of comments regarding the Site manager's work, listed here as interesting observations:

- Poland
  - Site managers think that carrying a tablet on site is not practical. Furthermore, they think that tablets can be a source of unnecessary distraction for the employees.
  - Site managers use FreeCAD, Microsoft Project, Autodesk Revit and OpenProject in their work.
  - Site managers exchange information using email, web-based project management software and printed documents. The frequency depends on the project, but generally information is exchanged few times per week.
  - Site managers exchange real-time information with architects.
  - Site managers use existing drawings, and documents, along with survey results in order to acquire building information.

- Site managers think that using hardhats with augmented reality headsets attached on-site could prove to be too expensive policy for the construction company.
- Site managers would like the augmented reality tools to have better accuracy.

- Spain
  - Site managers think that AR headset is too expensive to be considered for their daily work on site.
  - Site managers think that 3D representations are not common in renovation projects.
  - Site managers use ArchiCAD, AutoCAD, Revit, Microsoft Project and BIM collab in their everyday jobs.
  - The data formats that are supported for importing to/exporting from these tools are: PDF, IFC, XML, DWG, DOC, JPG.
  - BIM methodology is not used in residential renovation projects.
  - Site manager highlighted the importance of traceability of changes occurring at construction.
  - Site managers, when on site, don't have access on Wi-Fi. Cellular coverage is the only option. Inside buildings with thick walls, there is no internet connectivity.

8.2.5 Surveyors' requirements

In the first iteration 18 user requirements were elicited for the Surveyor user group. During the second iteration, requirements:

- BMRR-080 and BMRR-085 were revised
- BMRR-079 was omitted. This requirement was about the power supply availability at the construction site for the surveyor's work. Responses between the first workshop and the interviews of this iteration were contradictory.

In the third and last iteration 19 requirements were compiled:

- BMRR-085 and BMRR-086 were dropped
- BMRR-083 had its priority changed from High to Medium
- BMRR-084 had its priority changed from Medium to High
- BMRR-090 and BMRR-091 had their priority changed from High to Low
- BMRR-147 had its priority changed from Low to Medium
- BMRR-077, BMRR-078, BMRR-080, BMRR-082, BMRR-093, BMRR-094 were verified

The final list of requirements includes 17 requirements targeting building surveyors (Table 14).

Req ID	Description	Type	Priority

BMRR-077	Surveyors shall be able to work with mobile devices (Laptops) running Windows	Design Constraint	Medium
BMRR-078	Surveyors shall be able to work with mobile devices running Android	Design Constraint	Medium
BMRR-080	Surveyor shall be able to ask residents/facility managers to provide input via a mobile data collection app	Functional Pilot Specific	High
BMRR-081	Surveyors should be aware of any hidden installation of the building to be renovated	Functional	High
BMRR-082	Residents/facility managers should be able to provide pictures of hidden installations of the building to be renovated	Functional	High
BMRR-083	Residents/facility managers should be able to provide notes with information about the building to be renovated	Functional	Medium
BMRR-084	Residents/facility managers should be able to provide markups on existing drawings indicating information about the building to be renovated	Functional	Low
BMRR-087	The level of accuracy for the design models shall be less than 10 mm for building constructions	Performance	High or Medium depending on the specifications
BMRR-088	Surveyor shall be able to acquire 3D data	Functional	High
BMRR-089	Surveyor shall be able to acquire laser intensity data	Functional	High
BMRR-090	Surveyor shall be able to produce geo-referenced data	Functional	Low
BMRR-091	Surveyor shall be able to employ Level of Development specification from BIMForum	Design Constraint	Low
BMRR-092	Surveyor should be able to annotate the 3D model with information about the building using a mobile device application	Functional	High
BMRR-093	Surveyor shall be able to wear safety helmets during building survey	Design Constraint	High
BMRR-094	Surveyor shall be able to work in a well-lit environment	Legal	High
BMRR-147	Surveyor shall be able to ask residents/facility managers to provide input via email	Functional Pilot Specific	Medium
BMRR-148	Surveyors shall be able to use open formats for delivering as-is data.	Design Constraints Pilot Specific	High

Table 14: User requirements for the Building Surveyor user group

8.2.5.1 Comments regarding the Surveyor user group

Discussions during workshops produced some interesting observations:

- Poland
  - Surveyors don't need internet access when they work at the construction site.
  - Surveyors can carry all kind of mobile devices with them (smartphone, tablet)
  - Surveyors use RiSCAN as scanning software.
  - Surveyors usually validate the design model with cameras and scanners mounted on drones and airframes.

- Surveyors don't use mobile devices or field tools such as BIM 360 or PointLayout. They only use the mobile application of the laser scanner.
- The cost of 3D scanning and producing the as-is data depends on how many rooms the building has and how detailed the model should be. Additionally, after the scanning, the data cleansing process must also follow (remove useless data such as furniture).
- As an example, for an apartment with four rooms and 100 m^2 floor area the cost estimation is approximately 500 euros (including laser scanning and data cleansing). Regarding the time required to complete this work, the surveyor needs approximately 4 hours of work (1 hour of scanning and 3 hours for model elaboration).
- Surveyors had past experience from using Augmented Reality (AR) tools. They think that the devices used for running the AR application were too slow due to the increased demands of the 3D model.
- Surveyors do not use indoor navigation. They think that for renovation projects this is not so important.

- Spain
  - Surveyors, when on site, don't have access to Wi-Fi. Cellular coverage is the only option. Inside buildings with thick walls, there is no internet connectivity.
  - Surveyors won't use terrestrial laser scanning for residential renovation projects.
  - Surveyors work with open formats, but they never heard of E57 format.
  - Surveyors won't use AR tools for residential renovation projects.
  - Surveyors had never used AR applications running on phone/tablet.
  - Surveyors, during data acquisition, when the building is still in use, don't use PPE (personal protective equipment). However, during construction works PPE is mandatory.
  - The use of drones within the city is not allowed.

8.2.6 Workers' requirements

In the first iteration 18 user requirements targeting the Worker user group, were derived.

During the second iteration, requirements:

- BMRR-103 and BMRR-110 were revised
- BMRR-149 and BMRR-150 were added

In the third and last iteration 20 requirements were compiled, 1 of them was dropped, 3 requirements were changed to lower priority and 10 were verified. The

final list of requirements includes 19 requirements targeting Workers (Table 15). The following bullet list summarizes the changes of the third iteration:

- BMRR-096 was dropped.
- BMRR-104 was given a Medium priority instead of High
- BMRR-105 and BMRR-112 were given a Low priority instead of High
- BMRR-095, BMRR-097, BMRR-098, BMRR-099, BMRR-100, BMRR-102, BMRR-103, BMRR-107, BMRR-109 and BMRR-111 were verified.

Req ID	Description	Type	Priority
BMRR-095	Workers shall exchange information via the internet	Functional	High
BMRR-097	Workers should be able to exchange real-time information with other workers	Functional	High
BMRR-098	Workers should be able to exchange real-time information with the Health & Safety manager	Functional	High
BMRR-099	Workers should be able to exchange real-time information with the site manager	Functional	High
BMRR-100	Workers should be able to exchange real-time information with foreman	Functional	High
BMRR-101	Access to building information shall be restricted only to specific stakeholders	Legal	Low
BMRR-102	Workers should be able to send photos with text attached to the site manager in order to describe a construction defect	Functional	High
BMRR-103	Workers should be able to receive Health and Safety notifications using a mobile app running at their phones	Functional	High
BMRR-104	Workers should receive Health and Safety notification before their day-shift	Process	Medium
BMRR-105	Workers should receive Health and Safety (H&S) notification when H&S events are identified	Process	Low
BMRR-106	Worker should be able to operate his/her Augmented Reality Classes with gestures	Functional	High
BMRR-107	Workers should be able to receive instructions on-demand	Functional	High
BMRR-108	Workers should be able to detect moisture intrusion	Functional	Medium
BMRR-109	If 3D visualizations are available on site, workers should be able to track the location of their assigned tasks	Functional	High
BMRR-110	If 3D visualizations are available on site, workers should have access to BIM overlays	Functional Pilot Specific	Medium
BMRR-111	Workers should be able to receive on-site guidance for the technologies used at the construction site	Functional	Medium
BMRR-112	Workers shall be able to perform their tasks in highly noisy environments	Operational	Low
BMRR-149	Workers shall be able to get foreman (or construction manager) approval (guidance) during their work	Functional	High
BMRR-150	Worker should be able to operate his/her Augmented Reality Glasses with voice commands	Functional	Low

Table 15: User requirements for the Worker user group

8.2.6.1 Comments regarding the Workers user group

Discussions during workshops also produced some interesting observations:

- Poland
    - During work, workers will not carry tablets, however, they sometimes bring their smartphones.
    - Workers do not use any software applications for their work.

There are no comments from Workers that participated in the Spanish workshop in Valencia.

8.2.7 Occupants' requirements

Due to Covid-19 no physical meetings took place with the occupants of the pilot buildings in Poland and Spain, and hence, requirements are based solely on occupants' responses to the online questionnaires.

For the methodology, each requirement is derived from the responses with the higher participation/preference, while the priority of each requirement is derived based on the actual percentage of respondents to that particular response, i.e. when higher than 50% of responses target a specific functionality/constraint, then the derived requirement is classified as of High priority, when the same percentage is between 40-50% as of Medium priority, and finally when the responses are practically divided we are led to Low priority requirements.

There were questions designed to lead to more than one requirement, e.g. S13 (page 118 herein) of the Occupants' online questionnaire [7], in these cases the prioritization was based on comparisons between the most preferred options.

Note that only questions that had more than ten participants were processed for requirements elicitation.

This process led to 13 requirements targeting the occupants' user group (see Table 16).

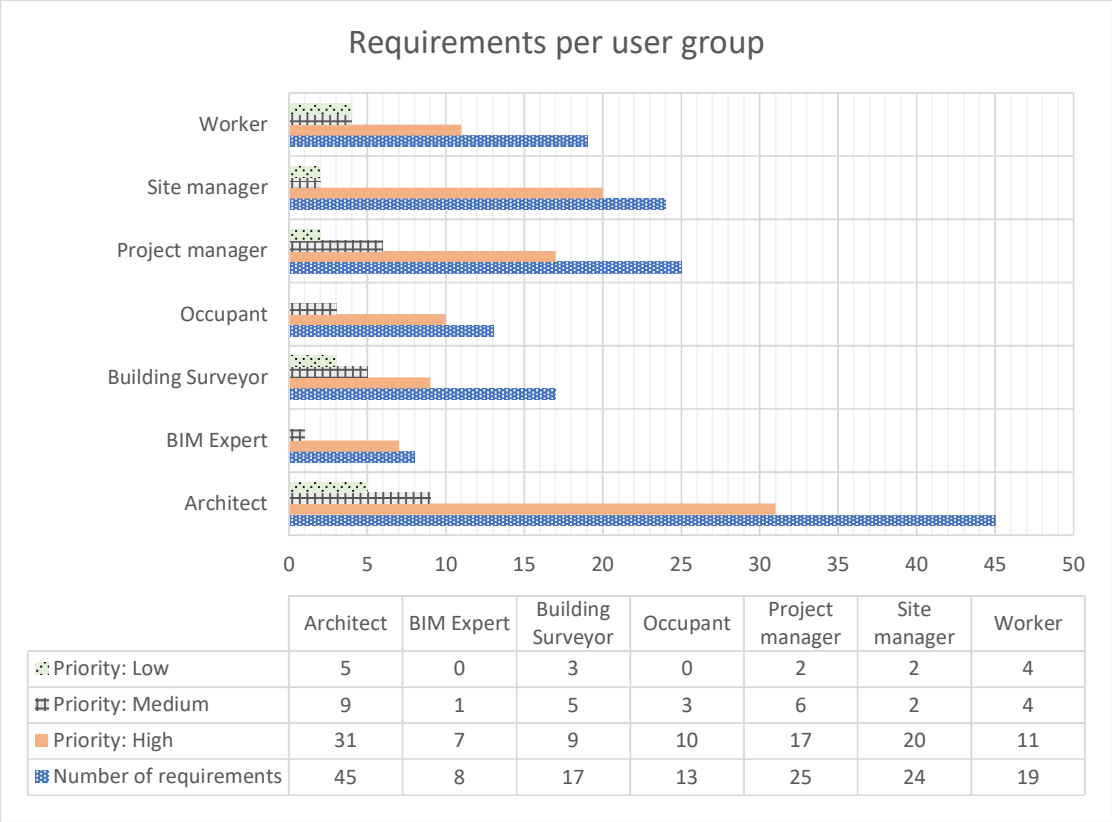
Req ID	Description	Type	Priority
BMRR-151	Occupants shall be able to use their smartphone for exchanging information with other stakeholders	Design Constraint	Medium
BMRR-152	Occupants will have Wi-Fi connectivity in their premises	Design Constraint	High
BMRR-153	Occupants shall be able to provide input regarding the building that is to be renovated	Functional	High
BMRR-154	Occupants shall be able to provide photos regarding their building/premises	Design Constraint	High
BMRR-155	Occupants should receive an email when information is needed from them.	Functional	High
BMRR-156	Occupants should be able to send information regarding their premises to be renovated via a mobile application	Design Constraint	High
BMRR-157	In case a location specific information is to be provided, occupants should be able to directly annotate photos for that purpose via a mobile application	Design Constraint	High
BMRR-158	Occupants should receive weekly alerts/instructions about construction site safety	Operational	Medium

BMRR-159	Occupants shall be informed about the renovation process activities when performed	Operational	High
BMRR-160	Regarding issues that occur on site and for which occupants' opinion is required, occupants should be able to watch a video regarding the issue and provide the necessary feedback	Functional	High
BMRR-161	Occupants should experience an improved air quality after renovating their premises	Performance	High
BMRR-162	Occupants should experience better temperature conditions after renovating their premises	Performance	Medium
BMRR-163	Occupants shall be able to know the progress level of the planned renovation activities at any given moment	Functional	High

Table 16: User requirements for the Occupants user group

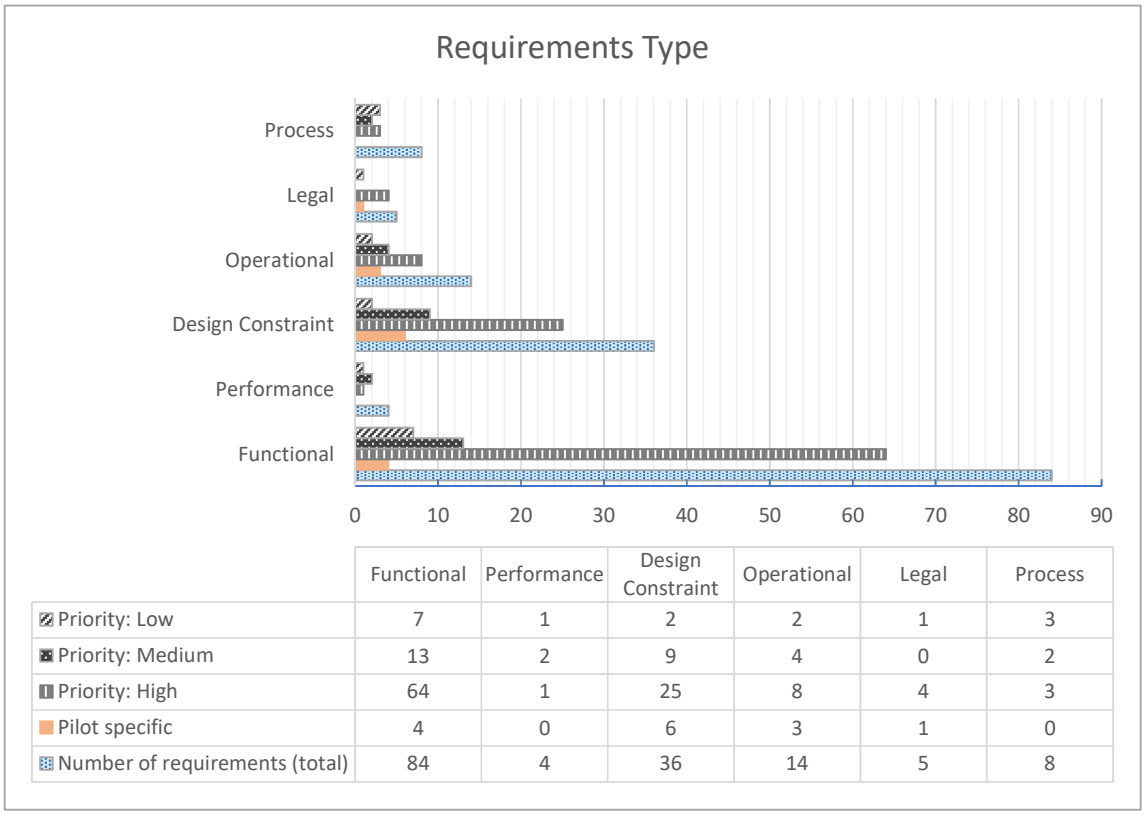
8.2.8 User requirements analysis

The final list of the user requirements is provided in Annex 9. Further analysis is provided here in terms of the originator, priority and type. Specifically, in Figure 11 the total number of requirements and the number of High/Medium/Low priority requirements per BIMERR user group is shown. Figure 12 focuses on the requirement type, reporting also the number of pilot specific requirements out of the total number. Again, the number of High/Medium/Low priority requirements per type has been added to Figure 12. Overall, almost half of the user requirements refer to functional requirements while two thirds are of high priority.



	Architect	BIM Expert	Building Surveyor	Occupant	Project manager	Site manager	Worker
Priority: Low	5	0	3	0	2	2	4
Priority: Medium	9	1	5	3	6	2	4
Priority: High	31	7	9	10	17	20	11
Number of requirements	45	8	17	13	25	24	19

Figure 11: Number of requirements per user group



	Functional	Performance	Design Constraint	Operational	Legal	Process
Priority: Low	7	1	2	2	1	3
Priority: Medium	13	2	9	4	0	2
Priority: High	64	1	25	8	4	3
Pilot specific	4	0	6	3	1	0
Number of requirements (total)	84	4	36	14	5	8

Figure 12: Number of requirements per type

CONCLUSIONS

This deliverable provides a thorough description of business scenarios, use cases and system requirements tailored to the BIMERR goals.

First, to facilitate the realization of project outcomes, five business scenarios were produced from the high-level business objectives of the project and after consultation with the consortium members they were expanded to sixteen appropriate use cases that will lead the development of the respective components of the BIMERR framework.

Based on the described renovation process along with the involved user groups and the subsequent grouping in the context of BIMERR, a series of questionnaires were produced, each targeting a different BIMERR main user group.

The originally proposed time limited requirements phase was extended with an iterative methodological approach in order to further increase the quality and validity of the produced results. The concept was to gather the feedback from the end users at different iterations and then reflected it to deliverable updates, in order to enhance the credibility of the produced user requirements.

Four workshops were organized, two in Poland and two in Spain, in the context of the Living Labs. The workshops included participants from all the main user groups, apart from the occupants who were targeted (together with the other user groups) only at the third iteration with an online survey, after the pilot buildings were finalized.

The analysis of the feedback from the workshops and the online questionnaires led to the definition of 151 requirements separated per user group. We have defined the different types of these requirements taking into account the taxonomy addressed in the project as well as a priority level in order to reflect the BIMERR project primary goals as well as user's feedback.

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[14] ISO/IEC/IEEE, “ISO/IEC/IEEE International Standard - Systems and software engineering -- Life cycle processes --Requirements engineering.” 2011.

ANNEX 1: USE CASE TEMPLATE

BIMERR Use Case Template	
UC ID	UC-x
Use Case Title	Short title
Related Business Scenario(s)	BSi
Description	Story-like description of the events, interactions between actors and systems
Involved Stakeholders	Roles that people have in relation to the renovation process
BIMERR components involved	BIMERR tools/components/modules
Pre-conditions	The conditions that must be met before the scenario described in this use case can be implemented.
Use Case Path	A short description of the workflow followed in the use case, based on BIMERR modules, defining the architecture.
Post Condition	What is achieved if this use case is successfully completed
Business Impact	The benefits to the involved stakeholders and to the BIMERR beneficiaries from the successful execution of the UC
Leading Partner	Consortium partner(s) highly involved in the development of the systems components and functionalities associated with the UC
Contributing Partners	Consortium partners with supporting roles
Priority	The priority of the UC for the Construction Companies

ANNEX 2: TEMPLATE FOR ACQUIRING TECHNICAL PARTNERS' QUESTIONS

User Group			
Use Cases: *The use cases that the specific user group participates in*	**UC-xx**	**UC-xx**	**UC-zz**
Leading Partner: *The leading partner of the UC*	***Partner***	***Partner***	***Partner***
Contributing Partners:	***Partners***	***Partners***	***Partners***
Bimerr Tools: *The BIMERR tools that are used in the UC*	*tool*	*tool*	*tool*
	tool	*tool*	*tool*
	tool	*tool*	*tool*
Questions in order to identify the User Group Requirements for the BIMERR tools in each Use Case			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

ANNEX 3: EXCERPTS FROM BIMERR MAIN USER GROUPS' QUESTIONNAIRES

Architect	
ID	**Question**
S1	Which devices do you use for work? A. Lap-top B. Phone C. Smartphone D. Tablet E. other Please specify……....
S2	What operating systems do these devices use? A. Windows D. Linux C. Android D. other, please specify …….
S3	Which applications and information systems do you typically use in your everyday job? A. ArchiCAD B. AutoCAD Architecture C. Autodesk Revit D. FreeCAD E. other, please specify ……
S4	What import functionality do they support? A. through APIs B. as files C. other, please specify……...
S5	What data formats are supported for importing data to these applications? (e.g. IFC, DGN, DWX, XML, JSON, CSV, ASCII, GML) Please specify ……
S6	What export functionality do they support? A. through APIs B. as files C. other, please specify ……...
S7	What data formats are supported for exporting data from these applications? (e.g. IFC, DGN, DWX, XML, JSON, CSV, ASCII, GML) Please specify …….
S8	Which tools/systems do you use for handling Building Information Modelling (BIM) models and 3D architectural design? A. AutoCAD

	B. Revit C. ArchiCAD D. other, please specify…… E. I don't use BIM models. <if 'E', please skip S9, S10>
S9	What are the main data formats that you use to import BIM models to these systems? (e.g. IFC, gbXML, etc.) Please specify ……
S10	Which formats do you export to your BIM models, when using these systems? (e.g. IFC, gbXML, etc.) Please specify …….
☐	⋮

Table 17: Excerpt from the Architects' Questionnaire

BIM expert	
ID	**Questions**
S1	Which data do you need to effectively generate BIM models, i.e. conduct a Scan-to-BIM (S2B) process? A. point clouds B. geo-referencing data C. 2D drawings D. 3D models E. other, please specify……
S2	Do you use other auxiliary data while producing a BIM model with a view on energy refurbishment? (e.g. heat transfer parameters, information about materials, etc.) Please specify……
S3	Do you employ (or are you required to adhere to) Level of Accuracy (LOA) and Level of Detail (LOD) specifications for your data? A. no B. yes, please specify any standards (e.g. GSA) that you may use……
S4	Which software platform do you use for the generation of BIM/S2B process? A. commercial software (e.g. REVIT) B. in-house built software C. other, please specify……
S5	Do you have any automated task in the BIM/S2B process? (e.g. structural components detection) A. no B. yes, please specify…….
S6	Which storage formats do you usually use for handling point clouds? A. basic formats (e.g. XYZ, PTS…) B. enriched data formats (e.g. PTX, E57…) C. others, please specify…….
S7	Do you use/require open formats for storing and sharing your data? A. yes B. no
S8	Are you aware of the existence of the E57 open format for point cloud data storage and exchange? A. yes B. no

☐	☐

Table 18: Excerpt from the BIM experts' Questionnaire

Surveyor	
ID	Questions
S1	What kind of internet connectivity do you have when working in the field? A. none B. Wi-Fi C. cellular (2G, 3G, 4G) D. other, please specify…….
S2	What devices do you have with you? A. laptop B. smartphone D. phone E. tablet F. other, please specify……
S3	What operating systems do these devices use? A. Windows D. Linux C. Android D. other, please specify…….
S4	How difficult is to have access to power connection at the construction site? A. Very easy B. Easy C. Difficult D. Very difficult
S5	What construction software platform do you use? A. COINS B. Primavera C. TheoLT D. other, please specify…….
S6	Suppose you have the option to ask residents/workers additional information about the building you are surveying. How would you like them to provide input? A. email B. SMS C. mobile data collection app D. web based survey E. other, please specify…….
S7	What kind of information would you require from the residents/workers? A. photos

	B. notes C. markups on existing drawings D. other, please specify…….
S8	Should the input from residents/workers A. be added directly in existing surveying reports B. be annotated onto existing drawings with exact locations C. other, please specify…….
S9	Have you used laser scanning to validate a design model (e.g. in CAD or BIM)? A. Yes B. No
S10	Do you use terrestrial laser scanners (e.g. FARO, LEICA) A. no B. yes, please specify the model ……..
⋮	⋮

Table 19: Excerpt from the Surveyors' Questionnaire

<table>
<tr><th colspan="2">Occupant</th></tr>
<tr><th>ID</th><th>Questions</th></tr>
<tr><td>S1</td><td>What kind of wireless technology devices do you normally use ?
A. smartphone
B. tablet
C. desktop/laptop
D. other, please specify ……..</td></tr>
<tr><td>S2</td><td>What kind of internet connectivity is there at your home?
A. fixed line
B. Wi-Fi
C. cellular (2G, 3G, 4G)
D. other, please specify……..</td></tr>
<tr><td>S3</td><td>If your building/premises is to be renovated, would you be interested in providing input (i.e. upload information for aspects of your building/premises, give feedback on the renovation activities, report Health and Safety issues, etc.)?
A. yes
B. no

<if “no”> skip S4-S6</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td>S13</td><td>Please rate (with a ‘x’) the following preferences regarding your living comfort:
<table>
<tr><th>Preference</th><th>Not important</th><th>Somewhat important</th><th>Important</th><th>Very Important</th></tr>
<tr><td>Temperature</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Humidity</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Luminance</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Air quality</td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>S14</td><td>Have you been asked about your preferences when renovating your property? Did you have a
choice between several alternatives?
A. yes
B. no
<if “no”>, skip S15-S16</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
</table>

Table 20: Excerpt from the Occupants’ Questionnaire

Project Manager	
ID	Questions
S1	What kind of internet connectivity do you have in your office? A. none B. fixed C. Wi-Fi D. cellular (2G, 3G, 4G)? E. other, please specify…….
S2	What devices do you use for your work? A. lap-top B. phone C. smartphone D. tablet E. other, please specify….
S3	What operating systems do these devices use? A. Windows B. Linux C. Android D. iOS E. other, please specify……..
S4	For your work, you exchange information with other stakeholders. Who are these stakeholders? (e.g. project manager, BIM expert, etc.) (*please specify a list*)
S5	How do you exchange information with other stakeholders? A. via email B. using a cloud content management and file sharing service (e.g. Box, Confluence, etc.) C. using a mobile and web-based project management software D. with printed documents E. other, please specify……
S6	How frequently do you exchange information with them? *Please specify time span:* [day],[week],[month]

	Please select frequency within the time span (how many times in the selected time span): [1],[2],[3],[4],[5],[6],[7],[8],[9],[10]
S7	What type of information do you exchange? A. drawings (2D/3D) B. documents/notes/text C. annotated photos D. other, please specify ……
S8	Which are the stakeholders with whom it is most critical to exchange data / information at real-time? (e.g. site manager, designer, etc.) Please specify …….
S9	What type of data you need from other stakeholders in order to properly complete your work? A. construction drawings B. specifications C. information from surveys D. pre-existing BIM model E. other, please specify……
S10	How do you find data that you need and do not have electronically in your information system? A. I request the data from another stakeholder B. I try to work without it, trusting my working experience C. I access the official project documents D. I search for it online in Open BIM libraries at manufacturer's libraries. E. other, please specify……
⋮	⋮

Table 21: Excerpt from the Project Managers' Questionnaire

Site Manager	
ID	**Questions**
S1	What kind of internet connectivity do you have when working in the field? A. none B. fixed C. Wi-Fi D. cellular (2G, 3G, 4G)? E. other, please specify…….
S2	What devices do you have with you? A. lap-top B. phone C. smartphone D. tablet E. other, please specify….
S3	What operating systems do these devices use? A. Windows D. Linux C. Android D. other, please specify …….
S4	Do you identify any issues in carrying a tablet on-site? A. yes B. no
S5	How would you prefer the changes at the construction site to be reported back to you? A. with pictures B. with video C. other, please specify…….
S6	Which applications and information systems do you typically use in your everyday job? A. ArchiCAD B. AutoCAD Architecture C. Autodesk Revit

	D. FreeCAD E. Microsoft Project F. JIRA G. Redmine H. Basecamp I. Primavera J. OpenProject K. other, please specify ……..
S7	What import functionality do they support? A. through APIs B. as files C. other, please specify …….
S8	What data formats are supported for importing data to these applications? (e.g. IFC, DGN, DWX, XML, JSON, CSV, ASCII, etc.) Please specify……..
S9	What export functionality do they support? A. through APIs B. as files C. other, please specify ……..
S10	What data formats are supported for exporting data from these applications? (e.g. IFC, DGN, DWX, XML, JSON, CSV, ASCII, etc.) Please specify……
⋮	⋮

Table 22: Excerpt from the Site Managers' Questionnaire

Worker

ID	Questions
S1	What kind of internet connectivity do you have at the construction site? A. none B. Wi-Fi C. cellular (2G, 3G, 4G)
S2	What devices do you have with you? A. smartphone B. tablet C. other, please specify…….
S3	Do you identify any issues in carrying a tablet on-site? A. yes B. no
S4	Do you use any software applications in your every day job (e.g. BIM 360 Field or BIM360 Docs)? A. no B. yes, (*please specify*)
S5	Please rate (with a 'x') how important to your work is to be able to exchange information (e.g. photos, notes, etc.) real-time with:

Construction Crew	Not important	Somewhat important	Important	Very Important
other workers				
site manager				
foreman				
H&S manager				

* H&S: Health and Safety

S6	You work in a construction site where a building is being renovated. You see that the owners have installed air conditioning equipment. Are you allowed to share this information with your friends who are not working at your company? A. yes B. no C. I don't know

S7	Would you prefer to receive on-site guidance for the technologies you can use at the construction site? A. yes B. no
S8	You walk around the construction site and you notice that a protection from falling is not fixed properly. Do you think it would be useful to be able to communicate this directly to the Site Manager (or the Health and Safety Manager) in real time? A. yes B. no
S9	You want to describe a construction defect to the site manager who is currently in his office. Which from the following do you find easier to do? A. Use an application installed in my phone (or tablet) that A1. allows me to describe the issue by filling in pre-defined fields. A2. shows me construction drawings and allows me to annotate them. A3. allows me to take a photo and write a short text about it. B. Use my smart glasses.
S10	How would you like to receive Health and Safety alerts, observations, etc. ? A. at my phone using a mobile app B. at my tablet using a tablet app C. at my smart glasses
⋮	⋮

Table 23: Excerpt from the Workers' Questionnaire

ANNEX 4: DEMOGRAPHIC QUESTIONS

What is your gender?

▢ Male
▢ Female
▢ Other
▢ Prefer not to say

What is your age?

▢ Under 30
▢ 30 - 45 years old
▢ 46 - 60 years old
▢ Over 60

What is the highest degree or level of school you have completed?

▢ Primary education
▢ Secondary education
▢ Vocational
▢ Bachelor
▢ Master
▢ Doctoral

Years of experience in the role for which you are completing this survey.

……

Are you familiar with Building Information Modeling (BIM) tools and processes?

▢ Yes, I am currently working in a BIM environment
▢ Yes, I have worked with BIM methods in the past
▢ Yes, but I have never worked with BIM tools
▢ Never heard of this

ANNEX 5 - DEMOGRAPHIC ANALYSIS FOR THE POLISH WORKSHOPS

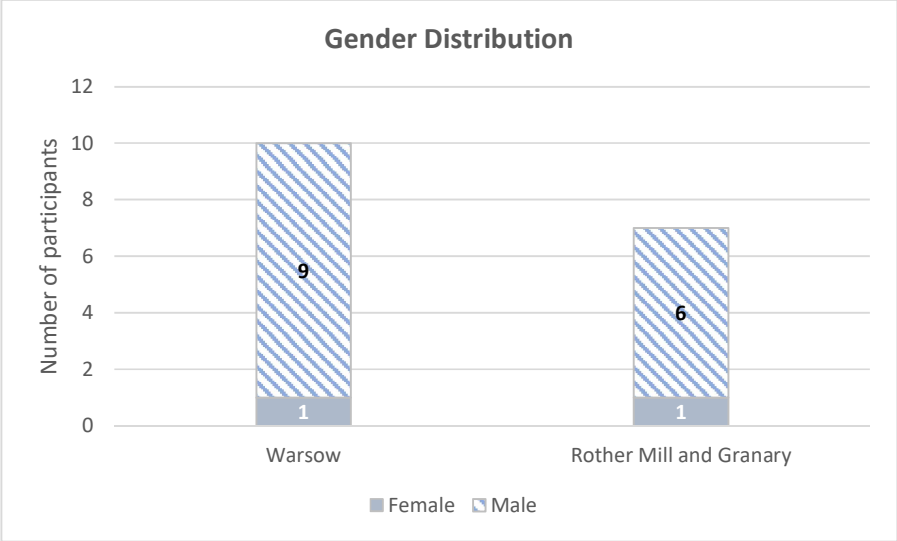

Figure 13: Polish workshops-Gender distribution

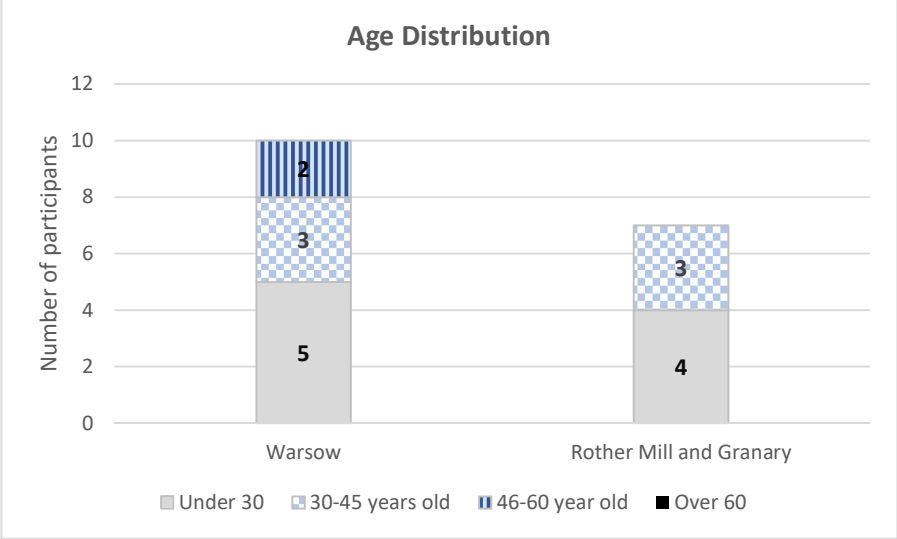

Figure 14: Polish workshops- Age distribution

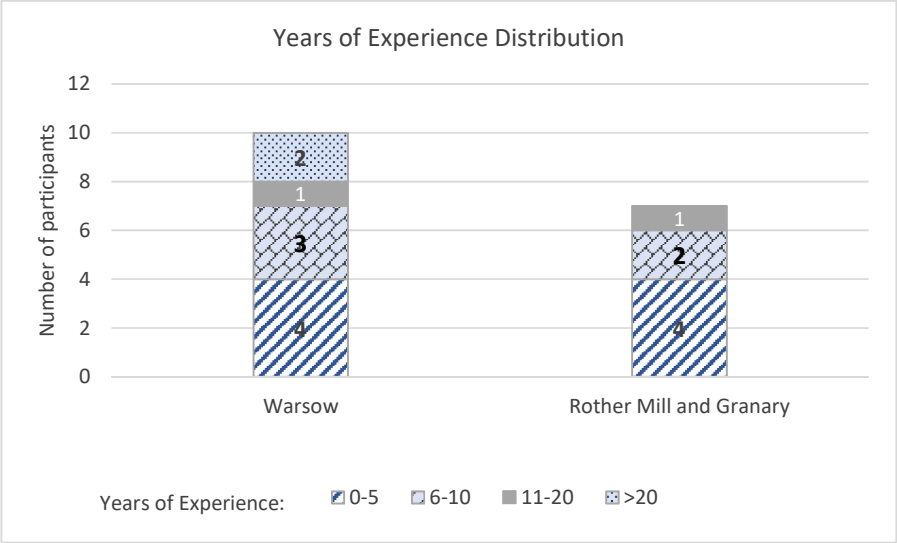

Figure 15: Polish workshops- Years of experience distribution

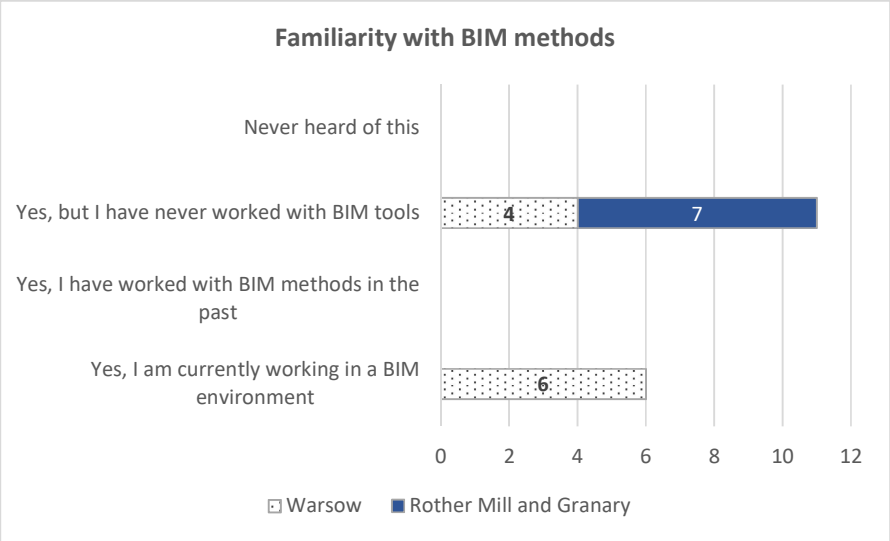

Figure 16: Polish workshops- Familiarity with BIM methods

ANNEX 6 - DEMOGRAPHIC ANALYSIS FOR THE SPANISH WORKSHOPS

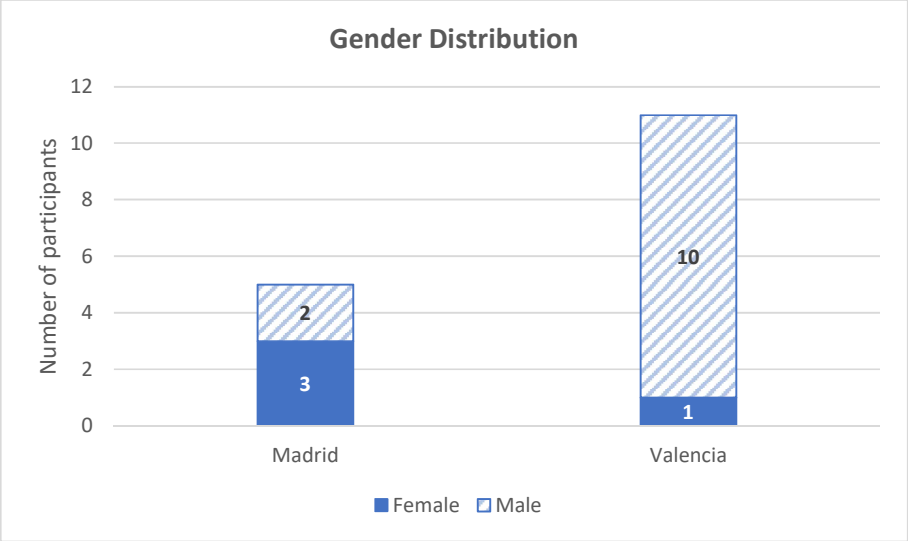

Figure 17: Spanish workshops- Gender distribution

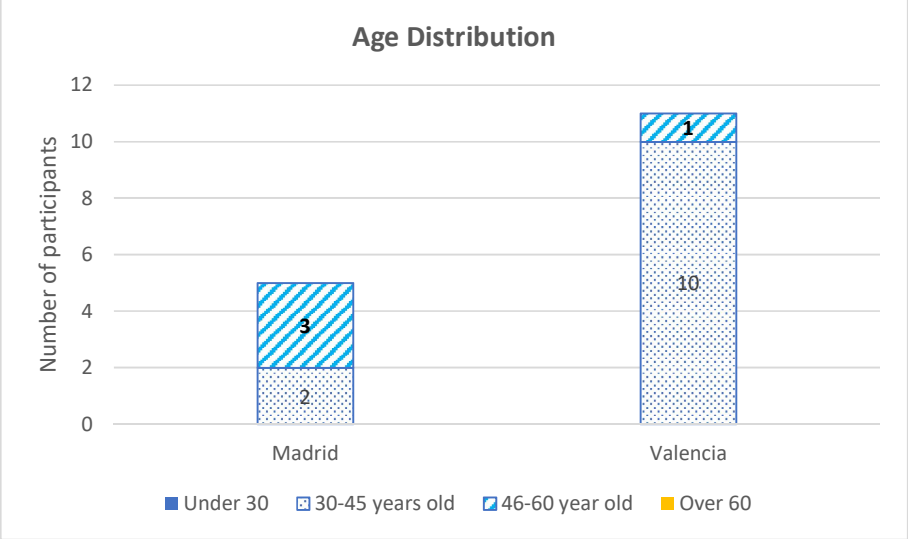

Figure 18: Spanish workshops- Age distribution

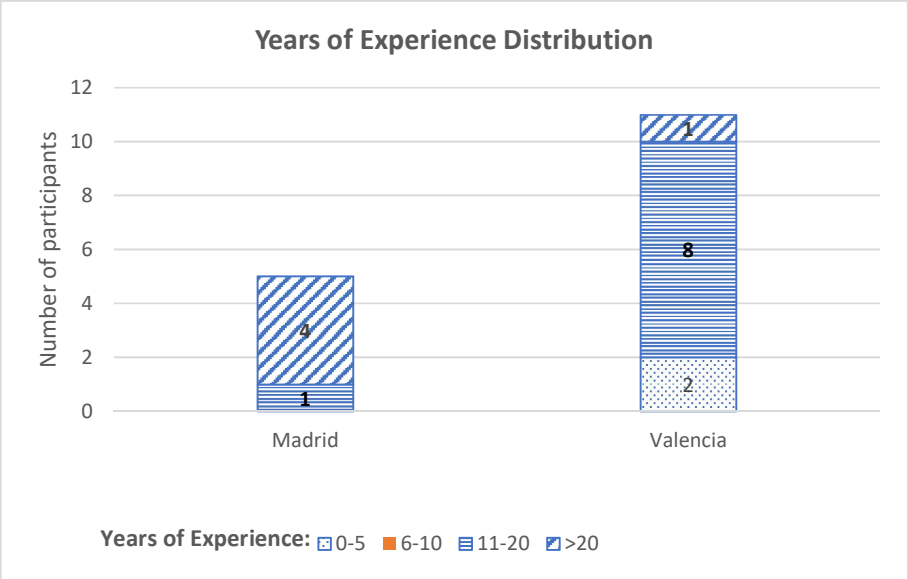

Figure 19: Spanish workshops- Years of experience distribution

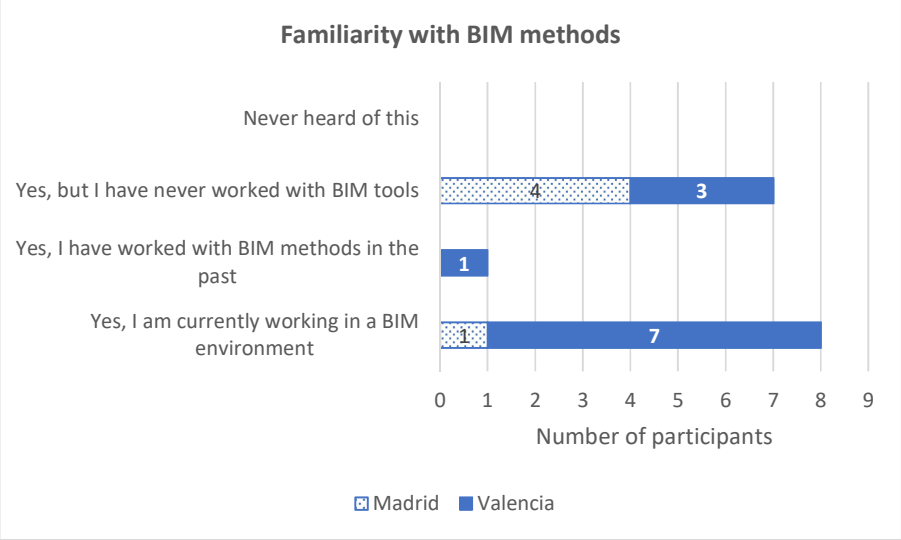

Figure 20: Spanish workshops- Familiarity with BIM methods

ANNEX 7 - DEMOGRAPHIC ANALYSIS FOR THE ONLINE SURVEY

Architects

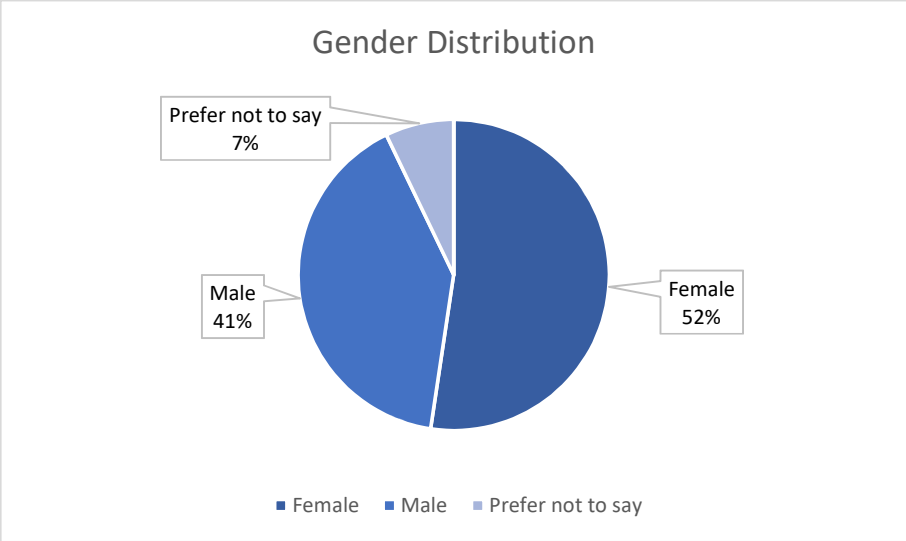

Figure 21: Online survey: Gender distribution - Architects

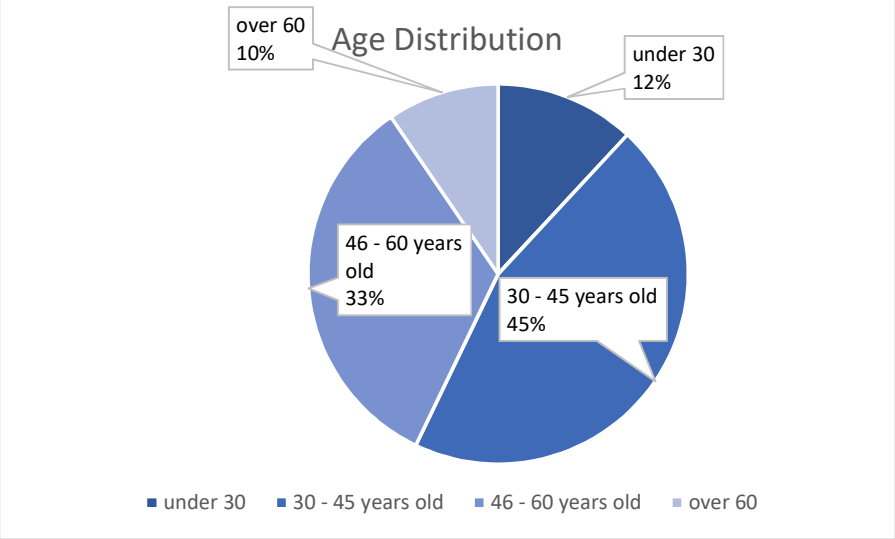

Figure 22: Online survey: Age distribution - Architects

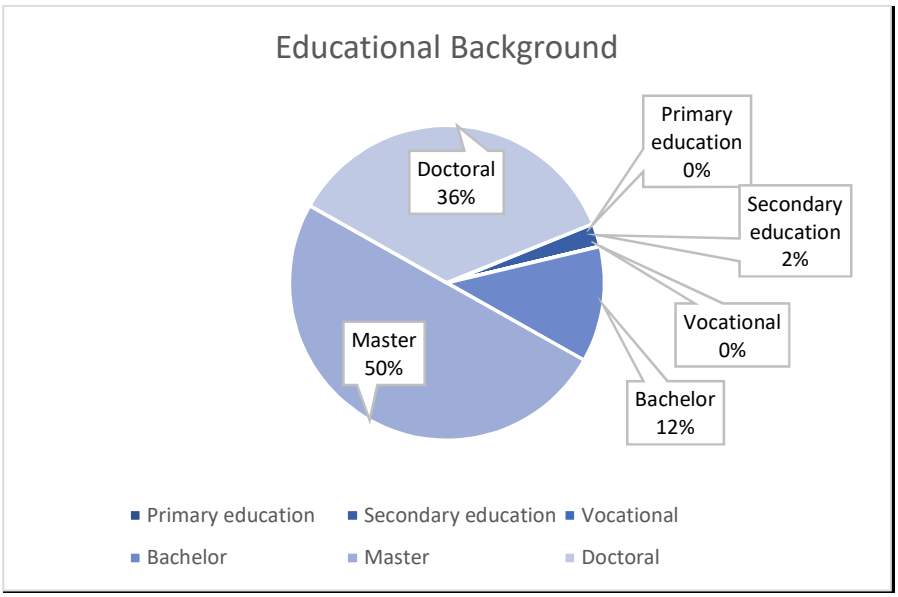

Figure 23: Online survey: Educational background - Architects

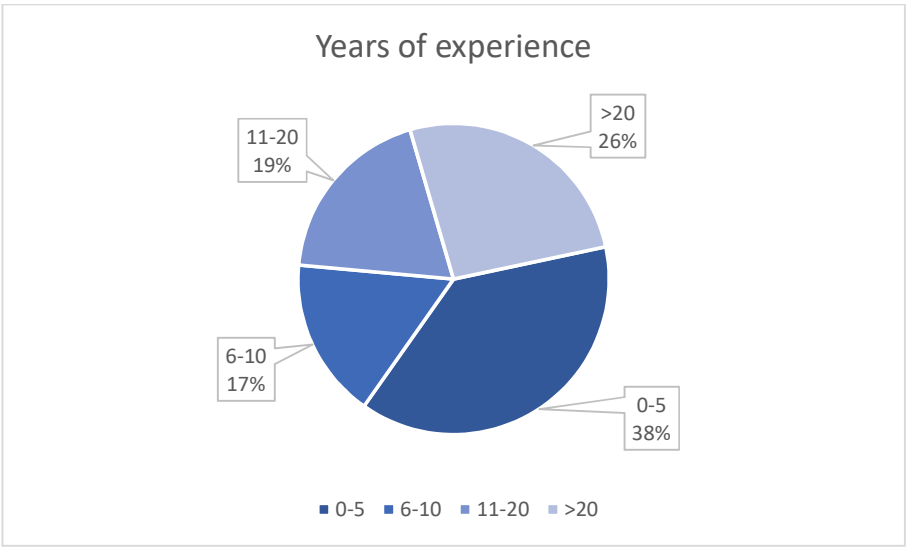

Figure 24: Online survey: Years of experience - Architects

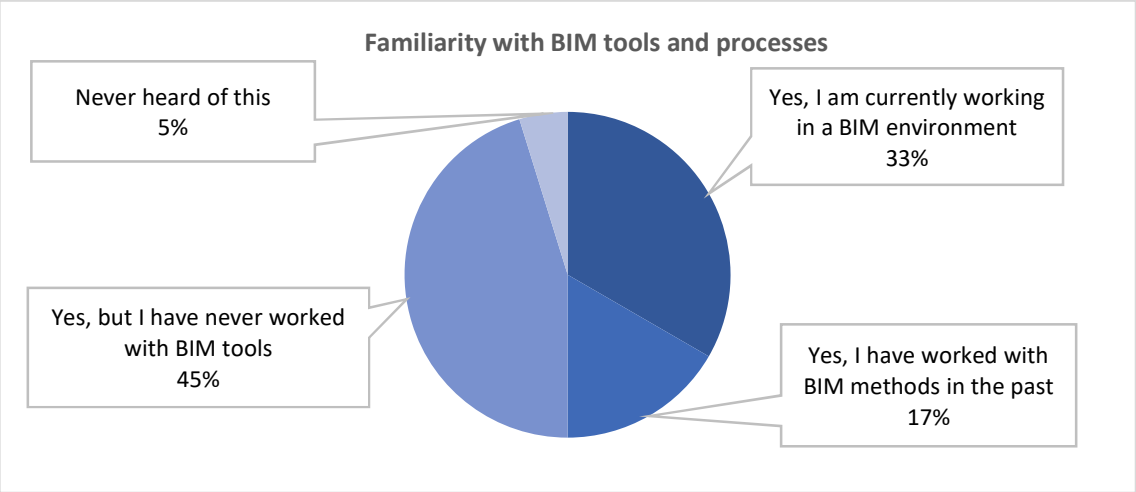

Figure 25: Online survey: Familiarity with BIM technology - Architects

Building surveyors

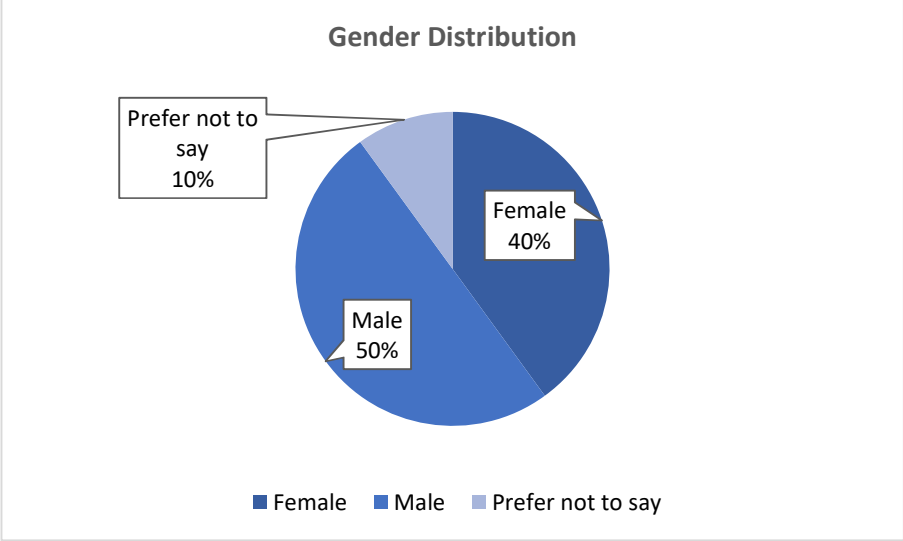

Figure 26: Online survey: Gender distribution – Building surveyors

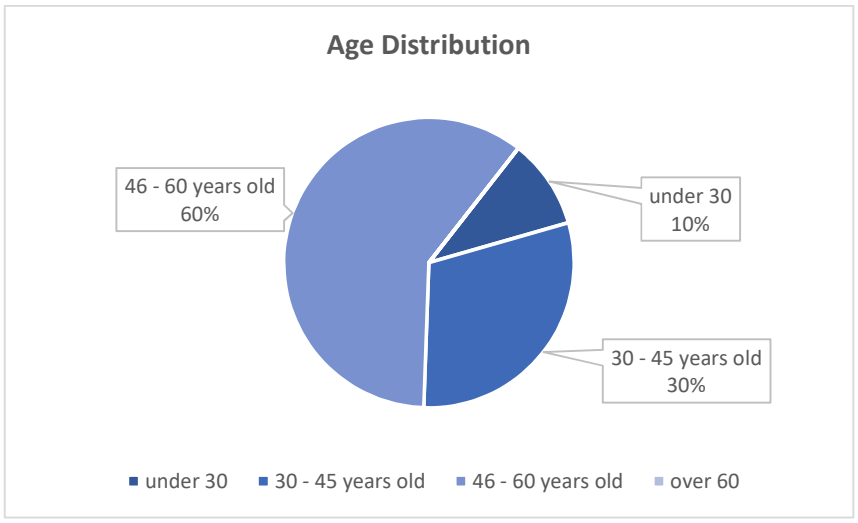

Figure 27: Online survey: Age distribution – Building surveyors

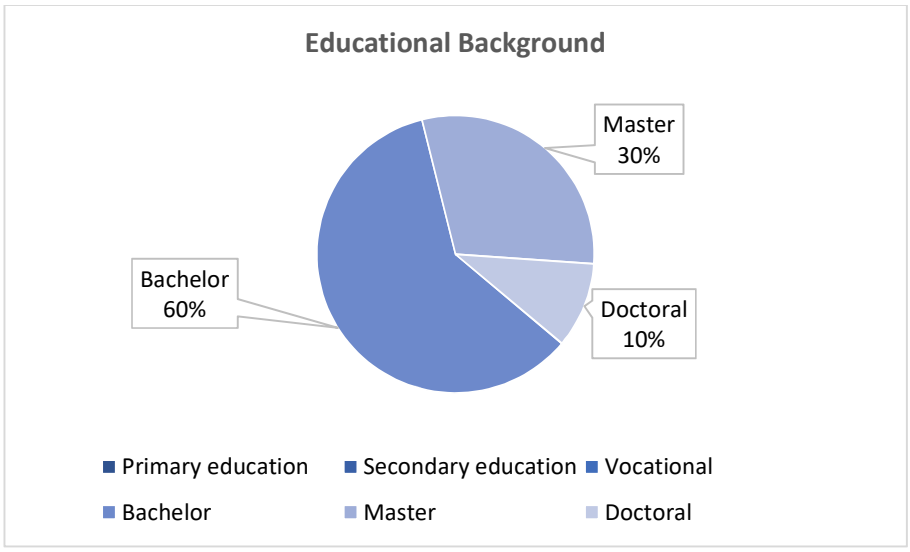

Figure 28: Online survey: Educational background - Building surveyors

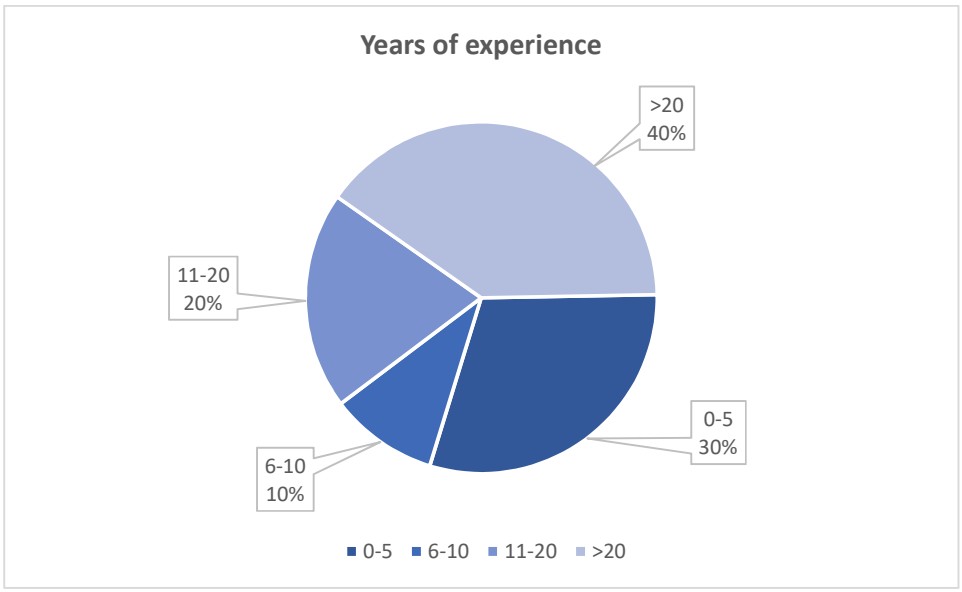

Figure 29: Online survey: Years of experience - Building surveyors

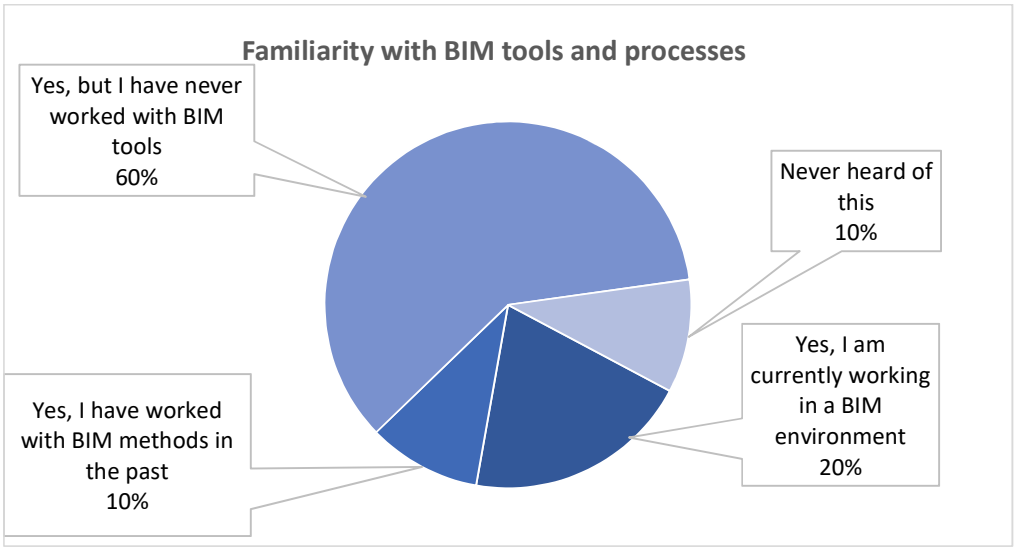

Figure 30: Online survey: Familiarity with BIM technology - Building surveyors

Project managers

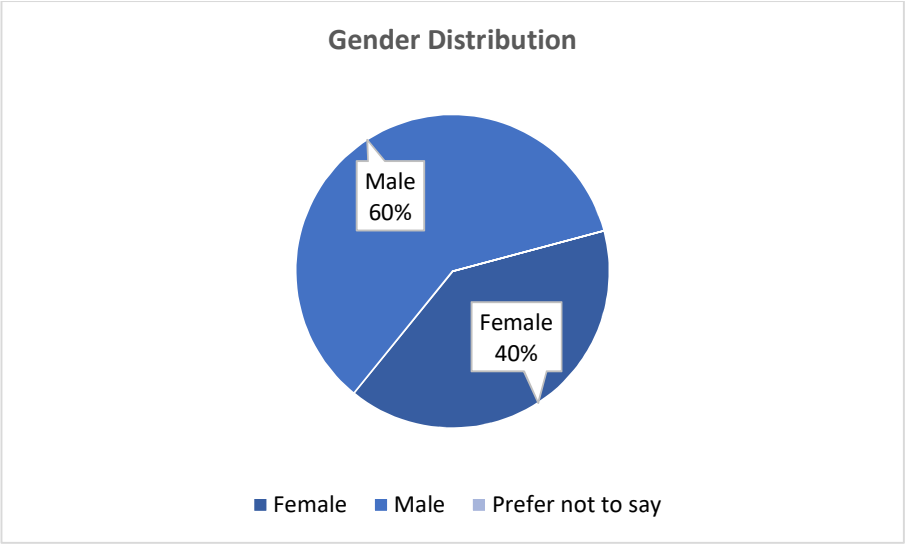

Figure 31: Online survey: Gender distribution – Project managers

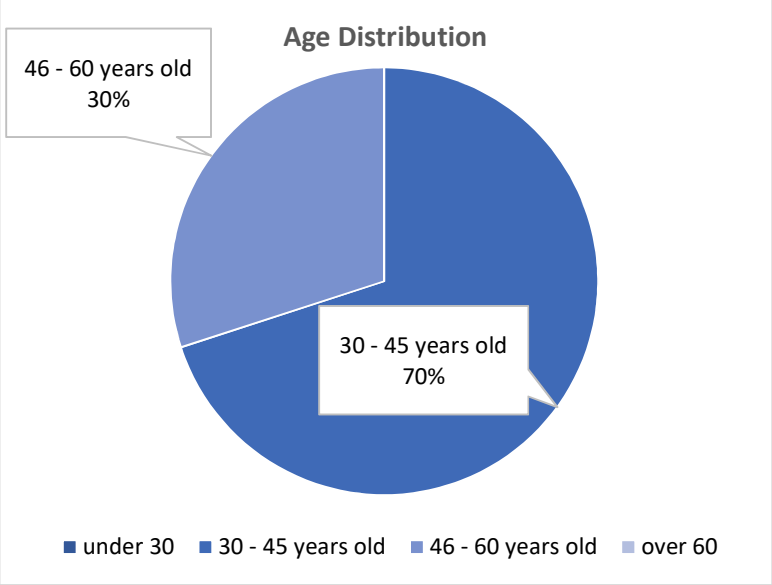

Figure 32: Online survey: Age distribution – Project managers

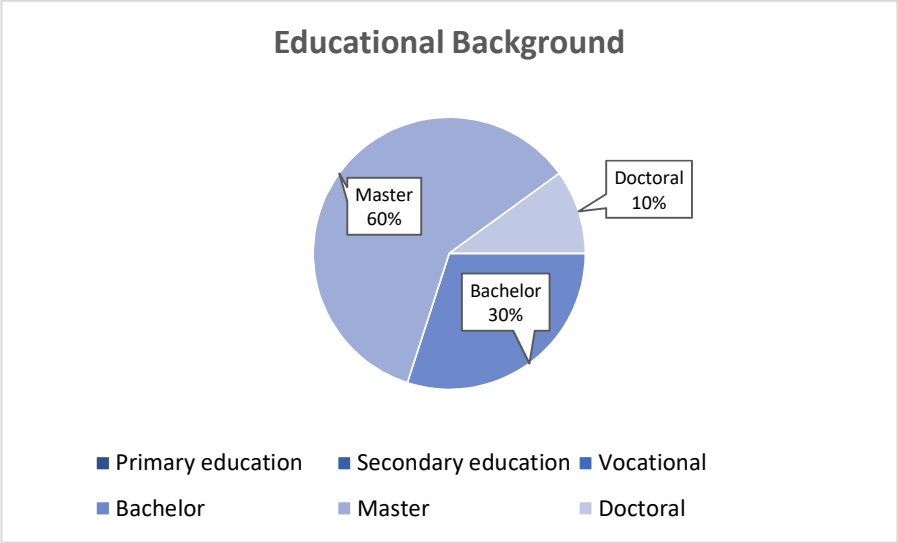

Figure 33: Online survey: Educational background - Project managers

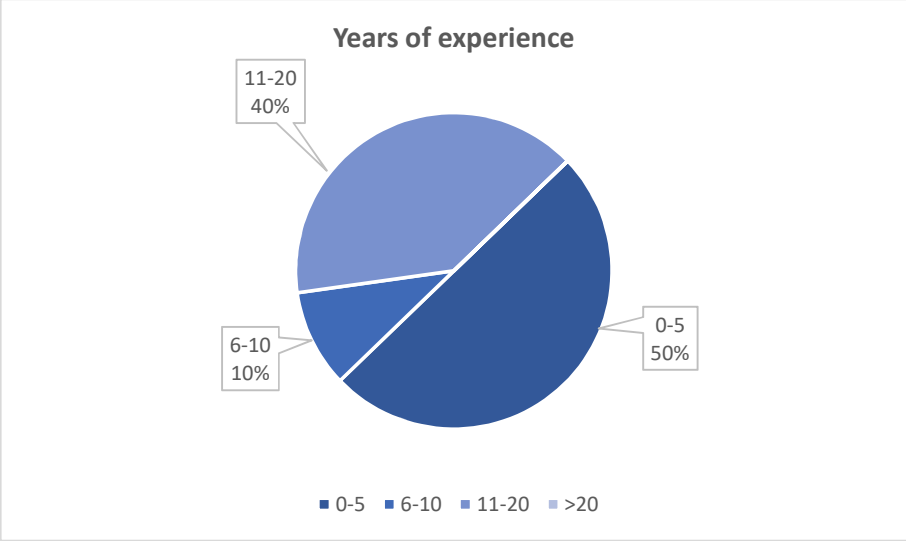

Figure 34: Online survey: Years of experience - Project managers

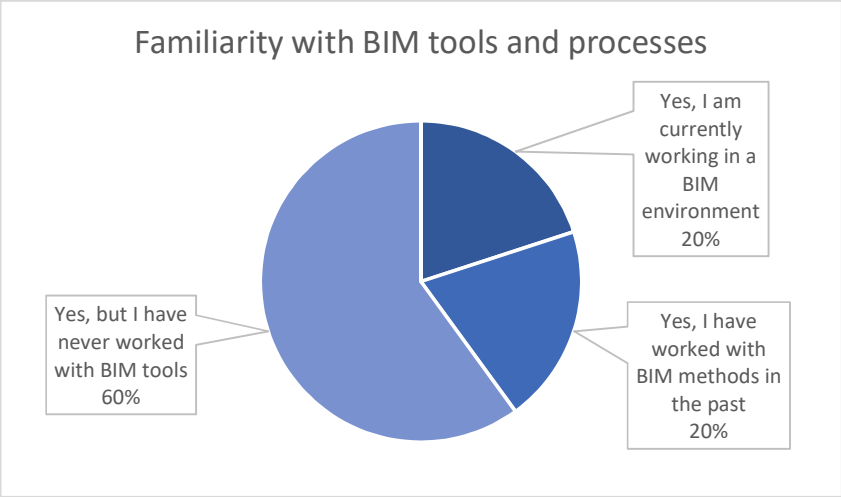

Figure 35: Online survey: Familiarity with BIM technology - Project managers

BIM experts (or BIM modellers)

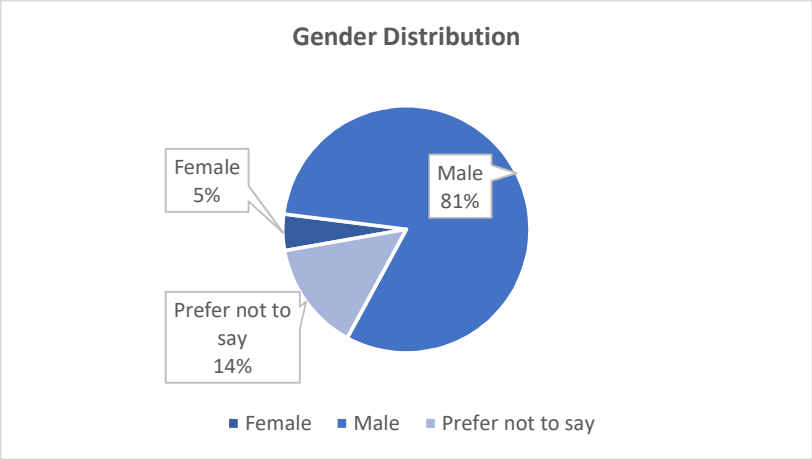

Figure 36: Online survey: Gender distribution – BIM experts

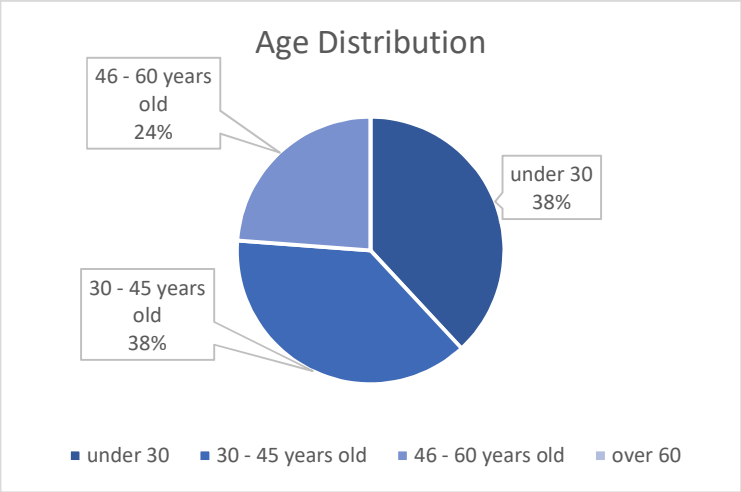

Figure 37: Online survey: Age distribution – BIM experts

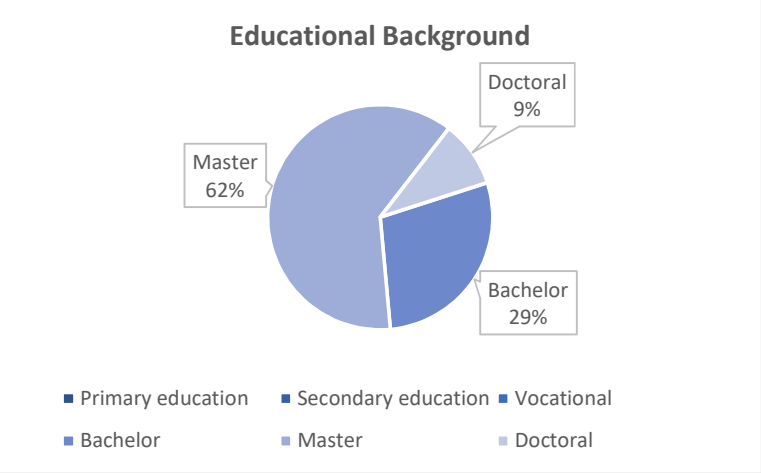

Figure 38: Online survey: Educational background - BIM experts

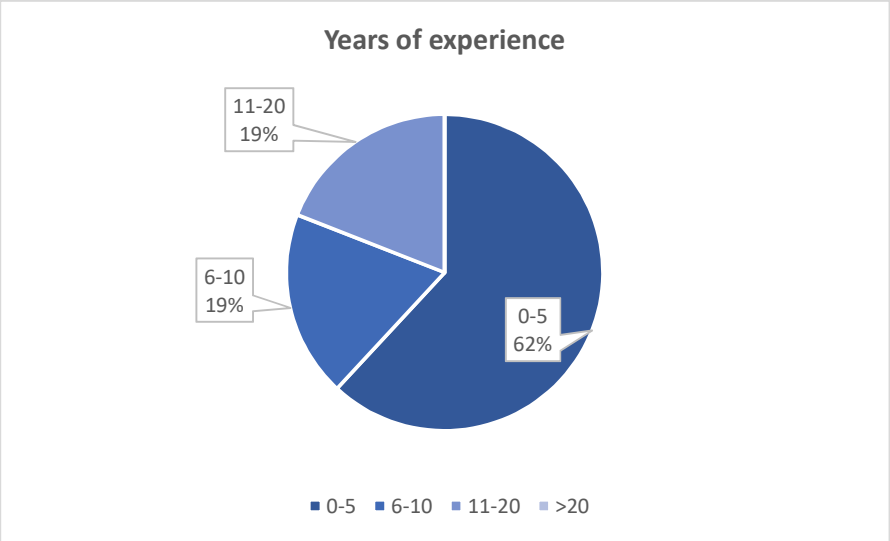

Figure 39: Online survey: Years of experience - BIM experts

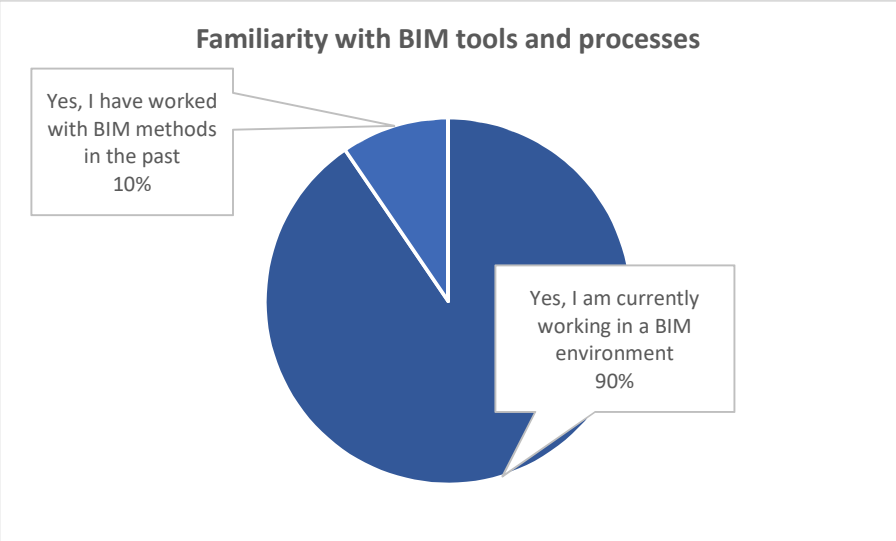

Figure 40: Online survey: Familiarity with BIM technology - BIM experts

Site managers

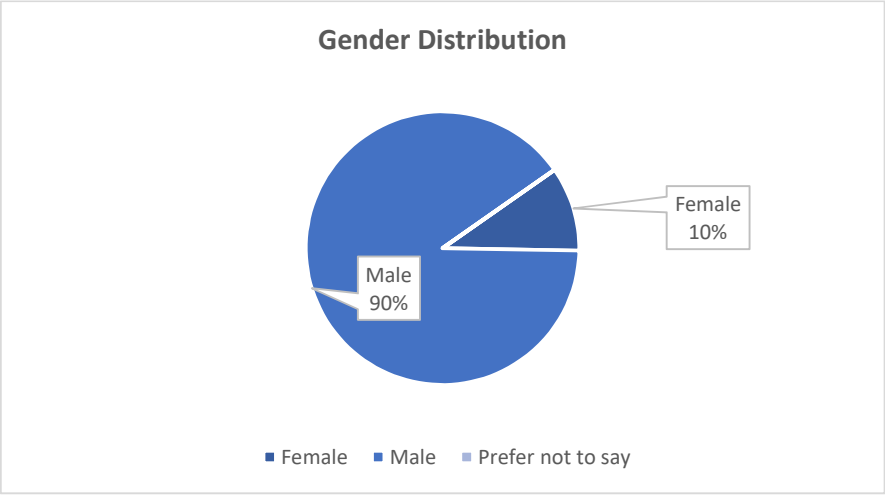

Figure 41: Online survey: Gender distribution – Site managers

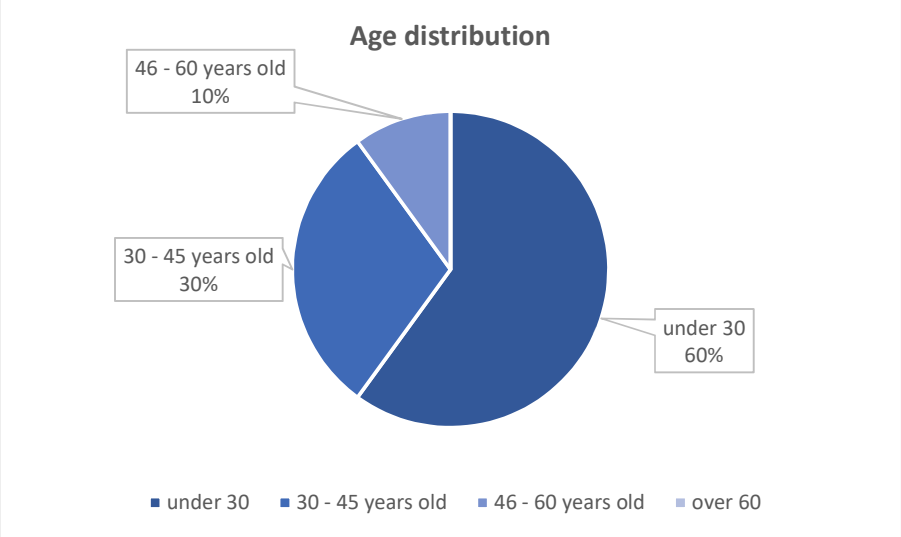

Figure 42: Online survey: Age distribution – Site managers

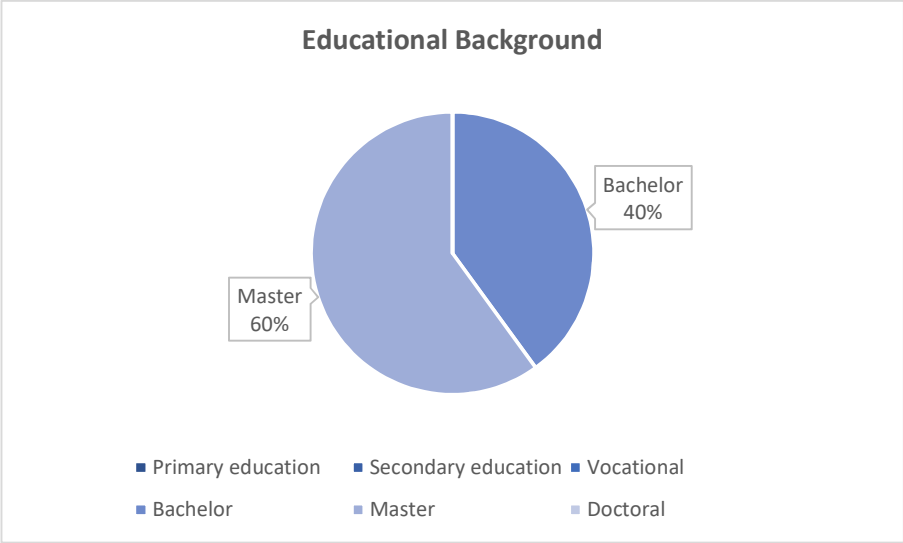

Figure 43: Online survey: Educational background - Site managers

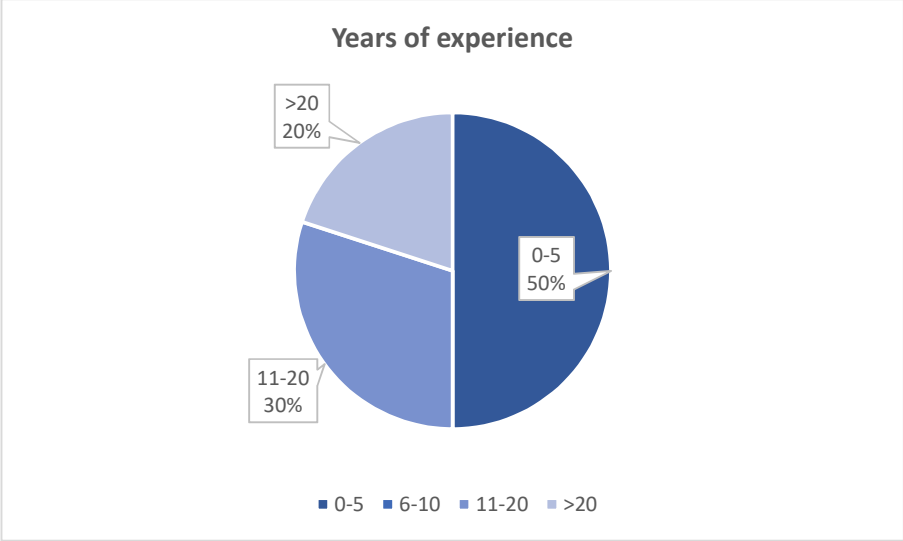

Figure 44: Online survey: Years of experience - Site managers

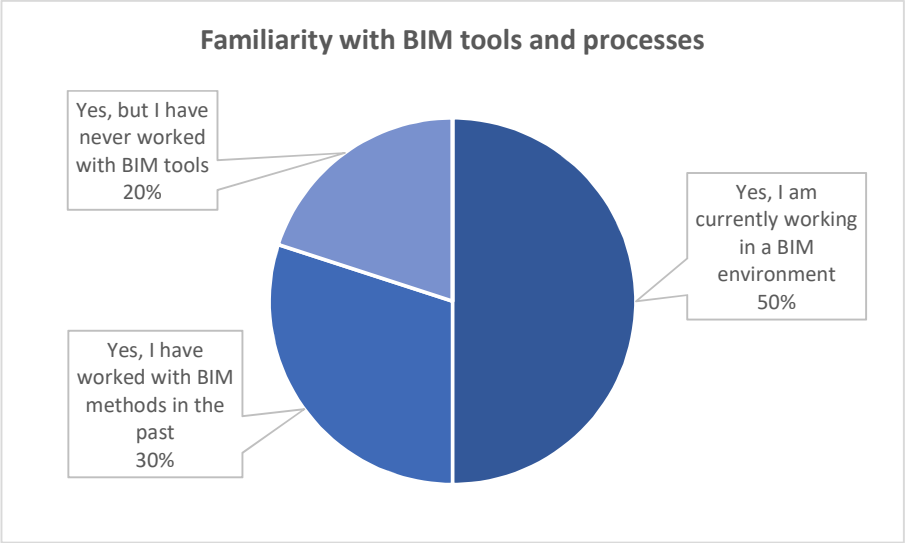

Figure 45: Online survey: Familiarity with BIM technology - Site managers

Workers

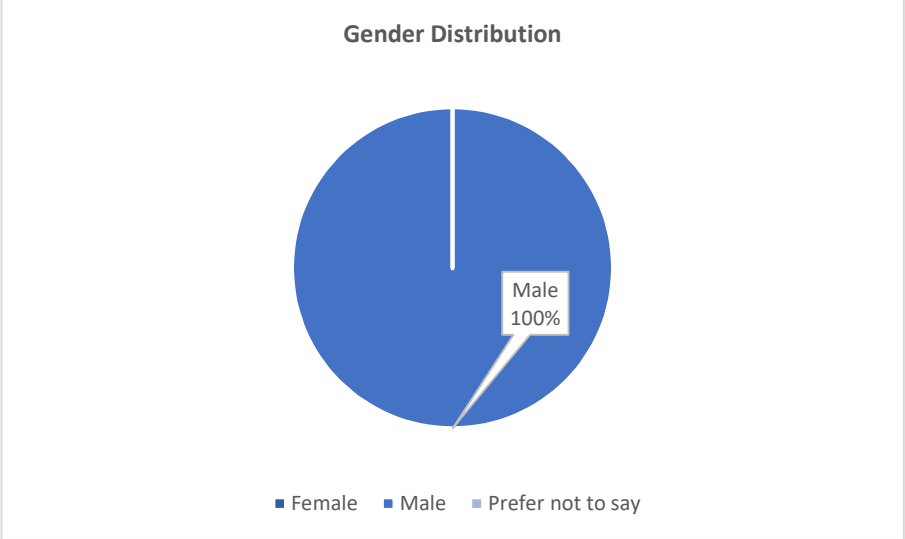

Figure 46: Online survey: Gender distribution – Workers

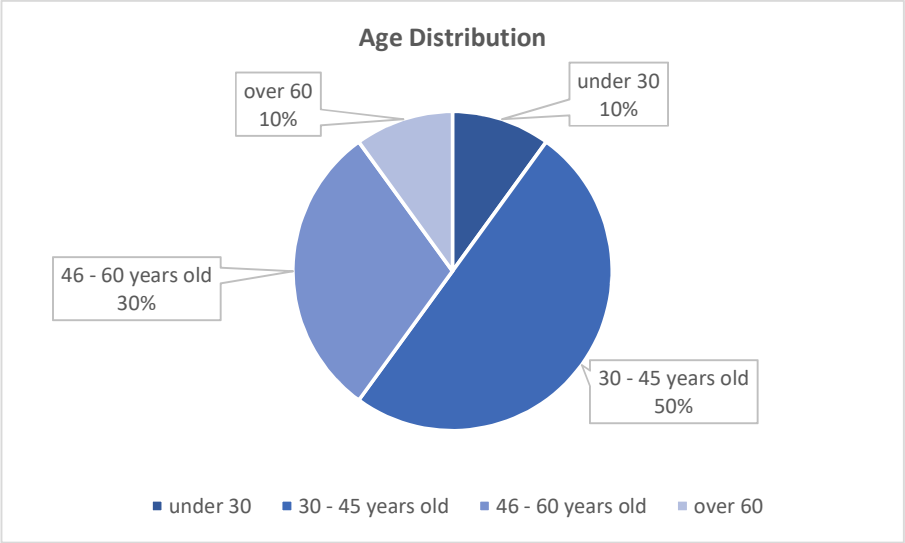

Figure 47: Online survey: Age distribution – Workers

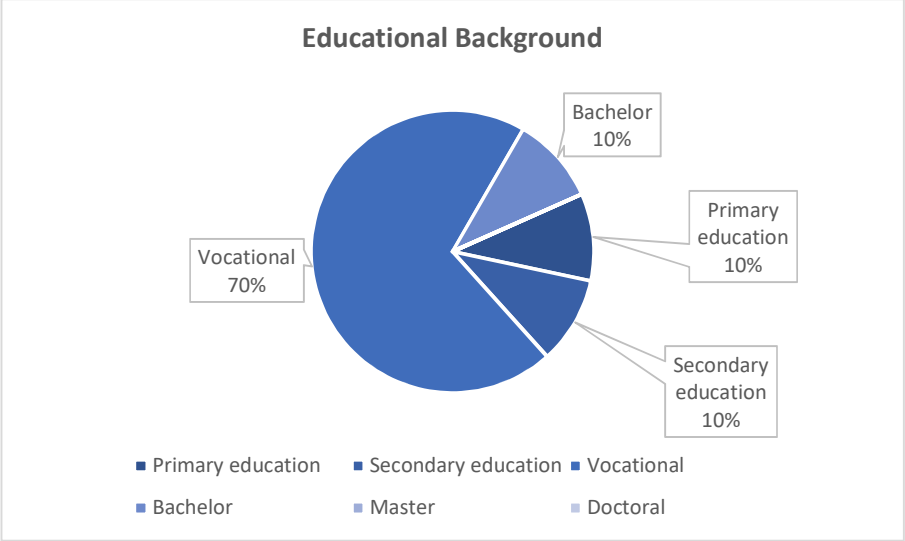

Figure 48: Online survey: Educational background - Workers

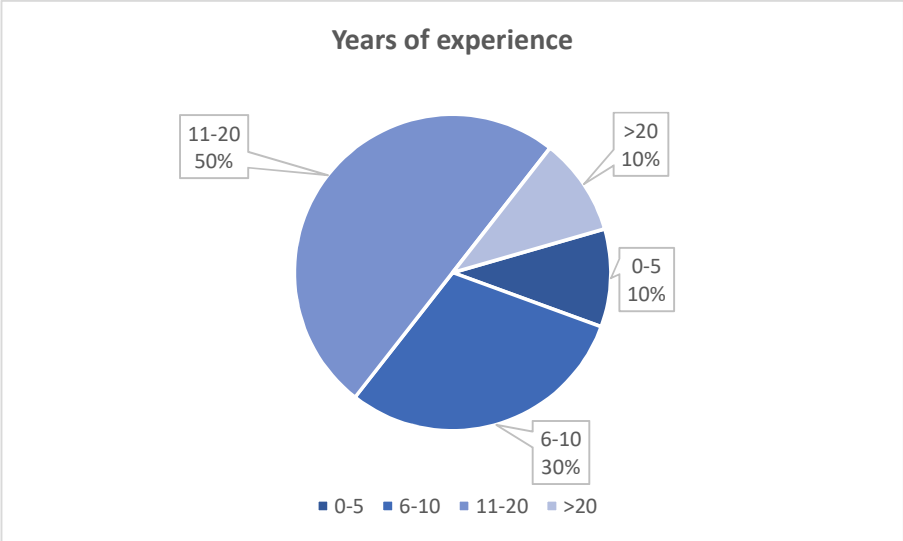

Figure 49: Online survey: Years of experience - Workers

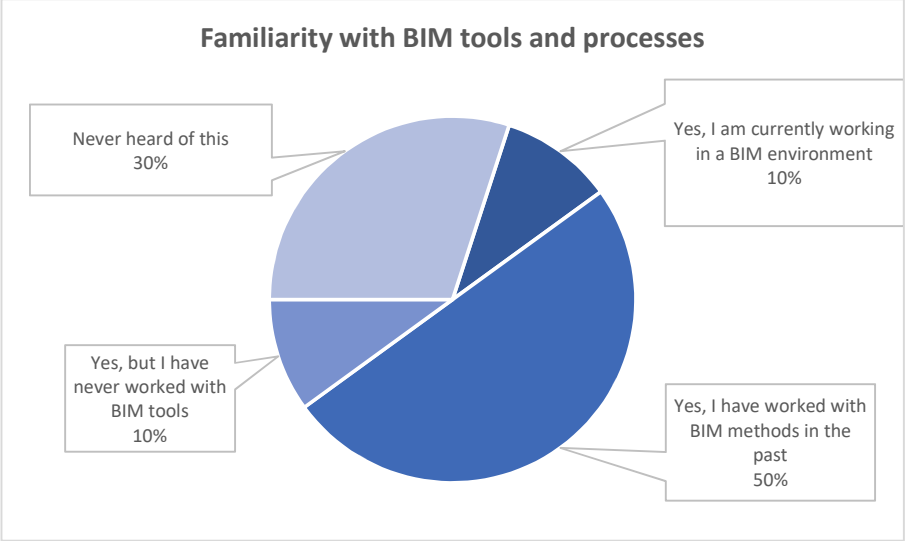

Figure 50: Online survey: Familiarity with BIM technology - Workers

Occupants

For the Occupants' demographic information only the first three questions of Annex 4 were used since the "Years of experience" and "BIM familiarity" target exclusively professionals of the AEC industry.

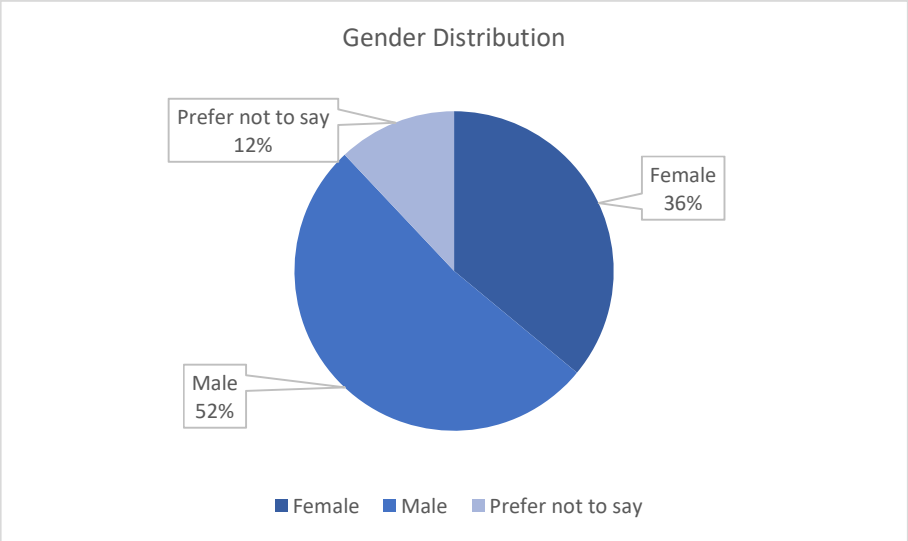

Figure 51: Online survey: Gender distribution – Occupants

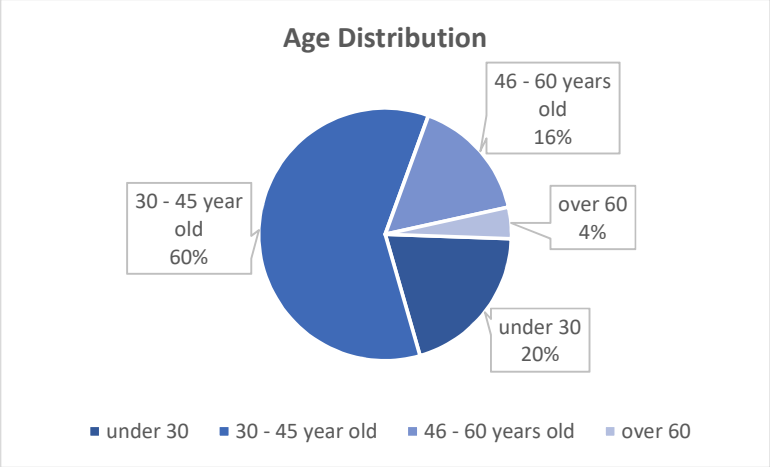

Figure 52: Online survey: Age distribution – Occupants

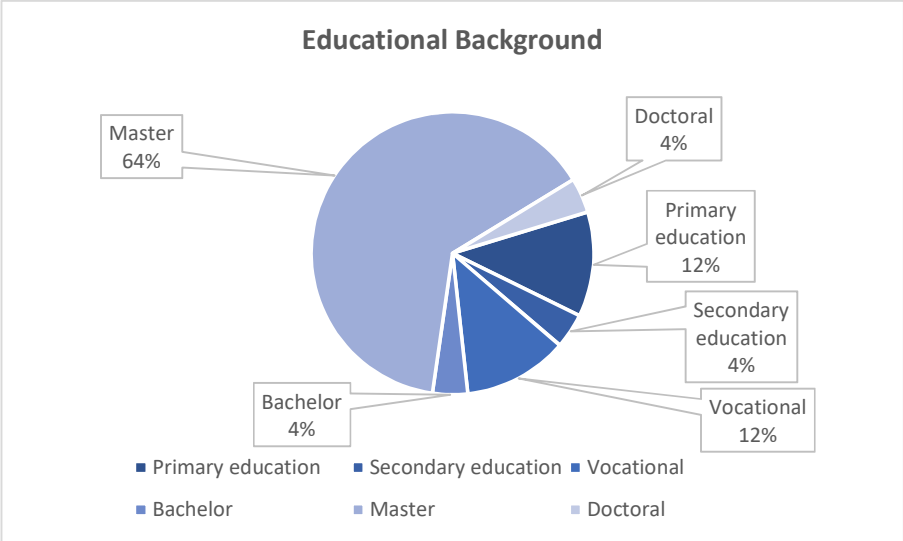

Figure 53: Online survey: Educational background - Occupants

ANNEX 8 - SAMPLE RESPONSES FROM THE ONLINE SURVEY

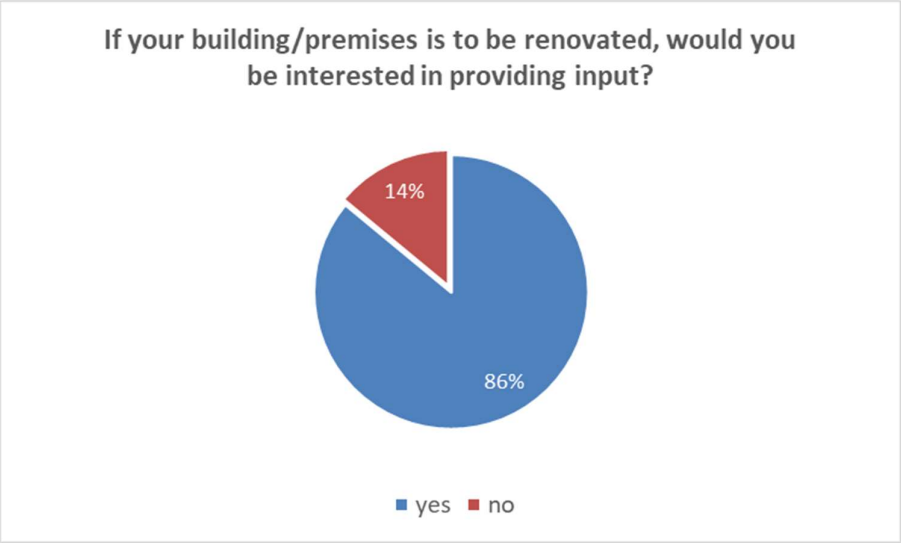

Figure 54: Occupants' response to online survey (question S3).

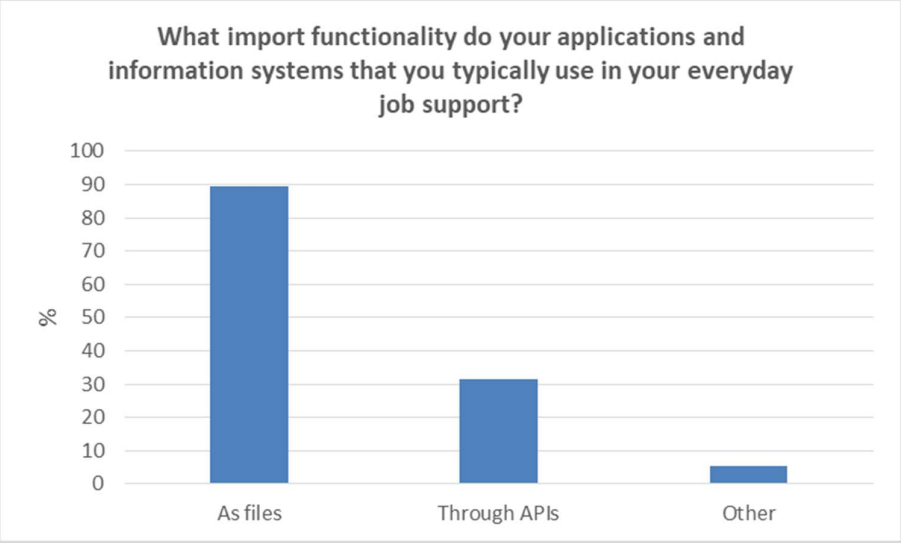

Figure 55: Architects' response to online survey (question S4).

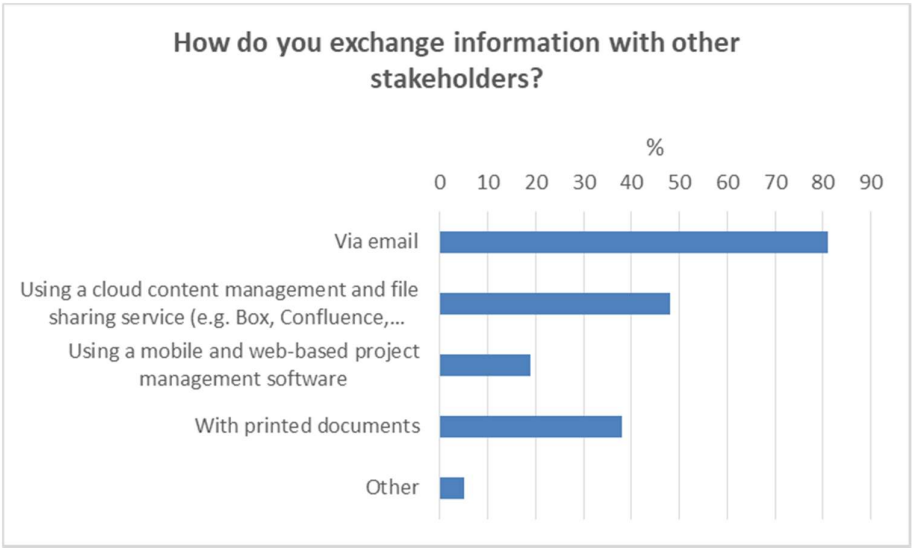

Figure 56: Architects' response to online survey (question S12).

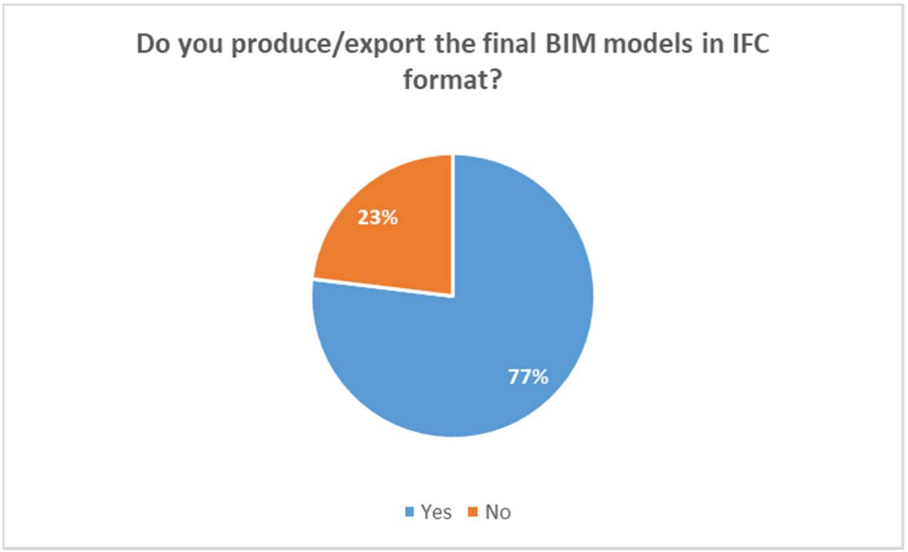

Figure 57: BIM Experts' response to online survey (question S10).

ANNEX 9 - LIST OF USER REQUIREMENTS

Table Row ID	Req ID	User Group / origin	Description	Type	Priority
1	BMRR-001	Architect	Architect shall be able to import data to the design software he uses in specific data formats. - Import in DWG format - Import in PDF format	Design Constraint/Polish Pilot	High
2	BMRR-002	Architect	Architect shall be able to export data from the design software she uses in specific data formats. - Export in DWG format - Export in PDF format	Design Constraint/Polish Pilot	High
3	BMRR-003	Architect	Architect shall be able to import BIM models to her design software in IFC format	Design Constraint	High
4	BMRR-004	Architect	Architect shall be able to export BIM models from the design software he uses in DWG or IFC format	Design Constraint	High
5	BMRR-005	Architect	Architect shall be able to exchange information with site manager	Functional	High
6	BMRR-006	Architect	Architect shall be able to exchange information with investor	Functional	High
7	BMRR-007	Architect	Architect shall be able to exchange drawings with other stakeholders	Functional	High
8	BMRR-008	Architect	Architect shall be able to exchange documents with other stakeholders	Functional	High
9	BMRR-009	Architect	Architect should exchange annotated photos with other stakeholders	Functional	Medium
10	BMRR-010	Architect	Architects shall be able to get Building log book in order to complete their work	Functional	High
11	BMRR-011	Architect	Architects shall be able to get materials specifications (coefficients and properties) in order to complete their work	Functional	High
12	BMRR-012	Architect	Architect shall be able to have an up-to-date representation of the building to be renovated	Functional	High
13	BMRR-013	Architect	Architect shall be able to use current survey results for construction representation	Functional	High
14	BMRR-014	Architect	Architect should be able to use BIM model in order to check geometrical properties of the building.	Functional	Low
15	BMRR-015	Architect	Architects shall be able to retrieve building information as PDF files	Functional	High
16	BMRR-016	Architect	Architects shall be able to retrieve building information as AutoCAD files	Functional	High
17	BMRR-017	Architect	Architects shall be able to retrieve building information as Images	Functional	Medium
18	BMRR-018	Architect	Architects shall be able to retrieve building information as Spreadsheets	Functional	Low
19	BMRR-019	Architect	Access to building information shall be restricted only to specific stakeholders	Legal	High

20	BMRR-020	Architect	Architects in Poland shall be able to use the following online database for design materials selection: http://www.e-bistyp.pl/	Operational Pilot specific	Medium
21	BMRR-021	Architect	Architects in Poland shall be able to use the following online database for design materials selection: http://alatea.pl/pliki/programy/kosztorysowanie/intercenbud.htm	Operational Pilot specific	Medium
22	BMRR-022	Architect	Architect shall be able to optimise the design material selection by standard calculations	Functional	High
23	BMRR-023	Architect	When the renovation project has to use specific technology/materials, architects will produce only one renovation scenario	Performance	Low
24	BMRR-024	Architect	Renovation scenarios proposals should be reported to the client via a written report	Functional	High
25	BMRR-025	Architect	Architect shall be able to consider insulation as an energy saving measure to the renovation design	Functional	High
26	BMRR-026	Architect	Architect shall be able to consider heating system as an energy saving measure to the renovation design	Functional	High
27	BMRR-027	Architect	Architect shall be able to consider cooling systems as an energy saving measure to the renovation design	Functional	High
28	BMRR-028	Architect	Architect shall be able to consider hot water production systems as an energy saving measure to the renovation design	Functional	Medium
29	BMRR-030	Architect	Climate data should be considered for life cycle cost calculations	Functional	High
30	BMRR-031	Architect	Architect shall be able to provide cost estimation for renovation projects	Functional	High
31	BMRR-032	Architect	Occupants' energy bills should be available in order for operational energy data to be considered.	Operational	High
32	BMRR-033	Architect	Occupants' comfort should be monitored with IoT solutions	Functional	High
33	BMRR-034	Architect	Energy consumption should be monitored with IoT solutions	Functional	High
34	BMRR-035	BIM Expert	BIM experts shall be able to get point clouds in order to generate BIM models	Functional	High
35	BMRR-036	BIM Expert	BIM experts shall be able to get 2D drawings in order to generate BIM models	Functional	High
36	BMRR-037	BIM Expert	BIM experts shall be able to use auxiliary data related to energy refurbishment	Functional	High
37	BMRR-038	BIM Expert	BIM experts shall be able to employ Level of Development specification from BIMForum	Design Constraint	Medium
38	BMRR-039	BIM Expert	BIM experts shall be able to use commercial software for the generation of BIM/S2B process	Operational	High
39	BMRR-040	BIM Expert	Point clouds shall be stored in basic formats	Design Constraint	High
40	BMRR-041	BIM Expert	Point clouds shall be stored in enriched formats	Design Constraint	High

41	BMRR-043	BIM Expert	BIM experts shall be able to produce BIM models in IFC format	Design Constraint	High
42	BMRR-044	Project Man.	Project managers shall be able to work with mobile devices (Laptops) running Windows	Design Constraint	High
43	BMRR-045	Project Man.	Project manager shall be able to work with mobile devices running Android	Design Constraint	Medium
44	BMRR-046	Project Man.	Project manager shall be able to work with internet connection limited to specific IPs	Design Constraint	High
45	BMRR-047	Project Man.	Project manager shall be able to exchange information with the architect (person who supervise the project's design)	Functional	High
46	BMRR-048	Project Man.	Project manager shall be able to exchange information with the construction manager (person who oversees the workflow on the construction site)	Functional	High
47	BMRR-051	Project Man.	Project manager shall be able to exchange drawings	Functional	High
48	BMRR-052	Project Man.	Project manager shall be able to exchange documents	Functional	High
49	BMRR-053	Project Man.	Project manager shall be able to exchange annotated photos	Functional	Medium
50	BMRR-054	Project Man.	Project manager shall be able to find construction drawings in order to properly complete his/her work	Functional	High
51	BMRR-055	Project Man.	Project manager shall be able to retrieve AutoCAD files of the building of the renovation project	Functional	High
52	BMRR-056	Project Man.	Project manager shall be able to retrieve Spreadsheets with building information of the renovation project	Functional	Medium
53	BMRR-057	Project Man.	Project manager shall be able to retrieve PDF documents with building information of the renovation project	Functional	High
54	BMRR-058	Project Man.	Access to building information shall be restricted only to specific stakeholders	Legal	High
55	BMRR-059	Project Man.	Site managers shall receive notification when planned construction works are rescheduled	Process	High
56	BMRR-060	Project Man.	Project manager should be able to order materials with an automated process	Functional	Medium
57	BMRR-062	Site Man.	Site manager shall be able to work with internet connection limited to specific IPs.	Design Constraint	High
58	BMRR-063	Site Man.	Site manager shall be able to work with mobile devices running Android	Design Constraint	Medium
59	BMRR-065	Site Man.	Site managers should receive pictures reporting changes at the construction site	Functional	High
60	BMRR-066	Site Man.	Site manager shall be able to exchange information with the architect (person who supervise the project's design)	Functional	High
61	BMRR-067	Site Man.	Site manager shall be able to exchange information with the construction manager (the person who oversees the construction works)	Functional	High

62	BMRR-068	Site Man.	Site manager shall be able to find construction drawings in order to properly complete his/her work	Functional	High
63	BMRR-069	Site Man.	Site manager shall be able to retrieve AutoCAD files of the building of the renovation project	Functional	High
64	BMRR-070	Site Man.	Site manager shall be able to retrieve Spreadsheets with building information of the renovation project	Functional	Low
65	BMRR-071	Site Man.	Site manager shall be able to retrieve PDF documents with building information of the renovation project	Functional	Medium
66	BMRR-072	Site Man.	Access to building information shall be restricted only to specific stakeholders	Legal Pilot Specific	High
67	BMRR-073	Site Man.	Site managers should be able to send out Health and Safety alerts by using a mobile app	Design Constraint	High
68	BMRR-074	Site Man.	Site managers should be able to send photos with text comments along with the Health and Safety alerts	Functional	High
69	BMRR-075	Site Man.	If 3D visualisations are available on site, site managers should have access to BIM overlays	Functional	High
70	BMRR-076	Site Man.	Site managers should be able to send Health and Safety alerts (H&S) when a H&S issue has been identified	Functional	High
71	BMRR-077	Surveyor	Surveyors shall be able to work with mobile devices (Laptops) running Windows	Design Constraint	Medium
72	BMRR-078	Surveyor	Surveyors shall be able to work with mobile devices running Android	Design Constraint	Medium
73	BMRR-080	Surveyor	Surveyor shall be able to ask residents/facility managers to provide input via a mobile data collection app	Functional Pilot Specific	High
74	BMRR-081	Surveyor	Surveyors should be aware of any hidden installation of the building to be renovated	Functional	High
75	BMRR-082	Surveyor	Residents/facility managers should be able to provide pictures of hidden installations of the building to be renovated	Functional	High
76	BMRR-083	Surveyor	Residents/facility managers should be able to provide notes with information about the building to be renovated	Functional	Medium
77	BMRR-084	Surveyor	Residents/facility managers should be able to provide markups on existing drawings indicating information about the building to be renovated	Functional	Low
78	BMRR-087	Surveyor	The level of accuracy for the design models shall be less than 10 mm for building constructions	Performance	High or Medium depending on the specifications
79	BMRR-088	Surveyor	Surveyor shall be able to acquire 3D data	Functional	High

80	BMRR-089	Surveyor	Surveyor shall be able to acquire laser intensity data	Functional	High
81	BMRR-090	Surveyor	Surveyor shall be able to produce geo-referenced data	Functional	Low
82	BMRR-091	Surveyor	Surveyor shall be able to employ Level of Development specification from BIMForum	Design Constraint	Low
83	BMRR-092	Surveyor	Surveyor should be able to annotate the 3D model with information about the building using a mobile device application	Functional	High
84	BMRR-093	Surveyor	Surveyor shall be able to wear safety helmets during building survey	Design Constraint	High
85	BMRR-094	Surveyor	Surveyor shall be able to work in a well-lit environment	Legal	High
86	BMRR-095	Worker	Workers shall exchange information via the internet	Functional	High
87	BMRR-097	Worker	Workers should be able to exchange real-time information with other workers	Functional	High
88	BMRR-098	Worker	Workers should be able to exchange real-time information with the Health & Safety manager	Functional	High
89	BMRR-099	Worker	Workers should be able to exchange real-time information with the site manager	Functional	High
90	BMRR-100	Worker	Workers should be able to exchange real-time information with foreman	Functional	High
91	BMRR-101	Worker	Access to building information shall be restricted only to specific stakeholders	Legal	Low
92	BMRR-102	Worker	Workers should be able to send photos with text attached to the site manager in order to describe a construction defect	Functional	High
93	BMRR-103	Worker	Workers should be able to receive Health and Safety notifications using a mobile app running at their phones	Functional	High
94	BMRR-104	Worker	Workers should receive Health and Safety notification before their day-shift	Process	Medium
95	BMRR-105	Worker	Workers should receive Health and Safety (H&S) notification when H&S events are identified	Process	Low
96	BMRR-106	Worker	Worker should be able to operate his/her Augmented Reality Classes with gestures	Functional	High
97	BMRR-107	Worker	Workers should be able to receive instructions on-demand	Functional	High
98	BMRR-108	Worker	Workers should be able to detect moisture intrusion	Functional	Medium
99	BMRR-109	Worker	If 3D visualisations are available on site, workers should be able to track the location of their assigned tasks	Functional	High
100	BMRR-110	Worker	If 3D visualisations are available on site, workers should have access to BIM overlays	Functional Pilot Specific	Medium
101	BMRR-111	Worker	Workers should be able to receive on-site guidance for the technologies used at the construction site	Functional	Medium
102	BMRR-112	Worker	Workers shall be able to perform their tasks in highly noisy environments	Operational	Low

103	BMRR-113	Architect	Architect shall be able to import data to the design software he uses in specific data formats. - Import in IFC format - Import in DWX format - Import in XML format	Design Constraint/Spanish Pilot	High
104	BMRR-114	Architect	Architect shall be able to export data from the design software she uses in specific data formats. - Export in DWG format - Export in PDF format	Design Constraint/Spanish Pilot	High
105	BMRR-115	Architect	Architects will calculate three (3) alterative scenarios per project	Operational Pilot specific	Medium
106	BMRR-116	Architect	Architect will use smartphones or tablets using Android	Design Constraint	Medium
107	BMRR-117	Architect	Architect's software tools can support files for import functionality	Functional	High
108	BMRR-118	Architect	Architect's software tools can support files for export functionality	Functional	High
109	BMRR-119	Architect	Architect stores building information in CAD, xml, pdf and doc files	Design Constraint	Medium
110	BMRR-120	Architect	Architect will use email to exchange information with other stakeholders	Design Constraint	Medium
111	BMRR-121	Architect	Architect will exchange information up to two times per day with other stakeholders	Operational	Low
112	BMRR-122	Architect	Architects will exchange information with site managers	Operational	High
113	BMRR-123	Architect	Architects will exchange information with clients (investors)	Operational	High
114	BMRR-124	Architect	Architects should be able to post-evaluate the energy performance of a building based on actual operational data	Functional	Low
115	BMRR-126	Project Man.	Project manager shall be able to exchange information with the client	Functional	High
116	BMRR-128	Project Man.	Project manager shall exchange information in real-time with the site manager	Functional	High
117	BMRR-129	Project Man.	Project managers will use tools that can support files for import functionality	Design Constraint	High
118	BMRR-130	Project Man.	Project managers will use tools that can support files for export functionality	Design Constraint	High
119	BMRR-131	Project Man.	Project managers shall be able to reduce the number of project re-schedules that occur due to poor initial planning of work	Functional	Medium
120	BMRR-132	Project Man.	Working crews shall receive notification when planned construction works are rescheduled	Process	High
121	BMRR-133	Project Man.	Occupants shall receive notification when planned construction works are rescheduled	Process	Medium
122	BMRR-134	Project Man.	The information of project rescheduling should reach all interested stakeholders within days of the project manager's decision	Process	Low
123	BMRR-135	Project Man.	After the project manager decides on a change in project's plan, an automated email notification should follow	Process	Low

124	BMRR-136	Project Man.	From a process perspective, project manager will exchange the following information: task scheduling, budget, unit cost, changes, drawings, notes	Process	High
125	BMRR-137	Site Man.	Site manager shall be able to work with lap tops running windows	Design Constraint	High
126	BMRR-138	Site Man.	Site managers will synchronize their data with the BIM model in a frequency that ranges from once a day to once a week	Design Constraint Pilot Specific	High
127	BMRR-139	Site Man.	Site managers will use tools that can support files for import functionality	Design Constraint	High
128	BMRR-140	Site Man.	Site managers will use tools that can support files for export functionality	Design Constraint	High
129	BMRR-141	Site Man.	Site managers will use email to exchange information with other stakeholders	Design Constraint	Low
130	BMRR-142	Site Man.	Site managers will continuously exchange information with working crews	Operational	High
131	BMRR-143	Site Man.	Site managers will exchange information with the architects and project manager at least twice a week real time	Operational	High
132	BMRR-144	Site Man.	Site managers will exchange information with the client no more than twice a month real time	Operational	High
133	BMRR-145	Site Man.	Energy efficient materials/equipment should be integrated into the procurement system	Functional Pilot Specific	High
134	BMRR-146	Site Man.	Site managers should be able to track all changes occurring at the construction site	Functional	High
135	BMRR-147	Surveyor	Surveyor shall be able to ask residents/facility managers to provide input via email	Functional Pilot Specific	Medium
136	BMRR-148	Surveyor	Surveyors shall be able to use open formats for delivering as-is data.	Design Constraints Pilot Specific	High
137	BMRR-149	Worker	Workers shall be able to get foreman (or construction manager) approval (guidance) during their work	Functional	High
138	BMRR-150	Worker	Worker should be able to operate his/her Augmented Reality Glasses with voice commands	Functional	Low
139	BMRR-151	Occupant	Occupants shall be able to use their smartphone for exchange information with other stakeholders	Design Constraint	Medium
140	BMRR-152	Occupant	Occupants will have Wi-Fi connectivity in their premises	Design Constraint	High
141	BMRR-153	Occupant	Occupants shall be able to provide input regarding the building that is to be renovated	Functional	High
142	BMRR-154	Occupant	Occupants shall be able to provide photos regarding their building/premises	Design Constraint	High
143	BMRR-155	Occupant	Occupants should receive an email when information is needed from them.	Functional	High

144	BMRR-156	Occupant	Occupants should be able to send information regarding their premises to be renovated via a mobile application	Design Constraint	High
145	BMRR-157	Occupant	In case a location specific information is to be provided, occupants should be able to directly annotate photos for that purpose via a mobile application	Design Constraint	High
146	BMRR-158	Occupant	Occupants should receive weekly alerts/instructions about construction site safety	Operational	Medium
147	BMRR-159	Occupant	Occupants shall be informed about the renovation process activities when performed	Operational	High
148	BMRR-160	Occupant	Regarding issues that occur on site and for which occupants' opinion is required, occupants should be able to watch a video regarding the issue and provide the necessary feeback	Functional	High
149	BMRR-161	Occupant	Occupants should experience an improved air quality after renovating their premises	Performance	High
150	BMRR-162	Occupant	Occupants should experience better temperature conditions after renovating their premises	Performance	Medium
151	BMRR-163	Occupant	Occupants shall be able to know the progress level of the planned renovation activites at any given moment	Functional	High