INSITER Guidelines for new construction

Deliverable report D1.2

Deliverable Report: Final version, issue date on 9 November 2018 (Revised version)

INSITER - Intuitive Self-Inspection Techniques using Augmented Reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components.

This research project has received funding from the European Union's H2020 Framework Programme for research and innovation under Grant Agreement no 636063.

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Colophon

This research project has received funding from the European Union's H2020 Framework Programme for research and innovation under Grant agreement no 636063.

Publishable executive summary

The main goal of the INSITER project is to improve building energy efficiency in the sector of new construction and refurbishment through **detecting and preventing quality and performance gaps between the design and the construction of buildings mostly made of prefab components**.

This objective is to be achieved adopting:

- "Self-**Instruction methods**" for construction workers **in order to prevent construction errors** and,
- "Self-**Inspection methods**" for construction workers and supervisors **in order to detect construction errors**.

These methods are supported by BIM-based software tools, Augmented Reality and 3D measurement instruments.

In order to meet the above-mentioned objective, the INSITER project proposes two reports which introduces the "INSITER Guidelines", that are the basis to develop the structure and the logic of the software tools:

- Deliverable 1.2: INSITER guidelines for new construction;
- Deliverable 1.3: INSITER guidelines for refurbishment.

The INSITER guidelines are:

1. **practical guiding principles for the application of INSITER self-instruction and self-inspection methods,** in order to meet the project goals and obtain an increase in the level of quality and energy efficiency on site. In other words, the "INSITER Guidelines" are the synthesis of the knowledge developed in INSITER, and the bridge to bring research knowledge into practical implementation.
2. **principles of application and implementation of practical contents to realize the "8-Step INSITER methodology"** referring to demonstration cases concerning the 9 main critical components (building and MEP-HVAC) that most influence the energy performance of buildings as presented and analysed in previous D1.4 and D1.6.

The 8-Step INSITER methodology is one of the main innovations proposed by INSITER and was initially presented in the project proposal. Progressive insight during research further evolved the 8-step INSITER methodology, **attributed to refocusing aligned with the primary setting of INSITER in the construction/refurbishment stage** (see figure 1 below).

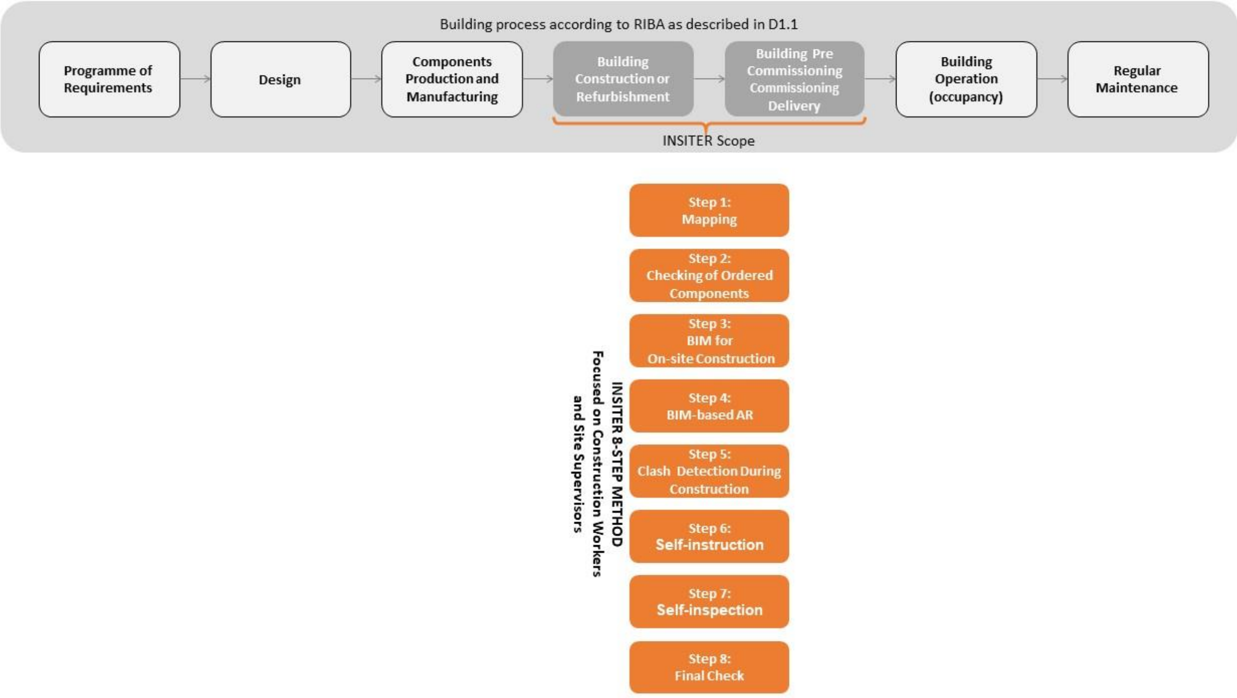


Figure 1: Overview of the INSITER methodology within the design and construction process

The revised 8-Step INSITER methodology process is summarized as follows:

- **Step 1: Mapping actual technical conditions of the site and building, and performing an economic assessment of the property and land; capture the requirements and compare them to as-is situation.**
  This step is performed by the construction workers after receiving the work assignment. The workers check whether the working areas (e.g. construction site designated for a new building or a storey in an existing building) are cleared and ready for the planned construction/refurbishment activities. In case of refurbishment of existing HVAC/MEP systems, “mapping” also means assessing the condition of the existing systems. Health and safety regulations are also addressed, for instance: the building site must be cleared of asbestos and the working areas must be safe/secured. Actual conditions (e.g. weather, accessibility, construction equipment, transport and logistic processes on-site) related to the planned works are also verified. The outcome of this mapping is used to verify the construction/ refurbishment work planning.
- **Step 2: Self-inspection at procurement, production and delivery of prefab components.**
  This step is dedicated: 1) to check the correctness and conditions of the delivered prefab components, also validating delivery schedules compared to logistic planning; 2) to connect the 3D product databases from manufacturers and the positions of the components in the BIM model.
  In the case that pre-assembly is done in the factory, checking also means pre-delivery product inspection. Tests on the quality conformity of the delivered prefab components are performed, including integration of Non-Destructive Testing (NDT) methods as necessary.
- **Step 3: Modelling of the [existing] building, site and surroundings in Building Information Model (BIM).**

When a BIM model of the building does not exist, the existing building will be modelled in BIM, including detailed modelling of the current building and MEP/HVAC components that are critical for building quality and energy performance. BIM modelling will incorporate available 2D and 3D drawings and documentations of the building, as well as 3D laser scanning and point cloud data processing. Relevant GIS data will be included in BIM; information models of building/MEP components will be aggregated and converted to open-standard BIM. The BIM model can be viewed on mobile devices on the construction site.

- **Step 4: Generating and deploying BIM-based Augmented Reality (AR) for self-instruction and self-inspection.**
  Two main actions are expected: 1) Embedding BIM and VR in Augmented Reality (AR), and extracting BIM / VR process information into 'self-instructions' (e.g. installation manuals and planning schedule) for construction workers on their mobile devices (e.g. iPad); and generating self-instruction modules. 2) Interfacing with data output from other inspection hardware (e.g. scanning, imaging and measurement equipment).
- **Step 5: Visual validation on-site based on the BIM clash detection performed prior to construction / refurbishment activities.**
  BIM-based clash detection is performed before construction/ refurbishment. Clashes found should be resolved by the design/ engineering team, and the discoveries are recorded to be visualized in AR on-site. Review the clash details, and then determine the severity of the clash in several degrees (e.g. from 'easily fixed [human] error' to 'fundamental error requiring redesign'). If unresolved clashes are still found on-site, trace back the defaulting components, and request those involved to perform a review and to propose recovery solutions.
- **Step 6: Self-instruction during preparation and execution of construction site and logistics.**
  This is one of the main innovative steps, and it is dedicated to help the construction workers in order to reduce construction errors. In detail the activities performed in this step are: 1) to check assembly manuals with support of BIM-based 3D visual instructions: 2) to implement 'self-instructions' on the mobile devices of the construction workers; 3) to provide supervision and support when needed; 5) to optimize time and cost schedules (also linked to production planning); 6) to analyse risks of delay and budget-overrun; and 7) to update the self-instruction guidelines for construction workers.
- **Step 7: Self-inspection during construction / refurbishment / maintenance process.**
  The workers check the result and quality of the performed work on their own, according to online / digital check lists depending on the assembled components. When detailed inspections are needed, the related specialists will be called in. For instance, thermal performance air tightness, acoustics and humidity for building elements will be measured on the construction site by means of the procedures developed in INSITER: thermal and acoustic leakages will be identified using IR camera and Sound Brush allowing to visualise 3D pictures of the building acoustic and thermal field and calculate the sound insulation and the global U-value.
- **Step 8: Final check (Self-inspection and self-instruction during pre-commissioning, commissioning and project delivery).**
  Comprehensive evaluation at certain intervals (e.g. weekly), performed by the site supervisor involving workers from contractors and sub-contractors. The preliminary quality and performance results are quantitatively measured and analysed as input for participatory decision-making. The self-inspection is proposed during pre-commissioning and commissioning as follow:
  - Final check during pre-commissioning by contractor and building owners:
    - Checking whether all systems work properly according to the specifications;

- Checking the preliminary performance of the building;
- Registration of deviations and necessary measures;
- Updating BIM towards ‘as-built / as-refurbished model’.

- Check during commissioning by contractor, building owners and occupants:
  - Checking whether all systems work properly according to the specifications;
  - Checking the preliminary performance of the building;
  - Registration of deviations and necessary measures;
  - Updating BIM towards “as-built / as-refurbished’ model”.

In consideration of the updated 8-Step methodology, the **INSITER Guidelines are mainly developed for “construction workers” and “site supervisors”** even if other players, as presented in D1.2 and D1.3, have a key role in order to create or collect the data and implement the complementary ICT solutions.

Three main levels of the key-players are involved in the guideline’s implementation and/or application:

- Level 1 (at the design stage)

  Who will prepare the project information that will be stored on the INSITER SharePoint, and that will be shown on the construction site using the mobile application:
  - Project manager;
  - Designer (Architects, structural engineers, MEP/HVAC engineers);
  - Surveyor and inspection expert;
  - Supplier.

- Level 2 (at the design stage)

  Who will link and manage all technical project information inside the INSITER ICT tools:
  - BIM manager / BIM modeller.

- Level 3 (at the construction stage)

  Who will use the guidelines (on mobile application INSITER App)
  - Construction and site workers;
  - Site supervisor;
  - Inspection expert and surveyor.

The scheme below (Fig. 2) presents the **wider picture of INSITER, in particular the ICT and process integration of the Guidelines,** developed in synergy between WP1 and WP3, introducing a general picture of the **role of the key players involved and a decision making process** starting with the design stage (implementation and preparation data) through the construction stage.

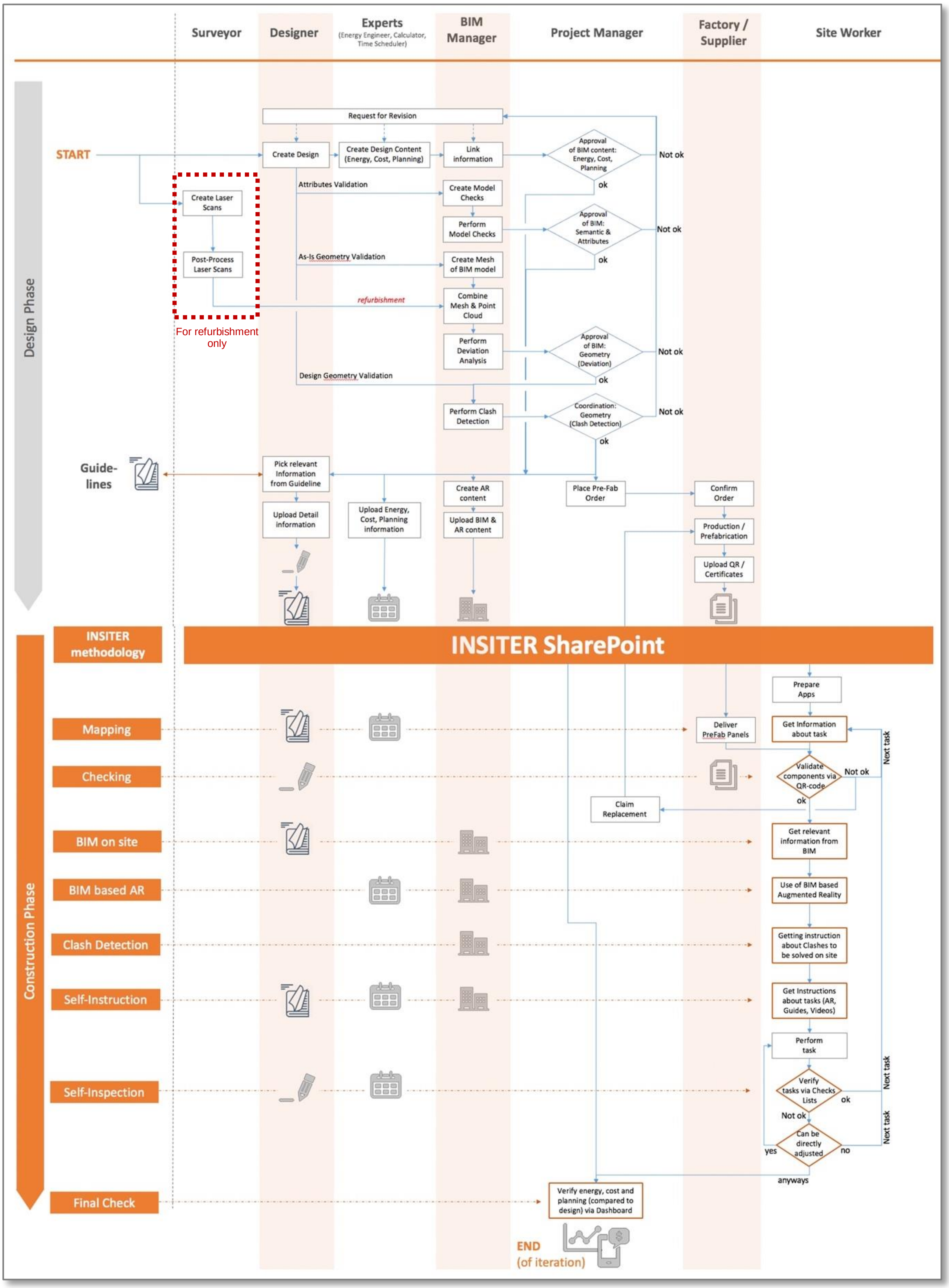


Figure 2: The wider picture of INSITER, the ICT and process integration of the Guidelines

From the technical point of view, the **INSITER Guidelines are designed as interactive and living data sheets in order to give the process instructions framework for self-instruction & self-inspection and allow practical implementation of the INSITER 8-step methodology**.

“INSITER Guidelines” will be digital and will become available through 2 main IT solutions elaborated in the WP1 and developed in WP3:

- **a mobile application** (with a user friendly interface) that interactively guides the construction worker;
- the **SharePoint platform** (expert interface) that stores all data, including BIM models, pictures, database of components, checklists.

The guidelines are organized in data sheets: each data sheet implements guidelines of the 8-Step INSITER methodology for the 9 selected critical components (building and MEP-HVAC), in agreement with the INSITER goals. Each critical component is presented with a short explanation that will also be proposed in the mobile application (INSITER app).

In synergy with the WP5 and with the purpose to test a concrete application of the guidelines, each datasheet describes a specific step of the “INSITER 8-step methodology” for a specific critical component at a specific demo case.

INSTER DEMONSTRATION CASE	NEW BUILDINGS (D1.2) / EXISTING BUILDINGS (D1.3)	ARCHITECTURAL COMPONENTS (defined in D1.4)					MEP/HVAC COMPONENTS (defined in D1.6)			
		FOUNDATION	EXTERNAL WALL AND OPENING	CURTAIN WALL / GLAZED FAÇADE	ROOF	CONNECTION OLD-NEW BUILDING SECTION	HEAT PUMP	MECHANICAL VENTILATION	SOLAR HOT WATER	LED LIGHTING
Enschede (NL)	E	-	X	X	X	-	X	X	-	X
Cologne (DE)	N	-	X	-	X	X	-	X	-	X
Delft (NL)	N	X	X	-	X	-	-	-	-	X
Pisa (IT)	E	X	X	-	X	-	-	X	-	X
Valladolid (ES)	E	-	-	-	-	-	-	-	-	X
GENERAL EXAMPLE NEW BUILDING	N	X	X	X	X	X	X	X	X	X
GENERAL EXAMPLE EXISTING BUILDING	E	X	X	X	X	X	X	X	X	X

Figure 3: Overview of the demonstration cases and use cases

The data sheets collected in D1.2 and D1.3 are organized in 5 main categories (Fig. 4) and sub-categories:

1. Category of intervention;
2. Critical EeB component that is analyzed;
3. INSITER methodology step;
4. Intervention description
    a. which are, in overall, the “*Main critical points*” of the step itself;
    b. which are the “*Key activities*” that the worker has to do within the step;
    c. which are the situations or points on which the worker has to place “*Special attention*”.
5. Technical data and information which contains all the useful documentation available for the worker.

GUIDELINES DATA SHEET CATEGORIES AND FRAMEWORK		DATA SHEET EXPLANATION
Category Intervention	New construction (Cologne demo case)	*Explanation of intervention categories considering 2 options: 1. New construction and 2. Refurbishment.*
Critical EeB Component	Exterior wall and opening	*Explanation of the Critical energy Efficient component analysed considering 9 options (See D1.4 and D1.6)*
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☒ **Step 6: Self-instruction** ☐ Step 7: Self-inspection ☐ Step 8: Final check	*Selection of INSITER methodology step analysed*
Intervention description	*Main critical points:* • Ensure that all façade panels are mounted properly; • Accurately follow the manufacturer's assembly/installation manual; • Focus on joints and sealing.	*Presentation of the main critical points that the construction workers will have to take into account for the component analysed in a specific step of the INSITER methodology. These information will be show on the INSITER app when the construction worker will open the daily activity on-site.*
	Key activities: • Follow the manual documents / videos / animations where the mounting of the new facade components is described in a step-by-step process; • Mark fixing points on the wall or on the installation surface (control lines); • Check the layout, determining the exact position of the facade according to the technical drawings; • Drill/install fixing points as required by manuals, tech specs, videos; • Check the mounting/anchoring of profiles and fasten (screw brackets on the wall/installation surface); • Check the façade element and mount on the supporting structure; • Place and fix insulation material, sealants and finishing if required, especially on joints/corners.	*Presentation of the key activities proposed to the construction worker for the component analysed in a specific step of the INSITER methodology. These information will be show on the INSITER app when the construction worker will start the activity on-site.*
	Special attention: • All frame joints are sealed properly during the construction/installation phase; • The manufacturer's installation instructions have been followed; • The work is done as per schedule; • Anchoring and fasteners; • Floor details and connection to the bearing structure; • Roof detailing.	*Presentation of alerts to check at the end of the activity proposed by the construction worker for each specific step of the methodology. These information will be show on the INSITER app when the construction worker will close the step.*
Technical data and information	• Example_Installation manual_fibre cement • Example_Installation manual_timber • Facade-Section_Cologne • Lower-Detail_Cologne • Upper-Detail_Cologne • Plan-Connection-with-wall_Cologne • Plan-Corner detail_Cologne • Plan-Joints_Cologne • Example_Mounting modules • BIM-based Self-Instruction model for mobile devices_Green Village	*Presentation of all technical data uploaded on the INSITER SharePoint for the components analysed in consideration of the interested step of the methodology.*

Figure 4: An example of data sheet presented in D1.2 and D1.3

The datasheets have been translated in the mobile application and in the collaboration platform in order to simplify the activities of the construction workers and site supervisor on-site for new construction and refurbishment (a demo movie of the INSITER software tool can be visualized at the following link: https://www.youtube.com/watch?v=ZucjFwfUpFM&feature=youtu.be).

In order to create a coherent and integrated framework for the end-user to control the construction process INSITER proposes a RE Suite IT Architecture which will be fundamental in order to translate the proposed guideline datasheets in digital contents, accessible on mobile devices. To attain an overview of the entire INSITER toolset and how all applications in this toolset relate to each other, we kindly redirect you to D3.2.

Figure 5 depicts how the RE Suite IT Architecture has been built upon within INSITER.

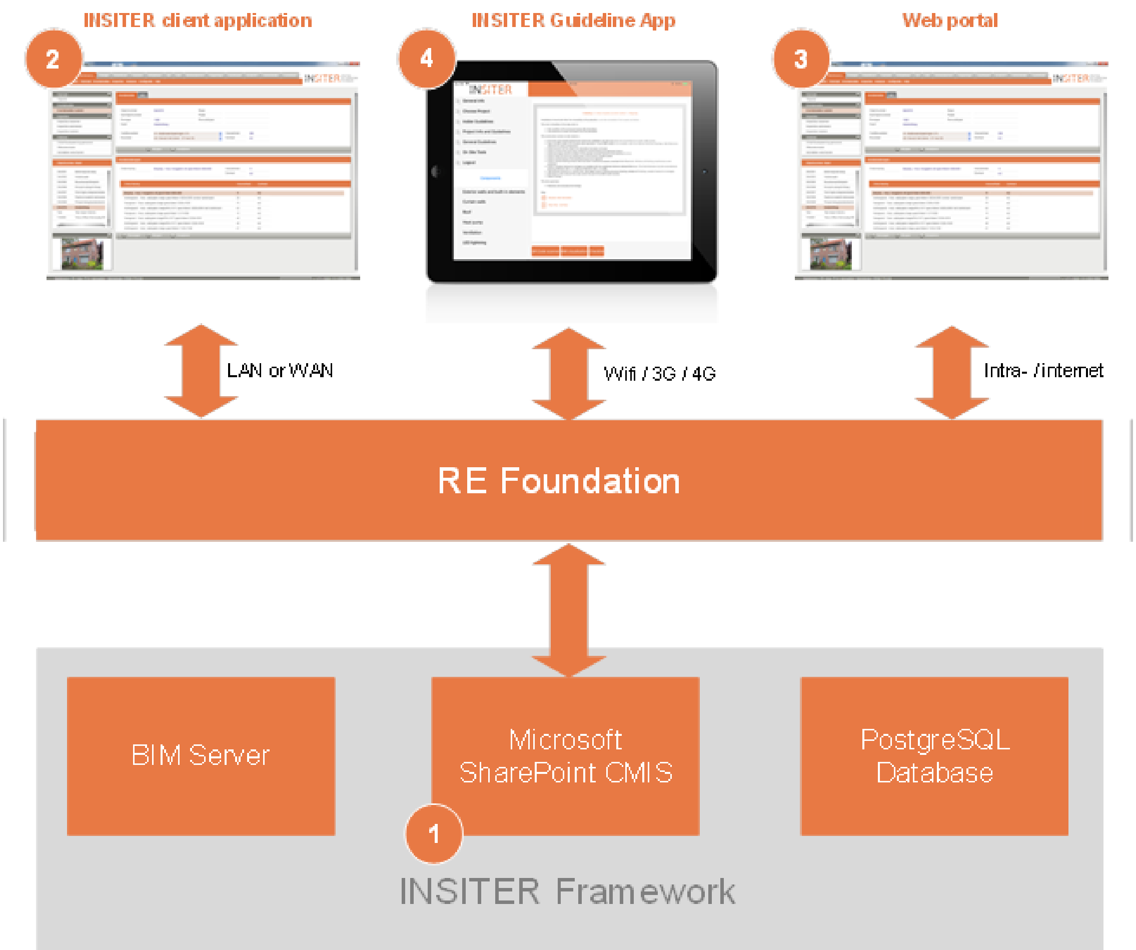


Figure 5: IT architecture of INSITER

Within INSITER a collection of data sources is combined in the INSITER Framework, a data store which is shared and used by many software applications within the INSITER toolset. One of the three elements in this framework is a Microsoft SharePoint (2013) environment.

The tabular data structure defined includes:

- Characterization of the guideline through project type, INSITER critical component and INSITER step
- Guideline content, including text or media

- Associated guideline content. This content has been categorized as follows: Audio; BIM-models; Documents; Drawings; Images; Videos.

Guidelines can be easily added and managed through the standard SharePoint list management interface, as defined in the datasheet of D1.2 and D1.3 (Fig.6).

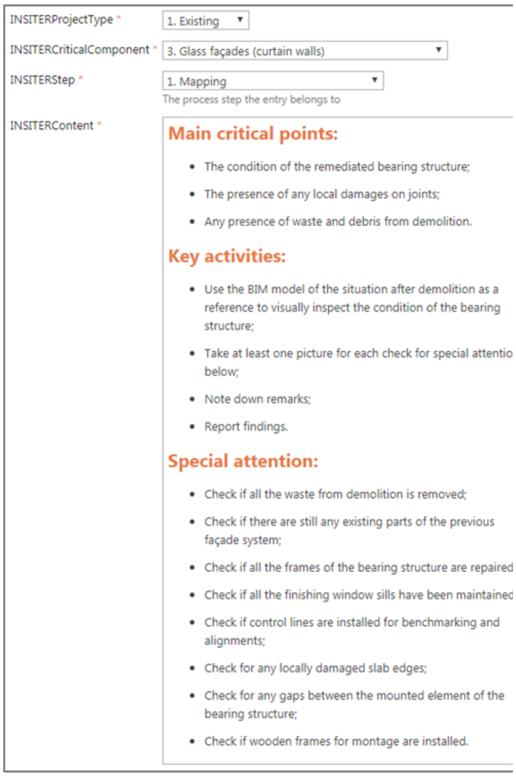


Figure 6: Standard SharePoint management interface

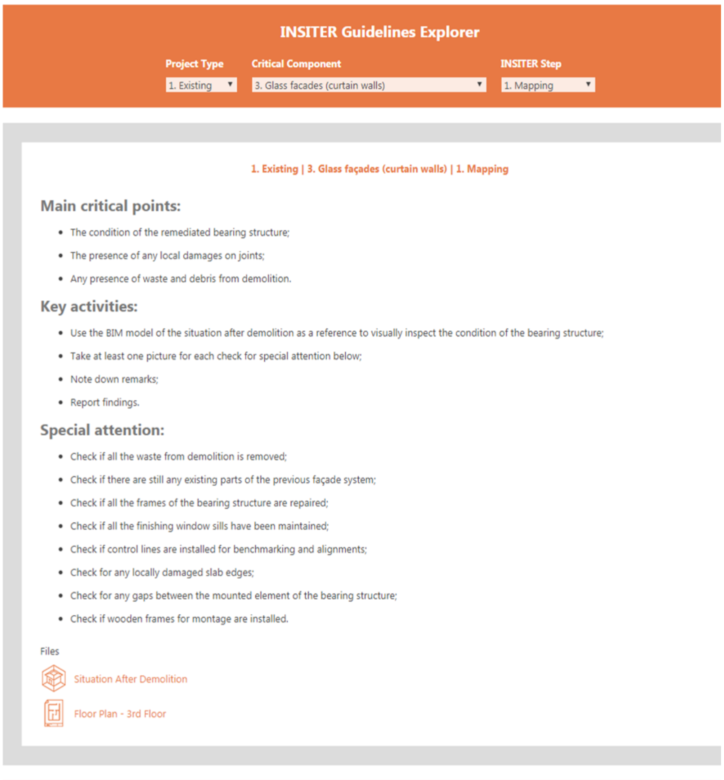


Figure 7: User-friendly configuration

The final step in capturing the INSITER Guidelines is the visualization of the guideline data. This is achieved through a custom SharePoint web part which transforms the raw (tabular) data and outputs in a structured and user-friendly manner (Fig. 7).

The process step results are described as following:

- INSITER guidelines are stored centrally, and can be efficiently managed;
- The visualization of the guidelines is a direct and automatic result of the data; the end-user is always presented with up-to-date guidelines;
- The guidelines can be viewed through multiple channels; they can be accessed both through a web browser as well as programmatically by software tools.

INSITER an RE Suite client application has been developed with the primary goal of managing the construction process. This application is envisioned to be used off-site by a construction supervisor, and is highly integrated with the INSITER mobile App.

In agreement with the guideline's principles, the INSITER mobile App provides practical and intuitive guidance for applying INSITER methods and tools on the construction site. All information available in the mobile application are collected and elaborated in the WP1 using the data-sheet guidelines presented in this report and will be stored in a private server (Share-Point).

The main characteristics of the app are:

- Available for different users with Login Profiles dedicated to 2 main user groups: Construction Workers and Site Supervisors.
- Display guidelines for projects, general purpose and new / existing, component and step specific guidelines.
- Utilize associated tools related functionality, such as the BIM Viewer, QR Code scanner, QR Code generator, Question list, Observations and the functionality provided through the link to the RDF web tool, conform the INSITER 8 steps methodology.
- View project information and view project specific guidelines.
- Download and view documents that the guideline document is linking to.
- Progress registration and monitoring.

The construction workers are the only categories (with the supervisor) involved in all steps of the 8-Step INSITER methodology. For this reason, **the following text will present a practical example of the use of the INSITER guidelines application for the construction workers step-by-step, applicable in new construction and refurbishment**.

- Step 1: The construction worker in this step needs to capture the conditions and compare them with the as-is situation. He begins his work by defining / mapping the location / room / space within the building where he needs to work for the installation / refurbishment of the critical EeB component. He goes to the location and makes a preliminary evaluation of the actual conditions on site. He can retrieve reference material for main energy-efficient and quality construction errors to be checked. Note: In case criticalities are detected, in the scenario of refurbishment, and measurements are necessary to be taken with special equipment, he notifies the site supervisor, and specialized personnel then come on site to perform the required measurements.
- Step 2: The critical EeB components to be installed are delivered on the building site. Using QR or RFID scanning tool, the construction worker checks whether these are the correct components as specified in the BIM model and the technical documents. In this step, he can check the correctness of the delivered components on site before assembly, and / or retrieve the component ID and visualize the positioning of each component.
- Step 3: This step includes visualization of the building or the critical EeB components in BIM. Using the mobile device, the construction worker opens the BIM model of the specific portion of the building where he has to perform his work with the critical EeB component. In this BIM model, he can observe how the critical EeB components are modelled and integrated within the building and use it as a reference for the actual work on site.

- Steps 4 and 5: Using the mobile device (smartphone, tablet or HoloLens) equipped with an AR application, the construction worker projects the BIM model of the new HVAC components or other critical EeB elements to be installed in the real spatial environment. This step can work complementary along with Step 5, where the worker on site can project the designed situation (correct situation) of the critical EeB components on the real situation within the building, while focusing on the criticalities (clashes). He facilitates AR to check if the critical EeB component to be assembled really fits within the intended building part / space / room, i.e. no "clashes" with building components.
- Step 6: The construction worker opens the manual documents / videos / animations where the mounting of the critical EeB components is described in a step-by-step process with easy guidance and hints / warnings of common errors to be avoided. As an INSITER tool for this step the mobile application of D4.4 has been developed, where the mounting process-critical assembly activities can be simulated and supporting reference material can be given.
- Step 7: During this step, the worker will check his own work on-site with the help of checklists. Subsequently, if needed, he notifies a specialist to measure the exact performance using specialised equipment (ref. to WP2). The measurement image (thermal, acoustic) can be either superimposed to BIM or AR for visual evaluation, or kept for integration into the BIM model later on off-site for the definition of the as-built situation and the equivalent calculation of the actual performance of the building according to how components were actually assembled in reality. Note: In case it is needed, measurements with special equipment will be performed by a specialist, upon notification by the construction worker. The evaluation of the result will be done off-site as time is required for the retrieval of the measurement results.
- Step 8: After collecting data from all the previous steps, the final step consists in the final evaluation of the work to be delivered. The construction worker completes his assignment by reporting on the finished work, including photos taken on-site. He should also note errors or doubts, if any, into his digital report through the mobile application. The site supervisor opens this report, and gives approval or asks for rework. The approved work appears on a common dashboard (off-site) showing the level of quality and performance during the on-site process. Quality, time and cost evaluation can be monitored in this way by the construction managers.

Deliverable positioning in WP1

D1.2 and D1.3 (the INSITER guidelines) are a follow-up of already produced deliverables in WP1 that analyse the construction errors and KPIs that should be avoided while applying the INSITER tool - see **D1.1 Best practices and existing shortcomings.**

The objective is to reduce the number and check the relevance of possible failures at a qualified level in order to reduce or even better avoid their impact, especially on the quality of the building envelope performance, as these failures create a higher consumption of energy and may cause on-going problems affected by density leaks. Especially in lightweight prefab constructions consisting of well manufactured components the influence on total energy performance and indoor air quality and building physics is extremely high if the joints between the elements and supporting structures are not well closed in terms of expected air density. Leakages cause follow up damages and increase bad performance of the total system.

Furthermore, in **D1.4 Calculation and analytical methods for building components** and **D1.6 Calculation and analytical methods for MEP/HVAC components** the critical components of the prefab building systems have been identified in order to ensure the quality based on their special nature, constructive task and depending on the position in the construction system and functionality expected.

The identified critical components are listed in D1.4 and D1.6 and will be treated following the INSITER 8-step approach of analysis in deliverables D1.4 and D1.6. Follow-up deliverables **D1.5 and D1.7 will report in detail measuring procedures and protocols for inspecting building components and MEP/HVAC respectively**.

NOTE: How to read deliverables D 1.2 and 1.3

In order to avoid going back and forth between the two deliverables, the generic part of the INSITER Guidelines for both applications (new construction and refurbishment) is the same and is presented in both deliverables. This part applies for both new construction as well as refurbishment projects: the common contents are **highlighted with a grey background** in the two reports. In this way, the Reader can read the two documents independently from one another, since the knowledge base and the structure that underlies the guidelines are the same for the new construction and for refurbishment. **The specific part concerning new construction OR refurbishment is left blank in each report**, and is basically included in the content of the data sheets (sections 4 and 5).

List of acronyms and abbreviations

- AEC: Architecture, Engineering and Construction industry
- AR: Augmented Reality
- BIM: Building Information Modelling
- BLC: Building Life Cycle
- CAD: Computer Aided Design
- CNC Computerised Numerical Control
- DoA: Description of the Action
- EE: Energy Efficiency
- EeB: Energy Efficient Buildings
- GUI: Graphical User Interface
- GUID: Globally Unique Identifier
- HFM: Heat Flow Method
- HTML: Hypertext Markup Language
- HVAC: Heating, Ventilation, Air Conditioning
- ICT: Information and Communications Technology
- IFC: Industrial Foundation Classes
- ISO: International Organisation for Standardization
- KPI: Key Performance Indicator
- LCA: Life Cycle Assessment
- LCC: Life Cycle Cost
- M&E: Mechanical and Electrical services
- MEP: Mechanical, Electrical, Plumbing
- MTT: Methods, Tools and Techniques
- NDT: Non-destructive test
- nZEB: Nearly Zero Energy Building
- QC: Quality Control
- QR code: Quick Response Code
- SIG: Special interest group
- TCO: Total Cost of Ownership
- URL: Uniform Resource Locator
- VR: Virtual Reality
- WBS: Work Breakdown Structure
- ZEB: Zero-Energy Building

Definitions

Project

INSITER demonstration deals with six real projects. The demonstration validation testing and training activities take place on these real building sites.

Physical settings

There are three different natures of testing levels and related cases:

- Lab testing case: performed at the laboratory or artificially created test sites at the factory
- Factory testing case: performed at the factory related to real projects and its components
- Field (on-site) demonstration case: performed at building sites

Self-inspection

Encourages, enables and equips construction workers to check their own working processes and the results respectively, both individually as well as peer-to-peer with other workers.

Self-instruction

Self-instruction is a pro-active approach to provide craftsmen and professionals with interactive guidance during their working processes. Self-instruction is facilitated on the workers' mobile devices, with continuous updates based on both pre-planned (designed) process as well as real-time feedback from self-inspection. Self-instruction prevents wrong actions, and helps the workers to rectify any error immediately.

Storyboard

A storyboard is a description of a follow up of steps in the real workflow related to a single building site. The storyboard approach identifies important project steps and interaction. The objective is to create use cases that are important related to characteristics for the application of the INSITER tool at building sites at the most effective and efficient level. Storyboards are representing a characteristic and important selection of building sites´ workflow.

For example: describing as a whole in a 'storytelling way' how the geometric checking is done –how, where, who.

Use case

A use case is defined as a sample case relevant and valuable for INSITER testing needs based on a storyboard representing the full workflow. The characteristics of the use case are transferable and therefore the results help to validate the INSITER methodology and tool application. For example: checking the geometric accuracy –what is the goal, what is the criticality. A use case can take place within a lab, factory, or field case.

Action

Is describing a specific activity within the storyboard – e.g. calibrating measurement device, taking measurement. Actions are related to the 8-Step INSITER methodology of quality assurances: mapping, checking ordered components. These steps must be consistent with the overview of the 8-Step INSITER method - see DoA p.15, part B.

Assembly Phase

The process of pre-fabrication of the building parts at factory level including an analogue mock-up at the factory.

Construction Phase

The process of constructing the building to meet the criteria established during the design phases and where the building performance as outlined in the construction documents is validated through observations and testing (source: NIBS Guideline 3-2012 Building Enclosure Commissioning Process BECx This Guideline is for Use with ASHRAE Guideline 0-2005: The Commissioning Process, 2012). Within the construction phase all processes related to the placement of pre-fab components at the site are embedded.

Maintenance Phase

The objective is to repair unscheduled and scheduled deficiencies during the time period in which they occur. This includes preventive maintenance for buildings, structures, and installed building equipment (IBE) as recommended by the manufacturer. It also includes engineering and/or contracted Architectural and Engineering (A&E) services that support planning, design and execution of maintenance activities.

Fulfilment of the Description of Action (DoA)

Accessibility of this deliverable

This deliverable is presented in 1 part: Report / documentation (this document). For INSITER consortium and European Commission representatives, the deliverable is available both in the EC Participant Portal (INSITER project) as well as in the SharePoint project website.

After approval by the European Commission, the public version of this deliverable will be published on the INSITER public website, and disseminated through the common dissemination channels.

The preliminary video showing the INSITER Guideline Mobile App can be watched on YouTube using this https://www.youtube.com/watch?v=ZucjFwfUpFM&feature=youtu.be

Fulfilment of WP, Task and Deliverable scope and objectives

In order to address the latest EC remarks received on 24 Oct 2018, the revised deliverable (09 Nov 2018) has been updated and integrated. In particular, the following issues shall be underlined:

- In order not to go back and forth the two deliverables, the main process for both applications (new construction and refurbishment) is the same and is presented in both deliverables: the overlapping contents have been highlighted with grey colour background in the two reports. In this way, the Reader can read the two documents independently from one another, since the knowledge base and the structure that underlies the guidelines are the same for the new construction and for refurbishment. This approach guarantees the maximum flexibility of the INSITER methodology, implies the possibility of having a wider field of application and is well suited to allow versatility to the software structure that has been produced. On the other hand, the content of the data sheets (sections 4 and 5) is different between the two deliverables because it refers to peculiar elements that characterize the types of intervention (new built versus refurbishment). Furthermore, the information and the elaborated contents of the data sheets are taken from real-world projects and mostly from the demonstration cases analyzed and developed in WP5.
- a chapter has been added (Ch. 3 “Key-actors involved in the Guideline implementation and application”), describing:
  - the wider picture of INSITER;
  - the main actors involved in the development and use of the INSITER guidelines, with roles and responsibilities;
  - the communication, responsibilities and decision-making process;
- a paragraph has been added (Ch. 3.4 “Construction workflows based on step-by-step INSITER methodology”) in order to describe the workflow of the construction process, on the basis of INSITER 8-step methodology. The workflows have been the basis to develop the “logic” of the INSITER App.

Summarised objectives as stated in DoA	Results presented in this deliverable
WP 1 scope and objectives: • Techniques for self-inspection and self-instruction in different types of projects (new construction, refurbishment, commissioning, and maintenance). • Key performance indicators (KPIs) and parameters addressing quality and energy performance level. The parameters are for instance: thermal bridges, air leakages, imaging of U-Value distribution, acoustic leakages, vibration transmissibility from MEP/HVAC.	Addressed: • For each critical EEB component (as defined in D1.4 and D1.5), the practical implementation of 8-steps methodology is developed, using data sheets that represents the structure and the contents to be “translated” into the INSITER Guideline Mobile App that will be used on site in real applications (See chapter 4). Each working step is described accordingly with practical real-world cases and, if applicable, with selected INSITER demo cases– in D1.2, as an integration of D1.3, the focus is on new construction. • Self-inspection (step 7) and self-instruction (step 8) procedures are provided in different types of projects for critical building components (e.g. roof, façade, openings) and MEP/HVAC components (e.g. energy and comfort systems). • The applicability of the hardware tools during on-site processes is outlined on a step-by-step basis. The measurement systems and related parameters considered are grouped in three main areas: thermal/imaging, acoustic/vibration, positioning/ sensing, that can be applied in the different steps. • This deliverable serves as an integration of deliverable D1.3 in case of refurbishment projects on existing buildings and as an input for creation of the Guideline Mobile App, in which the guidelines are embedded in a user-friendly, interactive and practical device.

Summarised objectives as stated in DoA	Results presented in this deliverable
Task 1.1 scope and objectives: • Lessons learned from the past-performance studies and evaluations, actual directives, guidelines. • Self-inspection during procurement, pre-commissioning, commissioning and project delivery. • Mapping of specificities of new and existing prefab based EeB. • Methodology concerning process, actors and instruments (systems, devices) for self-inspection and self-instruction. • Generalization of INSITER solutions for prefab buildings to other building typologies.	Addressed: • The main critical issues are defined for each EEB components and for each step of the proposed INSITER methodology, based on lessons learned from the demo cases, the past-performance studies, the actual reference standards, the theoretical protocols and practical procedures presented in the previous deliverables of the WP1 and WP5. • The involved stakeholders are outlined and specified for each working step in the construction process and for each critical EEB component, to provide the process workflow and guidelines framework to be included in the INSITER Guideline Mobile App. • For each EEB component, an in-depth selection of tools and methods relevant for inspection is developed, in accordance with WP2 results. • Starting from the analysis of INSITER demo cases (WP5) and real-world applications (WP2; WP3; WP4), the differences between new construction and refurbishment projects are outlined within the deliverable. In order to avoid repetition and to promote standardization, similar processes for new construction and refurbishment are set up and reported. D1.2 collects and describes only the specificities of new construction and is considered an integration of D1.3. • For each EEB component and for each step of the process, an in-depth selection of tools and methods relevant for inspection is developed and the applicability on site is verified. • This deliverable, together with deliverable D1.2, serves as an input for further elaboration of process methods for self-inspection of EEB components in new construction and refurbishment that will be completed in the follow-up deliverables D1.5 and D1.7.

<table>
<tr>
<td rowspan="2">Deliverable D1.2 scope and objectives:
To introduce the 8 step INSITER methodology as INSITER guidelines for refurbishment interventions.
To proposed the application on real cases of the innovative INSITER methodology for existing buildings considering energy efficiency refurbishment intervention using prefab technologies.</td>
<td>Achievement:
The deliverable introduces the INSITER methodology and presents the main activities and scopes of each specific step. The contents proposed in the report will be embedded in the INSITER Guideline Mobile App.
Two levels of contents are obtained:
- The guidelines that lead the project manager/workers into the construction process for each EEB components and are embedded in the INSITER Guideline Mobile App.
- the technical guidelines that represent the technical contents and are stored in the SharePoint. These kinds of information are collected and serve to describe components (technical specifications or datasheets), to illustrate installation procedures (instruction manuals), to define measurement procedures (standards or technical reports).</td>
<td>Percentage:

100%</td>
</tr>
<tr>
<td>Practical presentation of application on real cases and demo-cases of the INSITER methodology considering the main critical energy efficiency building and MEP-HVAC components. The technical guidelines which represent the technical contents are stored in the SharePoint. These kinds of information are collected and serve to describe components (technical specifications or datasheets), to illustrate installation procedures (instruction manuals), to define measurement procedures (standards or technical reports).</td>
<td>100%</td>
</tr>
<tr>
<td colspan="3">Project’s progress relevant to the deliverable within the corresponding timeframe:</td>
</tr>
</table>

• Developing self-inspection techniques and methods coherent with an efficient construction process workflow.	Achievement percentage: 100% • Explanation: Based on the main tasks of the building construction process, the report presents the main "self-inspection" techniques to reduce the construction errors and to improve the building quality with focus on energy efficiency. For each step of the INSITER methodology (1. Mapping; 2. Procurement, production and delivery; 3. Modelling; 4. Deploying BIM; 5. BIM model checking and clash detection; 6. Construction site preparation; 7. Construction/Refurbishment process; 8. Pre-commissioning, commissioning and project delivery) the datasheet proposed presents: the intervention category; the critical EeB components analysed; the intervention description; the technical data and information upload on the SharePoint.
• Stakeholders, process and actor mapping/analysis with focus on on-site self-inspection and self-instruction.	Achievement percentage: 100% • Explanation: For each step of the INSITER methodology the proposed guidelines presents the main process, procedures and tasks for self-inspection and self-instruction of the main users using the INSITER mobile app. The approach is proposed considering the intervention defined in the INSITER demo case of Delft (The Netherland) and Cologne (Germany).

D1.2: EC remark's at Final Review addressed in the Revised Deliverable	
Remark	**Improvement made**
The framework and level structure of the guidelines need to be detailed; describe what are the communication, responsibilities and decision-making involved when it comes to KPIs and INSITER measurements, including the role of the Supervisors.	Details of framework and level structure of the Guidelines, including communication, responsibilities and decision-making concerning measurements and KPIs, have been added in Subchapter 3.3. In addition, a more detailed description of the key-actors has been implemented, in order to clarify the roles and responsibilities in the application of INSITER guidelines on the construction site (Chapter 3, Sub. 3.2).
The wider picture of INSITER is expected to be integrated in guidelines.	The wider picture of INSITER, including ICT and process integration of the Guidelines as well as the roles and interrelationships between all involved actors in the construction workflows, have been added and elaborated in Chapter 2 and Chapter 3 (in particular, Sub. 3.1).

Table of contents

1. Introduction

1.1 Understanding the “INSITER Guidelines”

1.1.1 What is the aim of the “INSITER Guidelines”?

The INSITER project aims at detecting and preventing quality and performance gaps between the design and the realization of buildings made of prefab components. This aim is to be achieved by the “Self-Instruction and Self-Inspection methods”, supported by BIM-based software tools, Augmented Reality and 3D measurement instruments.

In this context, the “INSITER Guidelines” are practical guiding principles for applying the self-instruction or self-inspection methods and tools that have been developed within research project, in order to meet INSITER’s goal of improving the level of quality and energy efficiency on site. In other words, the “INSITER Guidelines” is the synthesis of the knowledge developed in INSITER, and the bridge to bring research knowledge into practical implementation.

A digital format was selected for the implementation of the “INSITER guidelines”, due to the hard requirement to be practical, as the guidelines are not:

- Paperwork, books;
- Product installation manuals; these are provided by manufacturers;
- Theoretical protocols, procedures, standards.

Instead, the “INSITER Guidelines are designed as “interactive and living data sheets”, thus avoiding lengthy reports/documents and allowing experts and users to extend, enrich and modify them continuously, as the guidelines are:

- Interactive, accessible on digital devices;
- Giving the process guidelines framework for self-instruction & self-inspection;
- Allowing practical implementation of the INSITER 8-steps methodology.

Figure 8: The storyline of the aim of the “INSITER Guidelines”

1.1.2 What is the scope of the “INSITER Guidelines”?

The focus of INSITER is on prefabricated components and the needs of the modular construction process with respect to the elimination of energy efficiency and quality assurance gap.

In this context, Critical EeB Components have been selected and explained in the preceding D1.4 and D1.6, representing physical reference objects for the given INSITER scope of the prefabricated construction process. The common errors and applicable technical norms have been analysed in the preceding D1.1. The "INSITER Guidelines" respectively, address these Critical EeB Components (both building as well as HVAC/MEP systems) with the highest risk of errors during construction and the highest impact for quality and performance of the Energy-efficient Building (EeB).

Critical EeB Building Components (D1.4)

- Foundation and ground floor
- Exterior walls and built-in elements
- Curtain walls
- Roof
- Connection between new and existing

Critical EeB HVAC/MEP Components (D1.6)

- Heat pump
- Ventilation
- Solar hot water
- LED lighting

Figure 9: The scope of the "INSITER Guidelines"

1.1.3 What is the format of the "INSITER Guidelines"?

The INSITER Guidelines bring together documentation and principles of WP1, BIM data of WP4 and measurement tools of WP2 within the same framework of the INSITER 8-step methodology; supported by IT solutions of WP3.

In practice, "INSITER Guidelines" will be digital and will become available through two main IT solutions elaborated in the WP1 and developed in WP3:

- a mobile application (user interface) that **interactively guides the construction worker**;
- the SharePoint platform (expert interface) that stores all data, including BIM models, pictures, database of components, checklists.

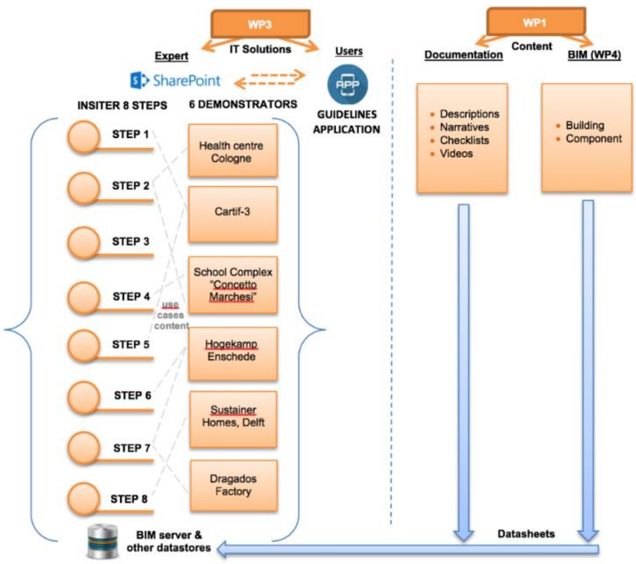


Figure 10: The "INSITER guidelines" relationship framework between content (WP1) and IT (WP3)

1.2 Framework structure and level of guidelines for new construction (D1.2) and refurbishment (D1.3)

In order to simplify the data collection for each critical building and MEP-HVAC component and to facilitate transfer information on supported IT solution (SharePoint and mobile application), the guidelines are organized in specific data sheets. Each data sheet, presented in sections 4 and 5 of the report, implements guidelines of INSITER 8-step methodology for each selected critical component in agreement of the INSITER aims and principals. In synergies with the WP5 and with the purpose to test a concrete implementation of the guidelines, each datasheet describes a specific step of the “INSITER 8-step methodology” for a specific critical component at a specific demo case. Not all INSITER demo case proposed construction activities on specific critical components and for this reason occasionally the data sheet refers to a “typical case”. D1.2 and D1.3 introduced overall 144 data sheets for 9 critical components. Each critical component is presented with a short explanation that will be proposed also in the mobile application (INSITER App). The data sheet is organized in 5 main categories and sub-categories as will be proposed in the INSITER app:

1. Category of intervention
    a. New construction or
    b. Refurbishment
2. Critical EeB component to be analysed
3. INSITER methodology step
4. Intervention description
    a. which are, in overall, the “***Main critical points***” of the step itself
    b. which are the “***Key activities***” that the worker has to do within the step, and
    c. which are the situations or points on which the worker has to put “***Special attention***”.
5. Technical data and information which contains all the useful documentation available for the construction worker.

The guidelines were conceived in order to be “translated” in the mobile application and in the collaboration platform: the final aim is to simplify the activities of the construction workers and site supervisor on-site for new construction and refurbishment. Excel forms (i.e. datasheets) will work as a channel of information for the mobile application, such as: text description to be displayed, links to the relevant BIM models, links to the relevant installation manuals stored in SharePoint or available online from the manufacturers. These data sheets will be made available online and will also be used for training purposes involving real practitioners, which will be organized in WP 6 in synergy with the Horizon 2020 project BuildUpSkills and CSA project PROF_TRAC.

INSTER DEMONSTRATION CASE	NEW BUILDINGS (D1.2) / EXISTING BUILDINGS (D1.3)	ARCHITECTURAL COMPONENTS (defined in D1.4)					MEP/HVAC COMPONENTS (defined in D1.6)			
		FOUNDATION	EXTERNAL WALL AND OPENING	CURTAIN WALL / GLAZED FAÇADE	ROOF	CONNECTION OLD-NEW BUILDING SECTION	HEAT PUMP	MECHANICAL VENTILATION	SOLAR HOT WATER	LED LIGHTING
Enschede (NL)	E	-	X	X	X	-	X	X	-	X
Cologne (DE)	N	-	X	-	X	X	-	X	-	X
Delft (NL)	N	X	X	-	X	-	-	-	-	X
Pisa (IT)	E	X	X	-	X	-	-	X	-	X
Valladolid (ES)	E	-	-	-	-	-	-	-	-	X
GENERAL EXAMPLE NEW BUILDING	N	X	X	X	X	X	X	X	X	X
GENERAL EXAMPLE EXISTING BUILDING	E	X	X	X	X	X	X	X	X	X

Table 1: Matrix of relevant critical components in INSITER demonstrators

INSITER INTUITIVE SELF-INSPECTION TECHNIQUES

GUIDELINES DATA SHEET CATEGORIES AND FRAMEWORK | **DATA SHEET EXPLANATION**

Category Intervention	New construction (Cologne demo case)	*Explanation of intervention categories considering 2 options: 1. New construction and 2. Refurbishment.*
Critical EeB Component	Exterior wall and opening	*Explanation of the Critical energy Efficient component analysed considering 9 options (See D1.4 and D1.6)*

INSITER Methodology	☐ Step 1: Mapping	
	☐ Step 2: Checking of ordered components	
	☐ Step 3: BIM for on-site construction	
	☐ Step 4: BIM-based Augmented Reality	
	☐ Step 5: Visual clash detection during construction	*Selection of INSITER methodology step analysed*
	☒ **Step 6: Self-instruction**	
	☐ Step 7: Self-inspection	
	☐ Step 8: Final check	

Intervention description

Main critical points:
- Ensure that all façade panels are mounted properly;
- Accurately follow the manufacturer's assembly/installation manual;
- Focus on joints and sealing.

Presentation of the main critical points that the construction workers will have to take into account for the component analysed in a specific step of the INSITER methodology. These information will be show on the INSITER app when the construction worker will open the daily activity on-site.

Key activities:
- Follow the manual documents / videos / animations where the mounting of the new facade components is described in a step-by-step process;
- Mark fixing points on the wall or on the installation surface (control lines);
- Check the layout, determining the exact position of the facade according to the technical drawings;
- Drill/install fixing points as required by manuals, tech specs, videos;
- Check the mounting/anchoring of profiles and fasten (screw brackets on the wall/installation surface);
- Check the façade element and mount on the supporting structure;
- Place and fix insulation material, sealants and finishing if required, especially on joints/corners.

Presentation of the key activities proposed to the construction worker for the component analysed in a specific step of the INSITER methodology. These information will be show on the INSITER app when the construction worker will start the activity on-site.

Special attention:
- All frame joints are sealed properly during the construction/installation phase;
- The manufacturer's installation instructions have been followed;
- The work is done as per schedule;
- Anchoring and fasteners;
- Floor details and connection to the bearing structure;
- Roof detailing.

Presentation of alerts to check at the end of the activity proposed by the construction worker for each specific step of the methodology. These information will be show on the INSITER app when the construction worker will close the step.

Technical data and information
- Example_Installation manual_fibre cement
- Example_Installation manual_timber
- Facade-Section_Cologne
- Lower-Detail_Cologne
- Upper-Detail_Cologne
- Plan-Connection-with-wall_Cologne
- Plan-Corner detail_Cologne
- Plan-Joints_Cologne
- Example_Mounting modules
- BIM-based Self-Instruction model for mobile devices_Green Village

Presentation of all technical data uploaded on the INSITER SharePoint for the components analysed in consideration of the interested step of the methodology.

1.3 INSITER 8-Step methodology

The 8-Step of INSITER method (applicable on construction site) was presented in the project proposal which became the Description of Action / part of Grant Agreement, and has been referred to in various deliverables and discussions.

As research progresses, the definition and scope of the 8 steps have been evolving during the 4-year project, due to refocusing aligned with the primary setting of INSITER in the on-site construction/refurbishment stage.

This refocusing has resulted in the definition as implemented of the INSITER Guidelines, that are mainly developed for construction workers and site supervisors, even if other actors, as presented in this Report, play a key role in order to create or collect the data and implement the digital tolls or ICT solutions (see next chapter). The clarification of the evolution of the INSITER steps is summarised in the following table, which is important in order to read in the best way the data-sheets presented in sections 4 and 5.

INSITER 8-step Method	Step description in the latest DoA	Further refocusing of the scope of 8 steps for the INSITER Guidelines in D1.2-D1.3
Step 1: Mapping	Mapping actual technical conditions of the site and building, and performing economic valuation of the property and land; capture the requirements and compare them to as-is situation. This step is performed by the building occupants, owners, and technical advisors / inspection specialists. Mapping is done using INSITER self-inspection software based on 3 types of input: • Technical performance of the system (e.g. temperature of heated air at the ventilator) • Operational performance in the relevant room (e.g. temperature of the workplace), thermal leakages identified by IR camera, acoustic insulation losses detected via SoundBrush) Norms and user's preferences (e.g. required and desired level of comfort, health norms) The outcome of this mapping is used to develop possible refurbishment scenarios, taking into account the project goals (e.g. refurbishment that also includes an upgrade of the energy label), KPIs, Total Cost of Ownership (TCO), Return on Investment (RoI), and time schedule. The scenarios are further analysed to decide single or multiple plans, among others: • Damage prevention • Recovery / repair • Replacement / reconstruction • Modification / redesign / transformation	Mapping actual technical conditions of the site and building, and performing economic valuation of the property and land; capture the requirements and compare them to as-is situation. This step is performed by the construction workers after receiving his work assignment. The workers check whether the working areas (e.g. construction site designated for a new building or a storey in the existing building) are cleared and ready for the planned construction/refurbishment activities. In case of refurbishment of existing HVAC/MEP systems, "mapping" also means assessing the condition of the existing systems. Health and safety regulations are also addressed, for instance: the building site must be cleared of asbestos and the working areas must be safe/secured. Actual conditions (e.g. weather, accessibility, construction equipment, transport and logistic processes on-site) related to the planned works are also verified. The outcome of this mapping is used to verify the construction/ refurbishment work planning.
Step 2: Checking of ordered components	Self-inspection at procurement, production and delivery of prefab components. • Pre-qualification based on Quality Management (QM) and reference projects • Selection and procurement methods for contractors and suppliers with industrialised design, engineering and certification / energy-performance labelling • Connecting 3D product databases from manufacturers with BIM systems of the refurbishment project, and in-factory / pre-delivery product inspection	Self-inspection at procurement, production and delivery of prefab components. • Checking the correctness and conditions of the delivered prefab components, as well as by validating delivery schedules against logistic planning • Connecting to the 3D product databases from manufacturers and the positions of the components in the BIM model • In case pre-assembly is done in factory, checking also means pre-delivery product inspection.

	• Tests on components and equipment will be performed for quality control on prefabricated panels, including integration of Non-Destructive Testing (NDT) methods.	• Tests on the quality conformity of the delivered prefab components are performed, including integration of Non-Destructive Testing (NDT) methods if necessary.
Step 3: BIM for on-site construction	Modelling of the [existing] building, site and surroundings in Building Information Model (BIM). When a BIM model of the building does not exist, the existing building will be modelled in BIM, including detailed modelling of the current building and MEP/HVAC components that are critical for building quality and energy performance. BIM modelling will incorporate available 2D and 3D drawings and documentations of the building, as well as 3D laser scanning and point cloud data processing. Relevant GIS data will be included in BIM; information models of building/MEP components will be aggregated and converted to open-standard BIM.	Modelling of the [existing] building, site and surroundings in Building Information Model (BIM). When a BIM model of the building does not exist, the existing building will be modelled in BIM, including detailed modelling of the current building and MEP/HVAC components that are critical for building quality and energy performance. BIM modelling will incorporate available 2D and 3D drawings and documentations of the building, as well as 3D laser scanning and point cloud data processing. Relevant GIS data will be included in BIM; information models of building/MEP components will be aggregated and converted to open-standard BIM. The BIM model can be viewed on mobile devices on construction site.
Step 4: BIM-based Augmented Reality	Generating and deploying BIM-based Augmented Reality (AR) for self-instruction and self-inspection. • Embedding BIM and VR in Augmented Reality (AR), and extracting BIM / VR process information into 'self-instructions' (e.g. installation manuals and planning schedule) for construction workers on their mobile devices (e.g. iPad); and generating self-instruction modules • Interfacing with inspection hardware (e.g. scanning, imaging and measurement equipment) • Incorporating BIM into the inspection software (e.g. DEMO RE Suite for condition assessment of building components, DWA MONAVISA for MEP/HVAC/energy systems performance)	Generating and deploying BIM-based Augmented Reality (AR) for self-instruction and self-inspection. • Embedding BIM and VR in Augmented Reality (AR), and extracting BIM / VR process information into 'self-instructions' (e.g. installation manuals and planning schedule) for construction workers on their mobile devices (e.g. iPad); and generating self-instruction modules • Interfacing with data output from other inspection hardware (e.g. scanning, imaging and measurement equipment).
Step 5: Clash detection during construction	Virtual validation of quality and performance by BIM Model Checking and Clash Detection; as well as value and process optimisation by Virtual Reality simulation. When errors / deviations are found, INSITER self-inspection protocols will apply for: • Review the clash details, and then determine the severity of this clash in several degrees (e.g. from 'easily fixed [human] error' to 'fundamental error requiring redesign'). • Trace back the defaulting components to their manufacturers/suppliers, and ask these actors to perform review and to propose recovery solutions. • Damage prevention or collaborative recovery involving multiple actors.	Visual validation on-site based on the BIM clash detection performed prior to construction / refurbishment activities. • BIM-based clash detection is performed before construction/ refurbishment. Found clashes should be resolved by the design/ engineering team, yet the discoveries are recorded to be visualised in AR on-site. • Review the clash details, and then determine the severity of this clash in several degrees (e.g. from 'easily fixed [human] error' to 'fundamental error requiring redesign'). • If unresolved clashes are still found on-site, trace back the defaulting components and ask these involved actors to perform review and to propose recovery solutions.
Step 6: Self-instruction	Self-instruction during preparation and execution of construction site and logistics. • Checking the construction site and updating BIM site modelling based on actual conditions (e.g. weather, accessibility, construction equipment, transport and logistic processes on-site) • Optimising time and cost schedules (also linked to production planning); analysing risks	Self-instruction during preparation and execution of construction site and logistics. • Checking the assembly manuals with support of BIM-based 3D visual instructions. • Implementing 'self-instructions' to mobile devices of construction workers; providing supervision and support when needed. • Optimising time and cost schedules (also linked to production planning); analysing risks

	of delay and budget-overrun; and updating the self-instruction guidelines for construction workers	of delay and budget-overrun; and updating the self-instruction guidelines for construction workers.
Step 7: Self-inspection	Self-inspection during construction / refurbishment / maintenance process. • Checking the correctness and conditions of the delivered prefab components, for instance by means of RFID, NDT, acoustic and thermal insulation tests, as well as by validating delivery schedules against logistic planning • Implementing ‘self-instructions’ to mobile devices of construction workers; providing supervision and support when needed • Comprehensive evaluation at certain intervals (e.g. weekly), performed by the site supervisor involving workers from contractors and sub-contractors. The preliminary quality and performance results are quantitatively measured and analysed as input for participatory decision-making. • The sound insulation and U-value will be measured on the building site by means of the procedure developed in INSITER. Thermal and acoustic leakages will be identified using IR camera and SoundBrush allowing to visualise 3D pictures of the building acoustic and thermal field and calculate the sound insulation and the global U-value.	Self-inspection during construction / refurbishment / maintenance process. • The workers check the result and quality of the performed works by them according to online / digital check lists depending on the assembled components. • When detailed inspections are needed, the specialists will be called in. The sound insulation and U-value will be measured on the building site by means of the procedure developed in INSITER. Thermal and acoustic leakages will be identified using IR camera and SoundBrush allowing to visualise 3D pictures of the building acoustic and thermal field and calculate the sound insulation and the global U-value.

Step 8: Final check	Self-inspection and self-instruction during pre-commissioning, commissioning and project delivery.
	
	• Self-inspection during pre-commissioning by contractor and building owners:
	  ▪ Checking whether all systems work properly according to the specifications
	  ▪ Checking the preliminary performance of the building
	  ▪ Registration of deviations and necessary measures
	  ▪ Updating BIM towards ‘as-built model’
	
	• Self-inspection during commissioning by contractor, building owners and occupants:
	  ▪ Setting up and adjusting the building and MEP/HVAC systems based on the desired conditions
	  ▪ Updating performance information in BIM; connecting BIM with Facility Management (FM) or Building Automation Systems (BAS), or energy monitoring systems, where available
	  ▪ BIM for self-instruction for the building occupants: as-built virtual building model that shows the operation manuals of the building–interactively accessible through the occupants’ mobile devices
	
	• Self-inspection during project delivery / handover:
	  ▪ Final inspection by the inspection specialist, contractor, building owners and occupants
	  ▪ Delivery of the building including ‘as-
		Self-inspection and self-instruction during pre-commissioning, commissioning and project delivery.
		
		• Comprehensive evaluation at certain intervals (e.g. weekly), performed by the site supervisor involving workers from contractors and sub-contractors. The preliminary quality and performance results are quantitatively measured and analysed as input for participatory decision-making
		
		• Final check during pre-commissioning by contractor and building owners:
		  ▪ Checking whether all systems work properly according to the specifications
		  ▪ Checking the preliminary performance of the building
		  ▪ Registration of deviations and necessary measures
		  ▪ Updating BIM towards ‘as-built / as-refurbished model’
		
		• Check during commissioning by contractor, building owners and occupants:
		  ▪ Checking whether all systems work properly according to the specifications
		  ▪ Checking the preliminary performance of the building
		  ▪ Registration of deviations and necessary measures
		  ▪ Updating BIM towards ‘as-built / as-refurbished’ model’
		
		BIM for self-instruction for the building occupants: as-built virtual building model that shows the

	built' and 'as-operated' BIM (containing setup information) ▪ Development of performance-based maintenance plans (short, mid and long term maintenance activities) refer to the 'as-operated' BIM; these can lead to (re)confirmation of warranty ▪ Building occupants will be able to update the actual building performance during operational phase through their mobile devices. Based on updated information of building operation fed by the energy monitoring systems, FM or BAS, or end-user input through INSITER self-inspection software, actual building performance is displayed, for example as an ECO indicator. Self-instruction for the building occupants accessible / operable on mobile devices.	operation manuals of the building–interactively accessible through the occupants' mobile devices

2. ICT solutions facilitating the Guideline Mobile App

2.1 Main features of iPad app

In order to simplify the activity of the construction worker and site supervisor, INSITER developed a mobile application. The framework of the mobile application has been defined in the WP1 in parallel with the elaboration of the INSITER guidelines and has been developed in WP3.

In agreement of the guideline principles, the INSITER mobile app provides practical and intuitive guidance for applying INSITER methods and tools on the construction site. All information available inside the mobile application are collected and elaborated in the WP1 using the data-sheets guidelines and will be stored in a private server (Share-Point).

The main characteristics of the INSITER App are as follows:

- Available for different users with Login Profiles dedicated to 2 main user groups: Construction Workers and Site Supervisors.
- Display guidelines for projects, general purpose and new/existing, component and step specific guidelines.
- Utilize associated tools related functionality, such as the BIM Viewer, QR Code scanner, QR Code generator, Question list, Observations and the functionality provided through the link to the RDF web tool, conform the INSITER 8 steps methodology.
- View project information and view project specific guidelines.
- Download and view documents that the guideline document is linking to.
- Progress registration and monitoring.

2.2 IT architecture

The development of the Guideline Mobile App was conducted in the framework of DEMO Consultants' primary software product: the Real Estate (RE) Suite.

In order to explain how the Guideline Mobile App is positioned within this IT architecture this chapter will discuss the following:

- The RE Suite Architecture; which components are located within this system, and what are their respective roles?
- The application of the RE Suite in the INSITER project; how is this architecture used and augmented in the context of INSITER?
- A description of the software components related to the Guideline Mobile App and the positioning of the app itself within this IT architecture.

2.2.1 RE Suite Architecture

The IT architecture of the RE is conceptually visualized in Figure 9. This paragraph will guide you, the reader, through the different components in this system with a brief description of their general role and functionality.

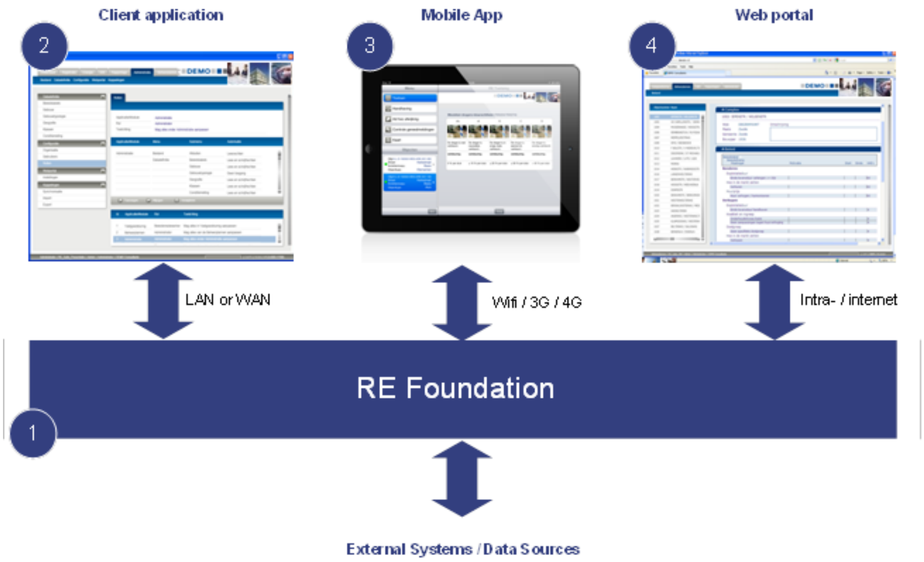


Figure 11: The RE Suite IT architecture

RE Foundation

The RE Foundation functions as the bedrock, the foundation, of all RE Suite applications. The key characteristic of this foundation layer is that it is platform-independent and can be used by all applications within the RE Suite system. The main functionalities of the RE Foundation are:

- Access and storage of data in the central RE Suite database;
- Providing and managing connections to external systems and data sources;
- Creating the possibility to use data described above on multiple platforms simultaneously;
- Providing generic functionality, for example user authentication, to applications built on top of it.

Client application

Built upon the RE Foundation, the RE Suite client application provides the end-user with software tools to attain, structure, analyze and disseminate information in the realm of real estate. This application is developed for the Microsoft Windows platform and is therefore a desktop application. As such, it meant for off-site usage.

Mobile App

Many processes in the real estate sector cannot be effectively managed only through off-site software tools. Therefore, mobile applications designed for on-site usage are also part of the RE Suite IT architecture. Examples of functionality offered in such apps are maintenance inspections or the inventorying of fire risks and safety of real estate objects. As the mobile applications are based on the same RE Foundation as the client application, there is extensive integration between both elements within the RE Suite IT Architecture.

Web portal

In the context of the trend of software products moving more and more towards being web-enabled or web-based, the RE Suite is also accessible through a web portal. This web portal can both provide access to a fully functional RE Suite client application as well as to dedicated web-based applications.

2.2.2 Application of the RE Suite IT Architecture in INSITER project

Within INSITER, the RE Suite IT Architecture is built upon to create to a coherent and integrated framework for the end-user to control the construction process.

It is important to note that while this framework is an integral part of the INSITER toolset, it is related to and supported by other tools. To attain an overview of the entire INSITER toolset and how all applications in this toolset relate to each other, we kindly redirect you to D3.2.

Figure 12 depicts how the RE Suite IT Architecture has been built upon within INSITER. The numbered elements within this diagram will subsequently be discussed.

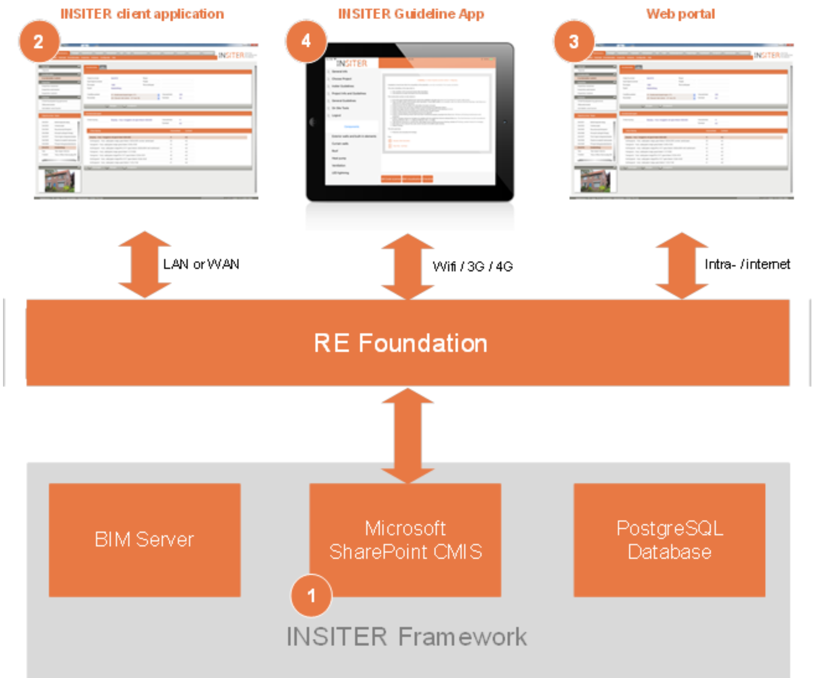


Figure 12: The application of the RE Suite IT Architecture in *INSITER*

Component 1: Microsoft SharePoint CMIS

Within INSITER a collection of data sources is combined in the INSITER Framework, a data store which is shared and used by many software applications within the INSITER toolset. One of the three elements in this framework is a Microsoft SharePoint (2013) environment.

The traditional usage of a SharePoint collaboration site is to use it as a general document or file exchange platform. One of the key advantages is that a SharePoint environment is both machine and human readable, which enables both software tools and end-users to access all data stored on the platform. Within INSITER, this functionality is used to store demonstration case content such as drawings and manuals.

Another advantage of SharePoint environment is that they feature sophisticated functionality for the definition, storage and dissemination of data (semantics). This functionality is used to capture INSITER Guidelines, which consists of the following steps:

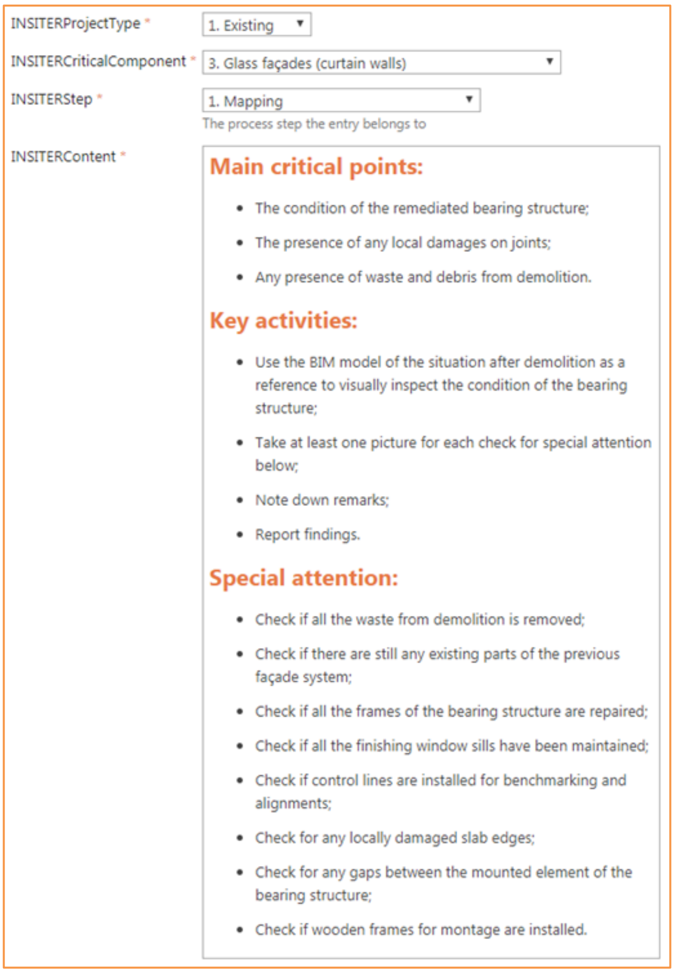
Data definition

A tabular data structure was defined which includes:

- Characterization of the guideline through project type, INSITER critical component and INSITER step
- Guideline content, including text or media
- Associated guideline content. This content has been categorized as follows:
  1. Audio
  2. BIM-models
  3. Documents
  4. Drawings
  5. Images
  6. Video’s

Data Entry

Guidelines can be easily added and managed through the standard SharePoint list management interface as defined in the datasheet of D1.2 and D1.3.



INSITERProjectType * 1. Existing

INSITERCriticalComponent * 3. Glass façades (curtain walls)

INSITERStep * 1. Mapping

The process step the entry belongs to

INSITERContent *

Main critical points:

- The condition of the remediated bearing structure;
- The presence of any local damages on joints;
- Any presence of waste and debris from demolition.

Key activities:

- Use the BIM model of the situation after demolition as a reference to visually inspect the condition of the bearing structure;
- Take at least one picture for each check for special attention below;
- Note down remarks;
- Report findings.

Special attention:

- Check if all the waste from demolition is removed;
- Check if there are still any existing parts of the previous façade system;
- Check if all the frames of the bearing structure are repaired;
- Check if all the finishing window sills have been maintained;
- Check if control lines are installed for benchmarking and alignments;
- Check for any locally damaged slab edges;
- Check for any gaps between the mounted element of the bearing structure;
- Check if wooden frames for montage are installed.

Figure 13: Guideline data entry in SharePoint

Data visualization

The final step in capturing the INSITER Guidelines is the visualization of the guideline data. This is achieved through a custom SharePoint web part which transforms the raw (tabular) data and outputs this in a structured and user-friendly manner.

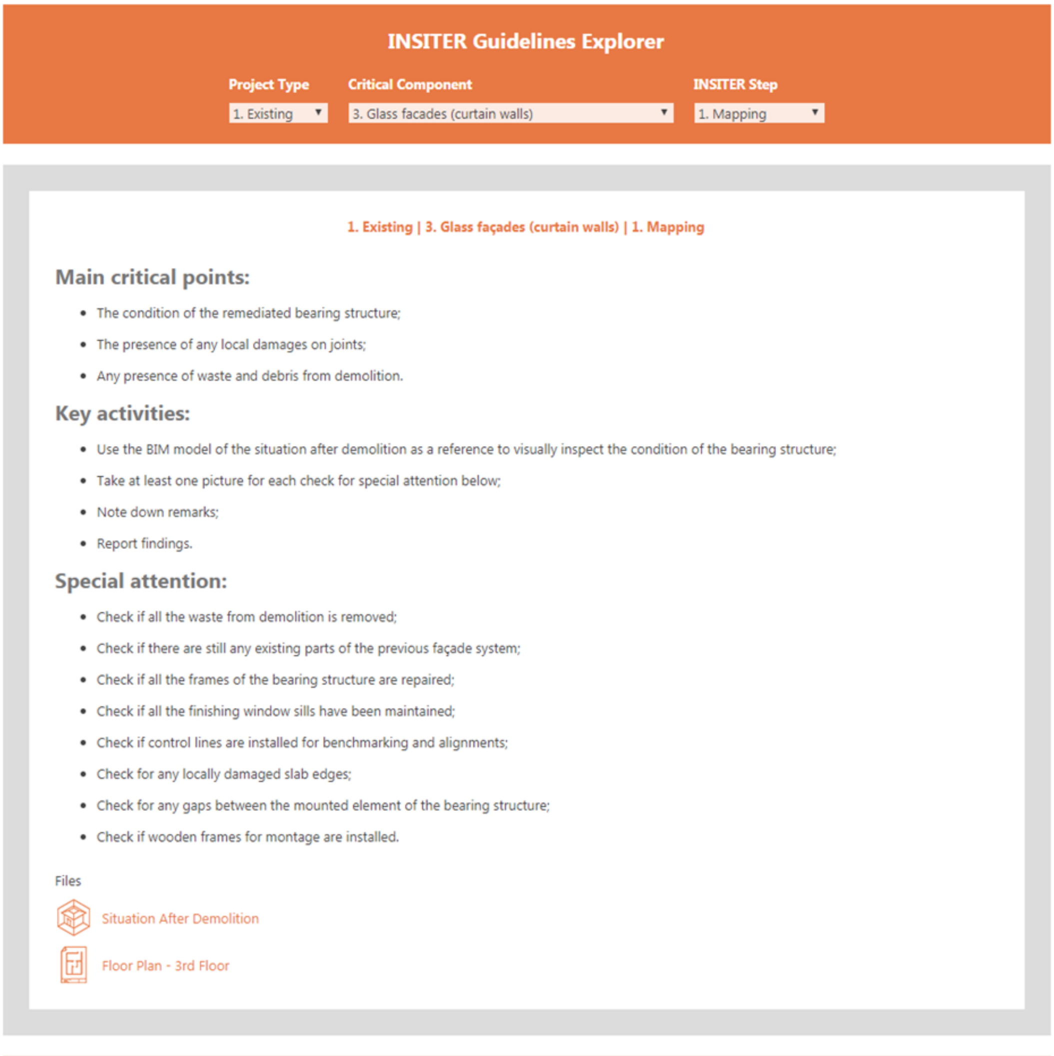


Figure 14: Guideline visualization through a web browser

The 3-step process as described yields the following:

- INSITER guidelines are stored centrally, and can be efficiently managed;
- The visualization of the guidelines is a direct and automatic result of the data; the end-user is always presented with up-to-date guidelines;
- The guidelines can be viewed through multiple channels; they can both be accessed through a web browser as well as programmatically by software tools.

The contents of the Microsoft SharePoint CMIS are made accessible to the applications within the RE Suite IT Architecture through the RE Foundation.

Component 2: INSITER client application

In INSITER an RE Suite client application has been developed with the primary goal of managing the construction process. This application is envisioned to be used off-site by a construction supervisor, and is highly integrated with the INSITER Guideline App. Conceptually, the client application should be seen as the software tool which is used to prepare the on-site usage of the INSITER Guideline App. Then, after the content has been prepared on-site activities can be performed. The results of these activities can once again be viewed in the client both during and after the activities have been performed. The client application contains the following functionalities:

- The definition and management of construction projects, including BIM and document management;
- The inventorying and inspection of an existing building in the case of a refurbishment project;
- Managing questionnaires to be conducted on-site;
- Viewing and summarizing the results of on-site inspections;
- The visualization of the state of the construction process through KPI's and dashboards.

Component 3: Web Portal

The INSITER client application is hosted on DEMO Consultants' servers, and can be accessed remotely through a web browser. This means that, while the client application is envisioned to be used off-site, it can be accessed from any physical location. This ensures that the construction supervisor can attain the insight he/she requires both at the office but also at the construction site.

Since the INSITER Guideline App is installed on a mobile tablet device and the Microsoft SharePoint CMIS is accessible through a web browser, these parts of the INSITER toolset can be used without any constraints with regards to the user's physical location and with minimal hardware requirements.

Component 4: INSITER Guideline App

The main features of this mobile app have been described in section 4 as well as practical use for the construction worker.

3. Key-actors involved in the Guideline implementation and application

3.1 The wider picture of INSITER: ICT and process integration of the Guidelines

The INSITER guidelines and complementary digital tools introduced in the previous chapter have been developed for construction workers and site supervisor in order “to reduce” and “to detect” the construction errors during the construction site. However, it shall be underlined that several other key-actors are involved in the implementation and elaboration of the INSITER methodology and guidelines.

The scope of this chapter is to propose an overview of the key-actors describing their role, their interaction and level of importance inside the INSITER methodology (8 step). Please note, not all actors are involved in all step of the INSITER methodology except the construction / site workers and site supervisor.

Three main levels of the key-actors are involved in the guideline implementation / application:

- Level 1 (at design stage)

  Who will prepare the project information that will be stored on the INSITER SharePoint and that will be show on-construction site using the mobile application:

  - Project manager;
  - Designer (Architects, structural engineers, MEP/HVAC engineers);
  - Surveyor and inspection expert;
  - Supplier.

- Level 2 (at design stage)

  Who and how will link and manage all technical project information inside the INSITER ICT tools:

  - BIM manager / BIM modeller.

- Level 3 (at construction stage)

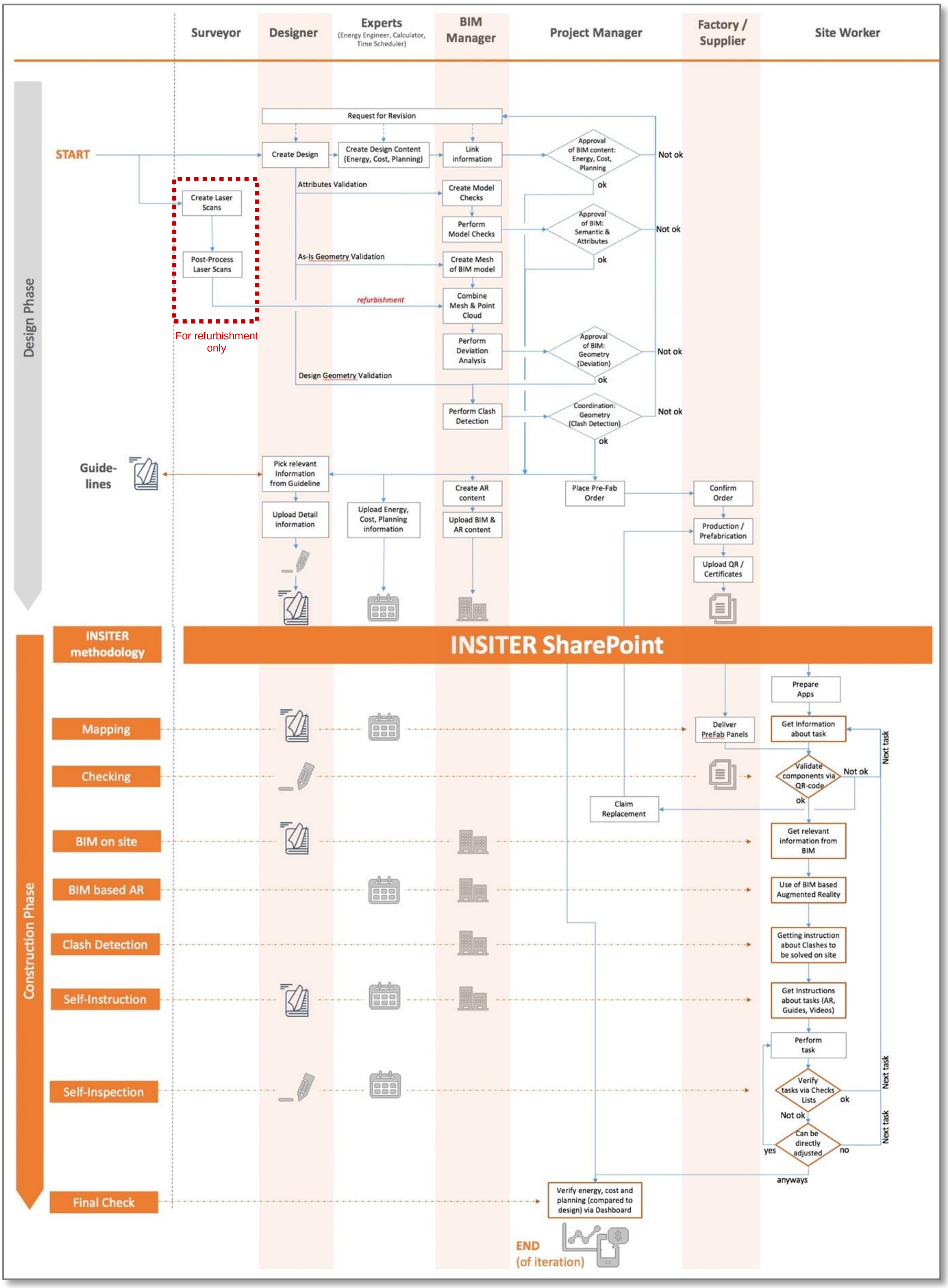
  Who, when and how will use the guidelines (base on mobile application):

  - Construction and site workers;
  - Site supervisor;
  - Inspection expert and surveyor.

An indirect role is assigned to the building owner and/or occupant because are not directly involved in the application or implementation of the INSITER guidelines but they are the categories which launch all process.

The following scheme presents the INSITER General Process Chart developed in synergies between WP1 and WP3. The scheme introduces a general picture of the role of the main actors involved and a process decision making starting at design stage (implementation and preparation data) till to the construction stage where is applied the INSITER methodology.

In order to get a better understanding of the main actors involved a more detail description will follow in 3.2.


Surveyor
Designer
Experts
(Energy Engineer, Calculator, Time Scheduler)
BIM Manager
Project Manager
Factory / Supplier
Site Worker
Design Phase
START
Request for Revision
Create Design
Create Design Content (Energy, Cost, Planning)
Link information
Approval of BIM content: Energy, Cost, Planning
Not ok
ok
Attributes Validation
Create Laser Scans
Create Model Checks
Perform Model Checks
Approval of BIM: Semantic & Attributes
Post-Process Laser Scans
As-Is Geometry Validation
Create Mesh of BIM model
refurbishment
Combine Mesh & Point Cloud
For refurbishment only
Perform Deviation Analysis
Approval of BIM: Geometry (Deviation)
Design Geometry Validation
Perform Clash Detection
Coordination: Geometry (Clash Detection)
Guide-lines
Pick relevant Information from Guideline
Create AR content
Place Pre-Fab Order
Confirm Order
Upload Detail information
Upload Energy, Cost, Planning information
Upload BIM & AR content
Production / Prefabrication
Upload QR / Certificates
INSITER methodology
INSITER SharePoint
Construction Phase
Prepare Apps
Mapping
Deliver PreFab Panels
Get Information about task
Checking
Validate components via QR-code
Claim Replacement
Next task
BIM on site
Get relevant information from BIM
BIM based AR
Use of BIM based Augmented Reality
Clash Detection
Getting instruction about Clashes to be solved on site
Self-Instruction
Get Instructions about tasks (AR, Guides, Videos)
Perform task
Self-Inspection
Verify tasks via Checks Lists
Can be directly adjusted
yes
no
anyways
Final Check
Verify energy, cost and planning (compared to design) via Dashboard
END
(of iteration)

3.2 Key-actors, roles and responsibilities

3.2.1 Construction worker / Site worker (Level 3 - At construction stage)

Construction workers are the main user of the INSITER guidelines.

They use the digital application at construction stage as new communication interface (between different actors); in order to receive detail instructions on a specific work task; to interact with the Site supervisor and the Project Manager; to provide final reports etc..

In general, construction workers will benefit from INSITER by different enhancement:

- acquiring greater autonomy;
- providing an interaction overlay by AR tools;
- speeding up training and experience;
- improving communications among the workforce on site;
- reducing errors/failures/inconsistencies with the design requirements and providing immediate feedback;
- speeding the workflow;
- getting a better quality in the installation of different building and MEP components, and providing a quality assured completed building.

The construction workers are the only categories (with supervisors) involved in all the steps of the INSITER methodologies. For this reason, the following text will present a practical example of the use of the INSITER guidelines application for the construction workers step-by-step applicable in new construction and refurbishment.

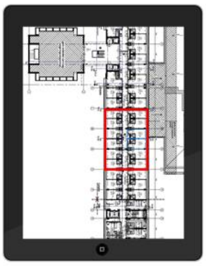
STEP 0 - Log-in & work schedule

The construction worker logs-in to the mobile application and receives a schedule and an overview of the activities that he has to do during the day. If he has to do a task that he has never perform before and he wants to get introduction in advance on a format of a video or other supporting document, he can find available material through links. Following the scope of the guidelines, he focuses on critical EeB components. He selects the critical EeB component that he has to work with according to his daily tasks and he starts the “guiding tour” through the INSITER 8-Steps based application.

STEP 1 – Mapping

The construction worker in this step needs to capture the conditions and to compare them with the as-is situation. He begins his work by defining/mapping the location/room/space within the building where he needs to work for the installation/refurbishment of the critical EeB component. He goes to the location and he makes a preliminary evaluation of the actual conditions on site. He can retrieve reference material for main energy-efficient and quality construction errors to be checked.

Note: In case he detects criticalities, in the scenario of refurbishment, and it is needed to take measurements with special equipment, he notifies the construction manager and specialized personnel arrives and performs the required measurements.



STEP 2 – Checking of ordered components

The critical EeB components to be installed are delivered on the building site.
Using QR or RFID scanning tool, the construction worker checks whether these are the correct components as specified in the BIM model and the technical documents. In this step, he can check the correctness of the delivered components on site before assemble them, or/and retrieve the components ID and visualize the positioning of it.

STEP 3 – BIM for on-site construction

This step includes visualization of the building or the critical EeB components in BIM.
Using the mobile device, the construction worker opens the BIM model of the specific part of the building where he has to perform his work with the critical EeB component. In this BIM model, he can observe how the critical EeB components are modelled and integrated within the building and use it as a reference for his actual work on site.

STEP 4 – BIM-based Augmented Reality and STEP 5 – Clash detection during construction

Using the mobile device (smartphone, tablet or HoloLens) equipped with an AR application, the construction worker projects the BIM model of the new HVAC components to be installed onto the real spatial environment.
This step can work complementary with Step 5 where the worker on site can project the designed situation (correct situation) of the critical EeB components on real situation within the building, while focusing on the criticalities (clashes). He facilitates AR to check if the critical EeB component to be assembled really fit within the intended building part/space/room, i.e. no "clashes" with building components.

STEP 6 – Self-instruction

The construction worker opens the manual documents/videos/animations where the mounting of the critical EeB components is described in a step-by-step process with easy guidance and hints/warnings of common errors to be avoided. As an INSITER tool for this step has been developed the mobile application of D4.4, where the mounting process-critical assembly activities can be simulated and supporting reference material can be given.

STEP 7 – Self-inspection

During this step, the worker on-site will check his own work with the help of checklists. Subsequently, if needed, he notifies a specialist to measure the exact performance using specialised equipment (ref. to WP2). The measurement image (thermal, acoustic) can be either superimposed to BIM or AR for visual evaluation, or kept for integration into the BIM model later on of-site for the definition of the as-is situation and the equivalent calculation of the actual performance of the building according to how components were assembled in reality.

Note: In case it is needed, the measurements with special equipment will be performed by a specialist, after the construction worker notifying him. The evaluation of the result will be done off-site as time is required for the retrieval of the measurement results.

STEP 8 – Final check

After collecting data from all the previous steps, the final step consists of the final evaluation of the work to be delivered. The construction worker completes his assignment by reporting on the finished work, including some photos taken on-site. He should also note errors or doubts, if any, into his digital report through the mobile application. The site supervisor opens this report, and gives approval or asks for rework. The approved works appear on a common dashboard (off-site) showing the level of quality and performance during the on-site process. Quality, time and cost evaluation can be monitored like that by the construction managers.

3.2.2 **Site supervisor** (Level 3 - At construction stage)

The role of the supervisor can vary depending on the size and type of the construction site and the works that shall be performed. As the point of reference of both workers and project manager, the site supervisor will be a key person for the completion of a project.

The site supervisor has a solid background in the field with leadership skills and extensive experience in order to direct the work of others. The site supervisor shall be well-organized and favour safety on construction sites.

The main tasks of the supervisor are:

- to coordinate the workers and organize them in teams according to the indications of the project manager;
- to allocate general and daily responsibilities in accordance with project manager indications;
- to coordinate tasks according to priorities and plans, supervising and training workers and tradespeople
- to verify the compliance to the time schedule, producing schedules and monitor attendance of crew;
- to deal with the logistics and to ensure that the building site is organized and well structured, in order to guarantee that all safety precautions and quality standards are met;
- to support the work of the project manager, by different activities.

Considering the scope of INSITER the role of supervisor is twofold:

1. Responding to real time inquiries of the workers that are sent through the communication module on the mobile app (i.e. when the worker asks for confirmation or decision about OK / Not OK / Further check).
2. Taking decisions regarding actions (accept, repair, replace) after all feedback from different workers is received at Step 8. In order to support the project manager activity, the site supervisor also considers implication of the decisions in terms of cost (rework/failure cost) and time (delay).

In reference to the INSITER methodology the site supervisor is involved in the following steps with specific tasks.

STEP 1 – Mapping

The site supervisor can use INSITER App providing the task assignments, performing the daily/weekly control that the workflow proceeds smoothly, generating a site construction overview with the mobile device, and reporting the status to the project manager.

By using the App, the site supervisor can check the works done by construction workers and verify if any inconsistency occurs.

The site supervisor will also support the construction workers in case of incongruence of the working area (e.g. construction site is not ready, safe/secured for the construction/refurbishment activities; absence of equipment; etc.). In that case a formal decision will be taken regarding the necessary actions to do. If necessary involving also the project manager.

STEP 2 – Checking of ordered components

The site supervisor can use the INSITER App in order to verify that all prefab components are delivery in the expected day on construction site.

He/she validate delivery schedules and logistic planning for example the correct stocking on-site of delivery components. The quality check of the components before the construction activity is demanded to the construction workers. Despite this the site supervisor will support the construction workers in case of discrepancy of the components (e.g. geometric dimension; U value; colour; etc.) and he/she will take a formal decision regarding the necessary actions to do involving, if necessary, also the project manager.

STEP 3 – BIM for on-site construction

The site supervisor will use the BIM uploaded on the INSITER App in order to monitor all different tasks, assigned by the project manager, and to check its properly developed in comparison to the Gantt. He/she can help the project manager to collect the reports using the BIM as status of the work (As-design *vs* As-built). In particular, the site supervisor can:

- Ensure manpower and resources are adequate;
- Supervise the use of equipment;
- Monitor expenditure and ensure it remains within budget;
- Provide support to the project manager in order to resolve problems when they arise;
- Report on progress to project managers.

Step 4_BIM-based Augmented Reality

The site supervisor will support the project manager in order to check that all construction activities scheduled are correctly integrated as self-instruction for the construction workers.

STEP 5 – Clash detection during construction

The site supervisor will be involved by the construction workers if the visual validation on-site, based on the BIM clash detection performed prior to construction / refurbishment activities, will found clashes. In case of clashes the site supervisor will stop the construction site activity, he/she will inform the project manager in order to involve the design team to review the clash details.

STEP 6 – Self-instruction

The site supervisor executes the indications of the project manager and checks that they are performed correctly on site by different teams. In particular, activities for "Step-Self instruction" for each building and MEP component to be installed. Supported by the App on mobile device, he/she is responsible to:

- Allocate general and daily responsibilities
- Coordinate construction workers according to priorities and plans
- Produce schedules and monitor attendance of crew
- Supervise the use of equipment
- Collect reports and any non-conformities.

The site supervisor will be involved by the construction workers in case that the self-instruction during preparation and executive of construction activities are not correct implemented on mobile device. To solve the problem, the site supervisor will inform the BIM manager in order to update the information on the BIM and mobile devices.

STEP 7 – Self-inspection

The site supervisor will support the construction workers in the self-inspection activities. The site supervisor is involved by the construction workers in case of different performance in comparison to the expected; in that case the site supervisor will accept or reject the work. In case of need of detail inspections (e.g. thermal and acoustic leakages, U value, etc), the site supervisor will involve inspection expert and specialist.

STEP 8 – Final check

The site supervisor performs regularly comprehensive evaluation involving construction workers, contractors and sub-contractors. He/she has an important role for participatory decision-making to check the building quality and performance.

The main duty of the site supervisor is to support the project manager in order to organize to the validation of the building quality and performance in accordance with design requirements till to the building commissioning.

3.2.3 **Surveyor / Inspection expert** (Level 3 - At construction stage and Level 1 – At design stage)

INSITER methodology is supported by different inspection tools to be used by "Inspection Expert". During an inspection, several operations will be monitored by conducting visual and measurement tests and required adjustments will be discussed with the owner and project manager. Key-roles and responsibilities of an inspection specialist with the scope of INSITER are as follows:

- Monitoring the condition of the building using infrared cameras;
- Surveying the building using 3D laser scanners;
- Detecting insulation losses via Sound Brush.

The inspection expert plays a complementary role in the decision-making process in consideration to the fact that they map the building quality and performance using advance technologies and instruments (e.g. 3D laser scanner, thermal and acoustic scanner).

In case of refurbishment of existing building, the inspection specialist could be involved by the project manager before the design phase. The inspection expert will map the actual technical conditions of the building that will be refurbished. The assessment activities performed by the inspection specialist are defined by the project manager based on a preliminary visual inspection of the site and building carried out with the owner and other technical advisors (architect, engineer, etc.). In order to simplify the work activities, the App will guide the inspection specialist proposing detail technical indication concerning the expected activities. After to log-in on the App the “inspection specialist” will receive indication concerns:

- geographic location (coordinate) of the site, building, rooms or dwelling to be survey;
- building – MEP-HVAC components that to be check;
- expected inspection procedure and results (guide-lines to set-up and use the instrument).

In agreement of the devices/tools used during the mapping different measurement aspects will be analysed (e.g. U value, acoustic performance, point of cloud, humidity, etc.). At the end of each inspection activities the “inspector” will fill in a specific digital form included inside the App. This action is really important in order to create a memory (date: hour, day, month, year) of each activity completed; including environmental condition (temperature, humidity, etc.) that could influence the result of the work completed. For this reason, the App will also allow to store short notes, information and pictures. This information will be directly stored also on the Share-Point and available for other actors in order to prepare the design stage

Considering the 8-step INSITER methodology the inspection expert is involved in two steps.

STEP 7 – Self-inspection and STEP 8 – Final check

The inspection expert is involved during the construction process and final check by the site supervisor when detailed inspections of the realized activities are needed.

Following the indication of the site supervisor the inspection expert will measure the technical quality of the work (e.g. sound insulation, air leakages, thermal bridge, etc.) by means of the procedure developed in INSITER.

The inspection specialist will compare the built performance with the expected design performance and he/she will produce a technical inspection report for the site supervisor using the INSITER App. The inspection report will support the decision making of the site supervisor and project manager.

3.2.4 **Project Manager** (Level 1 - At design stage)

The project manager is the first actor appointed by the Client / Building owner to ensure that all relevant design requirements are met during the construction process on site. The main tasks of the project manager are: to coordinate the team, to dialogue with the site supervisor in order to control the activities, to collect the information and to verify the compliance with the time and project schedule.

The role of the project manager is strategic since it involves planning and organizing time and resources throughout the entire process, in order to successfully achieve the project goals.

At design phase the project manager coordinates a team composed by designer; experts and BIM manager or modeller approving each task of the design stage including the final development of the BIM.

Typically, the project manager plays a “connecting role” between the construction team to the design team (off site), that is composed of architects and engineers. The key-roles and responsibilities are as follows:

- Activity and human resource planning;
- Selection and organization of a team at each construction stage;
- Monitoring the progress, cost and performance;
- Analysing and managing project risks.

Depending on the complexity of the project, it is possible that the project manager is supported by a team of deputies who supervise the activities for specific construction steps (site supervisor).

The project manager is lead of the final decision making to accept or not accept the work done by the construction workers comparing the As-Built with the As-Design.

With reference to the 8-step INSITER methodology, the “Project Manager” is involved in all step with the following tasks.

STEP 1 – Mapping

The Project Manager will propose, coordinate and establish preliminary site inspection in particularly in case of refurbishment project.

He/she establishes the time schedule and the people who will have to carry out the inspections and the mapping. Collects information. Decides whether to ask the intervention of experts to make specific measurements and tests. In order to simplify the project manager inspection, the App will guide the inspection specialist proposing detailed technical indication concerning the expected inspection activities. The App will also allow storing short notes, information and pictures. This information will be directly stored also on the Share-Point.

The scope of this work in the refurbishment interventions is to map the actual technical condition of the site or the building in order to define main designer figures (architects, engineer, etc.) and to give them detail information of the expected work.

Before to start the construction site activity (after design phase), the project manager is appointing a site supervisor in order to receive any relevant information regarding incongruity between the technical conditions of the site in comparison to as-design situation.

The project manager will consult also the main contractors and construction workers in order to optimised, only if necessary, construction time and costs. In relation to the project and expected work, the App will propose a check-list of condition that is important to check on-site:

- Construction site condition in terms of accessibility, safety / security and logistic;
- Construction site equipment;
- Construction workers preparation and their skills.

STEP 2 – Checking of ordered components

The project manager is involved by the site supervisor in case of important incongruity regarding the delivery prefab components. In that case, the project manager is the final actor that will take the decision of the necessary actions to follow like: accept the components arrived on construction site or reject and to informs the factory suppliers to manufacture and delivery new prefab components.

STEP 3 – BIM for on-site construction

Please note: the scope of this step for the project manager is the same of the site supervisor. The difference between these important actors is related to their management role. In fact, the site supervisor will involve the project manager in the following tasks only in case of needs.

The project manager as site supervisor will use the BIM uploaded on the INSITER App in order to monitor all different tasks, assigned by the project manager, and to check its properly developed in comparison to the Gantt. He/she analyses the reports produced by the site supervisor using the BIM as status of the work (As-design *vs* As-built).

STEP 4_BIM-based Augmented Reality

The project manager supported by the site supervisor checks that all construction activities scheduled at design phase are correctly integrated as self-instruction for the construction workers.

STEP 5 – Clash detection during construction

The project manager supervises each activity of this step accomplished by other actors. Using the App, the project manager receives a detail check-list of the main virtual technical checks; this check-list will be personalized for each refurbishment or new construction interventions. Usually, the project manager will review the clash detection activity and define the severity level of the clash (in relation to the expected performance of the design). Each detected clash is annotated on the digital wordbook included on the App. The project manager is also responsible of the decision-making process (accept or not accept); the final goal of the project manager for this step is to validate the virtual model for the on-site implementation.

STEP 6 – Self-instruction

The role of the project manager, supported by the appointed site supervisor, consists of the management/coordination activities for "Step-Self instruction" for each building and MEP component to be installed.

As previous introduced the project manager is involved by the site supervisor only in case of real needs in order to take relevant decision concerning:

- Coordination of construction workers according to priorities and plans
- Produce schedules and monitor attendance of crew
- Supervise the use of equipment
- Allocate general and daily responsibilities.

The project manager is involved by the site supervisor in case that the self-instruction during preparation and executive of construction activities are not correct implemented on mobile device. To solve the problem, the project manager will inform the BIM manager in order to update the information on the BIM and mobile devices.

STEP 7 – Self-inspection

The role of the project manager is dedicated to the management/coordination/monitoring activities. Supported by the App on mobile device, the project manager will propose a periodic assessment of the construction site on-going activities comparing them with the time schedule. During this inspection task, the project manager could involve also the construction workers, contractors and sub-contractors for a participatory decision-making. Each notification and decision will be directly included in the App and in real time shared with the other actors involved in the building process as: designer BIM manager and modellers. After App long-in procedure, in agreement with the Gantt time schedule and inspection/monitoring date, the project manager will receive specific information concerning the expected monitoring activities. For this reason, for each project a specific monitoring activity shall be defined. In case of delay in the construction works, the project manager will notify the Contractor on the App and, at the same time, will update the expected time schedule.

STEP 8 – Final check

The role of the project manager is dedicated to the validation of the building quality and performance in accordance with design requirements. Supported by the App, for each final stage of the building process, the project manager will monitor and check the building performance (energy efficiency and indoor environmental quality) supported by the work of inspection specialist. In fact, during this step the project managers could involve inspection specialist to map specific measurements aspects or to check geometric measurement parameters. Following the design information included on the Share-Point and accessible by the App, the project manager will check all energy efficiency KPIs. The final participatory decision-making process will be coordinated by the project manager and will involve the following actors: owner/building occupants; contractors/sub-contractors; BIM manager/modeller. Each not expected deviation between the as-realized with as-design will be annotated on the App; in agreement of the severity level of discrepancy the project manager will accept or will reject the work.

3.2.5 **Designer: Architects, structural engineers, MEP/HVAC engineers** (Level 1 - At design stage)

Usually the design team play a key-player in the design and construction process. However, in the context of INSITER, the design team has an indirect role, as, thanks to the mediation action of the project manager, the designers provide information and data into the system. The designer does not use directly the guidelines and the SharePoint but they provide the technical contents.

In particular, after receiving project manager's instruction, the designer:

- elaborates the final technical design of the building (new or refurbished);
- Prepares the technical contents that will be transfer into the BIM (technical details, drawings, 3D models, data sheets, cost estimates, description of works and actions to be taken on site).

During the implementation and validation of the BIM, the designer can be involved by the project manager in case of necessary revision of the project proposed.

3.2.6 **Supplier / Factory inspector**

Following the indication received by the project manager the supplier:

- Confirms the received order
- Start the manufacture procedure of the ordered components

- Prepares QR code for each delivery components and prepares EU certifications of the component's performance
- Deliver the ordered components on construction site.

The suppliers will produce the ordered prefab component and is supported by a factory inspector which is a professional actor that examines prefab components / elements defined by the design team for a specific project, in order to ensure quality and compliance with design (in terms of expected performance and characteristics), as well as per applicable standards and regulations.

Factory inspectors can have different and complementary areas of expertise, depending on the building and MEP component. The main task of any factory inspector is to help to improve the safety of a factory and its products for both workers and final consumers. Complementary scope of the factory inspector goal is to assurance that the building components delivery on construction site in agreement to design requirement.

The activity of the suppliers and factory inspector can be supported by the INSITER app where is possible to found any information of the project including the main technical characteristics of the components.

Accessing to the App (log-in with personnel user-password) the suppliers / factory inspector will analyse the ordered building components and will compare them with components manufactured.

In order to simplify the activity of the factory inspector the App will guide their activity proposing a detail check-list of technical information that will be check before the delivery of the ordered components on construction site.

Example of the main actions that could be performed are:

- Prefab panels dimension (length, thickness, width);
- U value of prefab panels and windows;
- Prefab panels surface finish, colour and breakage;
- Fire, wind and water resistance;
- Destructive testing;
- Characteristic and material of the windows frames;
- Pre-functional test off-site of the MEP-HVAC;
- Etc.

For each building and MEP-HVAC components will be defined a specific inspection checklist that will be uploaded on the App. In agreement to the design specification of the ordered components the factory inspectors could be accept or reject the manufacture components.

The App will also allow storing short notes, information and pictures annotated by the factory inspector. This information will be directly stored also on the Share-Point and share with the project manager and design team.

Each delivered component will be provided of QR / IFD bar code that will contain any technical description and certification of the components.

The suppliers can be invited by the project manager to replace the prefab components arrived on construction site in case of relevant discrepancy in comparison the expected technical characteristics (included in the BIM) defined during the previous design phase.

3.2.7 BIM Manager / Modeller

The BIM modelling team, consisting of a BIM manager and one or more BIM modeller, is mainly involved in the preparation of Step 3, 4, 5, 6 of the INSITER methodology in order to model/update/revise the BIM model based on information collected on site.

The BIM manager proposed the following main tasks that will be accepted by the project manager:

- To collect all information of the project elaborated by the designer team and link them into BIM that will be validated (accept or not accept) by the project manager;
- To create the model check;
- To create mesh of the BIM model;
- To combine mesh & point of cloud (in case of refurbishment);
- To perform deviation analysis of the project;
- To perform clash detection.

Considering the 8-step of INSITER methodology the BIM manager and modeler proposed the following activities.

STEP 3 – BIM for on-site construction

Modelling of the building, site and surroundings in Building Information Model (BIM).

Based on specific building and project, the model can have different levels of details, but, in general, it can include:

- Building and MEP/HVAC components that are critical for building quality and energy performance.
- Available 2D and 3D drawings and documentations of the facility
- Relevant GIS data. BIM.

The BIM model, converted in open-standard BIM, will be viewed on mobile devices on construction site.

STEP 4 – BIM-based Augmented Reality

The main task of the BIM team is to generate and deploy BIM-based Augmented Reality (AR) for self-instruction and self-inspection. In particular, this task includes:

- Embed BIM and VR in Augmented Reality (AR)

Extract BIM / VR process information into 'self-instructions' (e.g. installation manuals and planning schedule) for construction workers on their mobile devices (e.g. iPad); and generating self-instruction modules.

STEP 5 – Clash detection during construction

In case of different site condition, the BIM team will support the project manager and the workers that have to validate ON SITE the quality and energy performance by BIM Model Checking and Clash Detection. These activities are performed by the workers prior to construction / refurbishment. The results are collected by the project manager and, if any inconsistency or clash occurs, he will transfer the information to the design team that will modify the project and provide a solution. Then, the BIM team will be responsible to incorporate the updated information in the BIM model and related AR instructions.

STEP 6 – Self-instruction

The BIM manager will propose assembly manual with support of BIM-based 3D visual instructions. The self-instruction will be used by construction workers in order to reduce the construction errors. The BIM manager will be contact by the project manager to solve clashes of the system in case of these self-instruction do not correctly function on mobile devices.

3.2.8 Building Owner / occupant

The building owner is often the only non-technical key-actor in the entire construction process. His role, however, can have multiple features, and can vary from providing finance to several critical decision makings. Fundamental considerations such as user preferences and needs, budget cost, energy efficiency goals and planning will be communicated to the other actors by the owner.

Building owners can interact directly with the INSITER process using the INSITER App: in this way, they can monitor the status of the construction process, the quality of materials and products installed on site, the compliance with the deadlines and the costs as per design input.

The following table describes the main actions of the building owner concerning the use of the App and/or the implementation of relevant information inside the Share-Point.

In case of refurbishment interventions, the building owner can explain to the project manager preliminary information concerning the status of the building. In that case, the INSITER app can be support this preliminary assessment phase proposing a specific check-list that will suggest all actions that could be perform by them (including available user-friendly devices / tools on the market to be use). The App will also allow storing short notes, information and pictures. This information will be directly stored also on the Share-Point. Example of the main actions that can be performed are:

- To periodically measure indoor room temperature and humidity
- To take pictures of the building/rooms characterized by technical problems or deteriorated components (especially regarding the main critical components of the building envelope and MEP-HVAC);
- To describe existing technical problems (thermal, acoustic, water and air leakages) that influence the indoor environmental quality and energy performance;
- To monitor the correct function of the heating and cooling systems;
- To monitor existing energy consumptions;
- To define the construction/refurbishment budget;
- To propose the construction time schedule in relation of their needs

Considering the 8-step of the INSITER methodology the building owner are directly involved in the step 8.

STEP 8 – Final check

In this step, several inspections will be performed to compare the actual performance of the building with the desired performance.

In detail the building owner will participate to the building final check in order to:

- Check whether all systems work properly according to the specifications;
- Check the performance of the building;
- Registration of deviations and necessary measures;
- Update BIM towards ‘as-built / as-refurbished model’.

Based on the outcomes and with the support of other actors, the Client / Building owner will participate in development of different performance-based maintenance plans. In order to simplify tasks, the App will guide the Client / Building owner proposing specific digital self-instruction accessible / operable on mobile devices. During this step the Client / Building owner will be informed also of the maintenance plan; this information will be included inside the App which will propose periodically self-inspection tasks (based on check-lists) to monitor of the main critical components. The App will remember (through calendar alert) to the owner this inspection actions. In case of relevant and emerging problems, the owners will contact other specialist actors (project managers, contractors, advisors, inspection specialist).

3.3 Communication, responsibilities and decision-making concerning measurements and KPIs

3.3.1 Communication and decision-making process

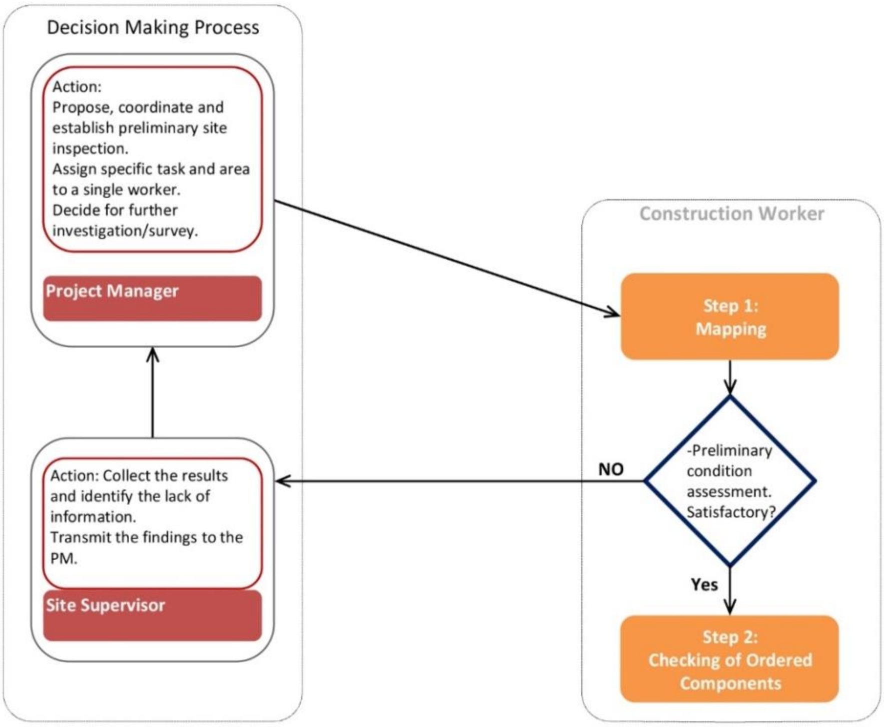
The INSITER methodology, throughout the use of the App and the SharePoint, aims at enhancing the communication flow among the main stakeholders on the construction site. Such improvement shall also support the decision-making process. The basic assumption is that the way decisions are made on construction site should be structured, ordered and controlled, in order to obtain that the decisions made at any particular step should *actually* reflect the activities that are being undertaken at that stage. They should not backtrack, as this will involve an increase in time and costs, and the repetition of tasks that have already been undertaken, and they should not leap ahead as this will prejudice activities that have not been undertaken and may produce to inappropriate outcomes.

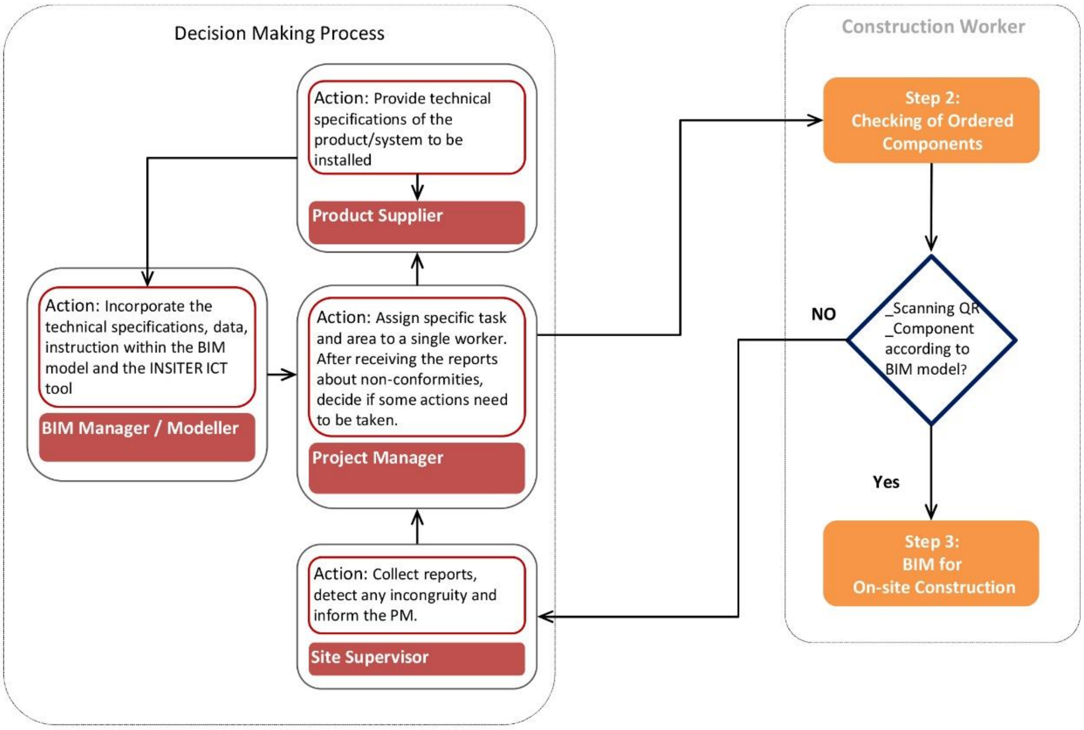
An effective way to avoid making the wrong decisions at the wrong time is by establishing a series of “gateways” at which the construction workers compile information describing the progress of the work as it stands, the site supervisor collects and revise the information to be transmitted to the project manager, that assesses that information and either asks for changes or approves it and gives instructions to progress to the next step.

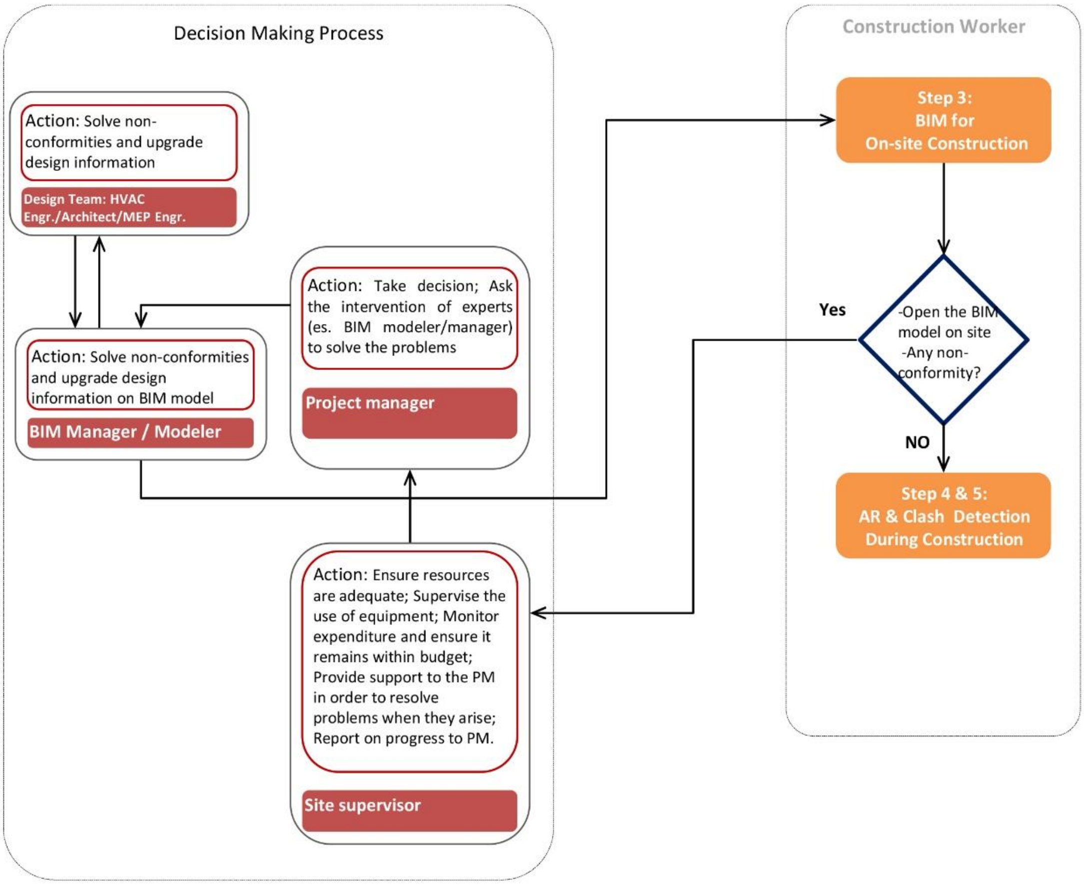
Some other key-actors can be involved, at certain stages of construction, in order to make available or upgrade design data (i.e. BIM manager/modeller, Design Team), or to provide further investigation and inspection results (i.e. Surveyor / Inspection Expert).

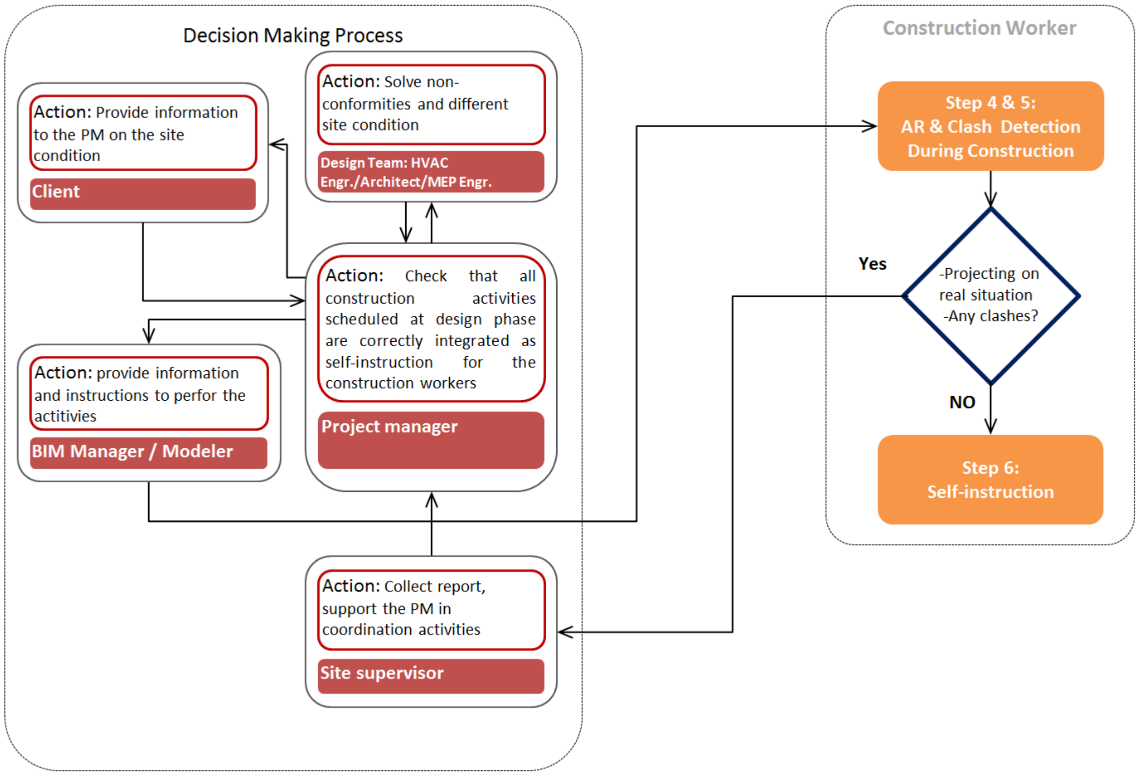
The following schemes have been developed, on a step-by-step basis, **to visualize the communication, interaction and decision-making process that occurs on site** and that is **made possible by the use of INSITER App**.

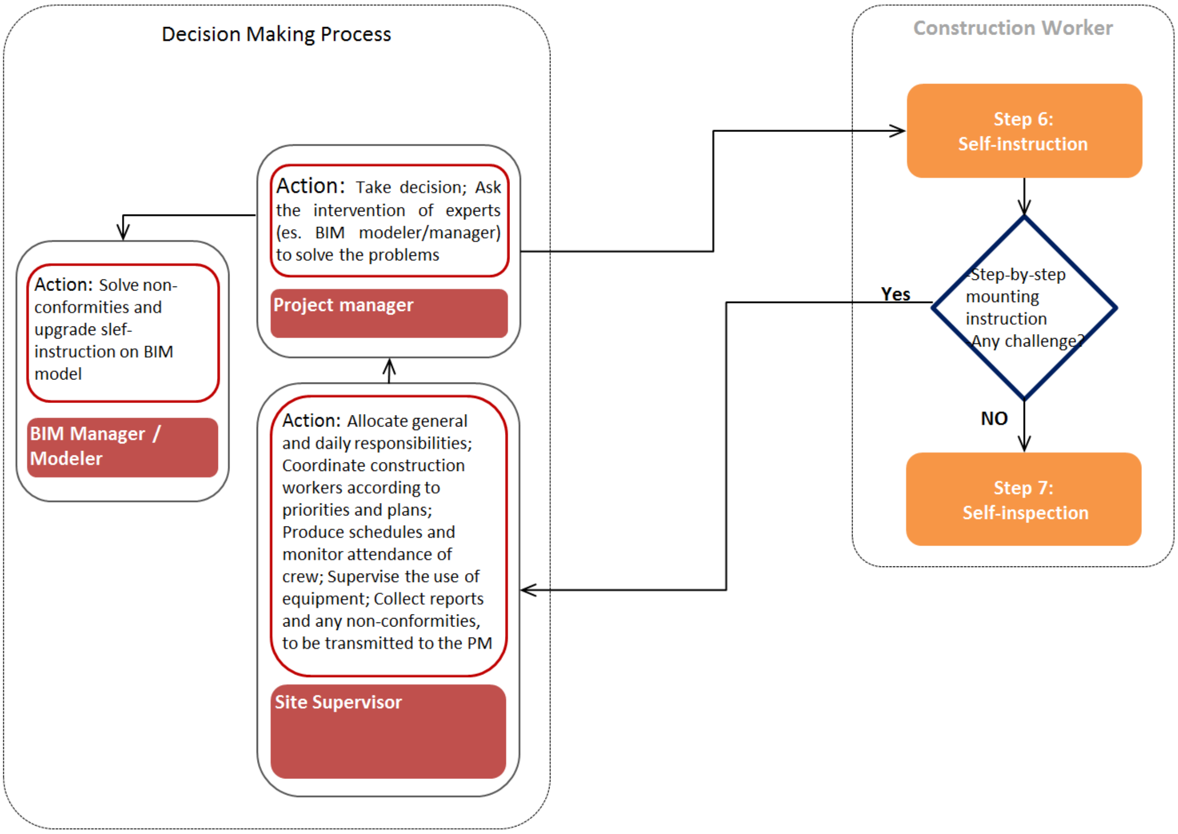
At each of these stages, certain aspects of the project may be frozen and change control procedures introduced for those aspects. The process is in fact iterative and the flow of information is digitally managed by the INSITER App.

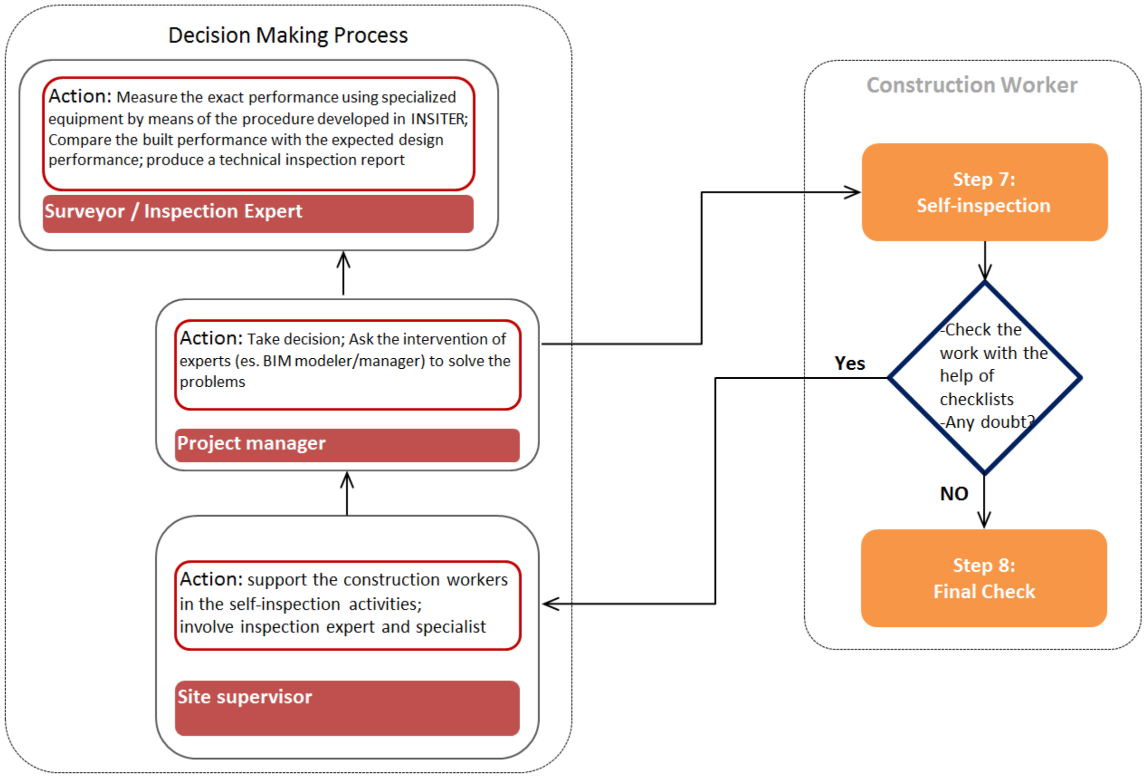


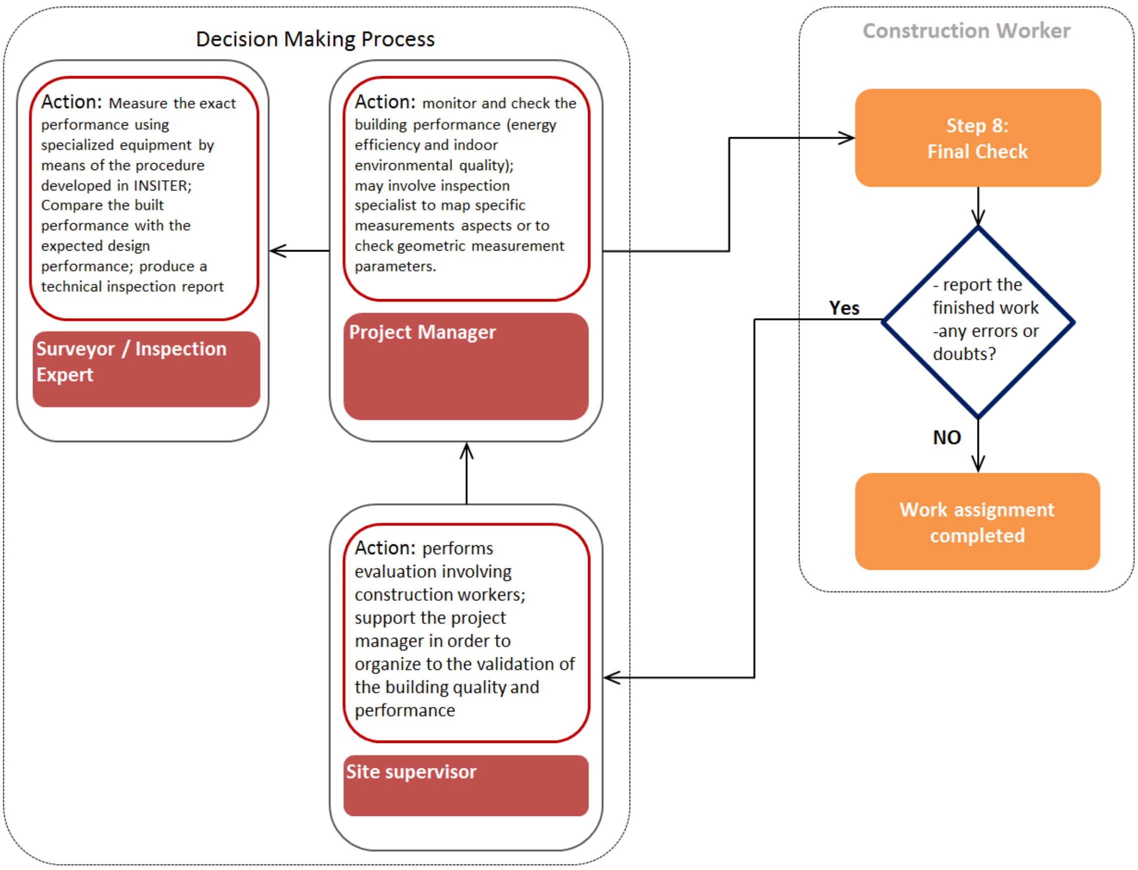

Decision Making Process
Action: Provide technical specifications of the product/system to be installed
Product Supplier
Action: Incorporate the technical specifications, data, instruction within the BIM model and the INSITER ICT tool
BIM Manager / Modeller
Action: Assign specific task and area to a single worker. After receiving the reports about non-conformities, decide if some actions need to be taken.
Project Manager
Action: Collect reports, detect any incongruity and inform the PM.
Site Supervisor
Construction Worker
Step 2: Checking of Ordered Components
NO
_Scanning QR _Component according to BIM model?
Yes
Step 3: BIM for On-site Construction


Decision Making Process
Action: Solve non-conformities and upgrade design information
Design Team: HVAC Engr./Architect/MEP Engr.
Action: Solve non-conformities and upgrade design information on BIM model
BIM Manager / Modeler
Action: Take decision; Ask the intervention of experts (es. BIM modeler/manager) to solve the problems
Project manager
Action: Ensure resources are adequate; Supervise the use of equipment; Monitor expenditure and ensure it remains within budget; Provide support to the PM in order to resolve problems when they arise; Report on progress to PM.
Site supervisor
Construction Worker
Step 3: BIM for On-site Construction
Yes
-Open the BIM model on site -Any non-conformity?
NO
Step 4 & 5: AR & Clash Detection During Construction


Decision Making Process
Action: Provide information to the PM on the site condition
Client
Action: Solve non-conformities and different site condition
Design Team: HVAC Engr./Architect/MEP Engr.
Action: Check that all construction activities scheduled at design phase are correctly integrated as self-instruction for the construction workers
Project manager
Action: provide information and instructions to perfor the actitivies
BIM Manager / Modeler
Action: Collect report, support the PM in coordination activities
Site supervisor
Construction Worker
Step 4 & 5: AR & Clash Detection During Construction
-Projecting on real situation
-Any clashes?
Yes
NO
Step 6: Self-instruction


Decision Making Process
Action: Take decision; Ask the intervention of experts (es. BIM modeler/manager) to solve the problems
Project manager
Action: Solve non-conformities and upgrade slef-instruction on BIM model
BIM Manager / Modeler
Action: Allocate general and daily responsibilities; Coordinate construction workers according to priorities and plans; Produce schedules and monitor attendance of crew; Supervise the use of equipment; Collect reports and any non-conformities, to be transmitted to the PM
Site Supervisor
Construction Worker
Step 6: Self-instruction
Step-by-step mounting instruction
Any challenge?
Yes
NO
Step 7: Self-inspection


Decision Making Process
Action: Measure the exact performance using specialized equipment by means of the procedure developed in INSITER; Compare the built performance with the expected design performance; produce a technical inspection report
Surveyor / Inspection Expert
Action: Take decision; Ask the intervention of experts (es. BIM modeler/manager) to solve the problems
Project manager
Action: support the construction workers in the self-inspection activities; involve inspection expert and specialist
Site supervisor
Construction Worker
Step 7: Self-inspection
-Check the work with the help of checklists
-Any doubt?
Yes
NO
Step 8: Final Check


Decision Making Process
Action: Measure the exact performance using specialized equipment by means of the procedure developed in INSITER; Compare the built performance with the expected design performance; produce a technical inspection report
Surveyor / Inspection Expert
Action: monitor and check the building performance (energy efficiency and indoor environmental quality); may involve inspection specialist to map specific measurements aspects or to check geometric measurement parameters.
Project Manager
Action: performs evaluation involving construction workers; support the project manager in order to organize to the validation of the building quality and performance
Site supervisor
Construction Worker
Step 8: Final Check
- report the finished work
-any errors or doubts?
Yes
NO
Work assignment completed

3.3.2 Measurements and KPIs

The decision-making procedure regarding the measurements and KPIs, implemented within the INSITER project, involves the analysis of a set of factors:

1. Decisive factors influencing the selection of the actor who **performs** the inspection;
2. Decisive factors influencing the selection of the actor who **assesses** the outcome of the inspection.

To facilitate the process of decision-making, a guideline is proposed by which a course of action and consideration to select the key inspector and decision maker is described. The main underlying considerations to formulate the guideline are:

For inspection:

- The relevant inspection method;
- The duration and occurrence of an inspection (when it takes place and how long it takes to perform);
- The required level of expertise to perform an inspection.

For Assessment:

- The required level of expertise to compare the results against the set of KPIs and measurements;
- The decision's impact (how critical is a decision in terms of cost, quality and planning);
- The nature of an inspection's outcome (qualitative, quantitative or analytic) and the level of expertise required to judge the outcome.

The main steps of the proposed guideline are presented in the following scheme.

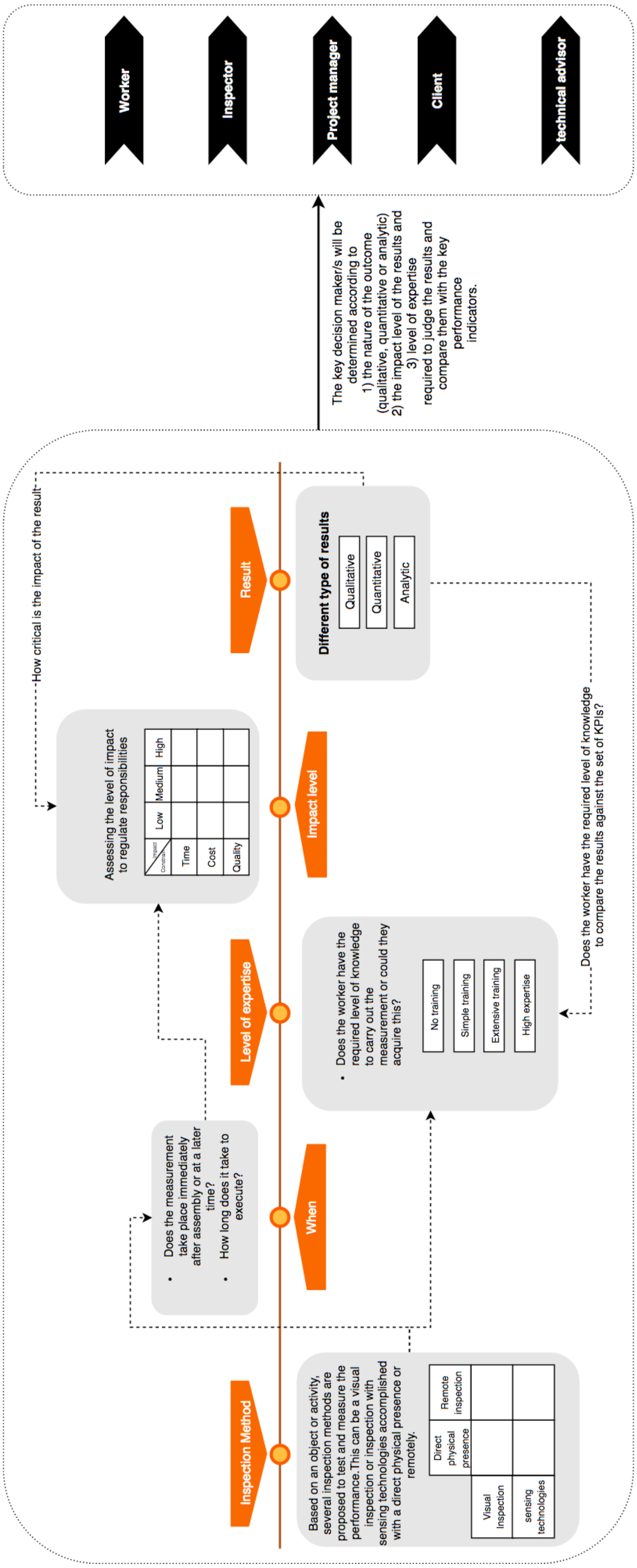


Figure 15: Guideline for inspection and decision making

To show the impact of the guideline for inspection and decision making a detailed and elaborated example is demonstrated for the measurement of the air tightness of the building envelope in table 2.

In addition, on an expert-level, the detailed measurement on-site procedures for different tools, such as laser scanning, thermal measurements and acoustic measurements etc. are described in detail in D1.5 and D1.7.

Inspection method	Result	When	By whom	Explanation
Visual inspection of received goods	Ensures that the right material is used for making the joints airtight. Ensures that the prefab elements are in the right condition to make an airtight connection	At reception of the incoming goods	Performing inspection: by worker on site (carpenter, prefab element assembler) Judgement of results: supervisor.	With a clear instruction, guidelines and checklists a worker is able to perform the tasks.
Visual inspection of the work	Ensures that the work is well performed. Link photo of work to specific building part to BIM	Direct after the work is done and still visible.	Performing inspection: by worker on site (carpenter, prefab element assembler) Judgement of results: supervisor.	With a clear instruction, guidelines and checklists a worker is able to perform the tasks.
Ultrasonic (prescan)	Gives an indication by a sound signal of possible air leakages. Quick method.	As soon as the connection or lead through is made and adjustment of joint is still possible..	Performing measurement: by worker on site (carpenter, prefab element assembler) Judgement of results: supervisor.	Ultrasonic scan is relative simple to perform, but the worker needs a training to perform the Ultrasonic test.
Ultragraphics	Gives an indication and graduation by an image with the possible air leakages. Link image to specific building part to BIM.	As soon as the connection or lead through is made and adjustment of joint is still possible.. Can also be used by completion of the building for quality assurance. (no limitations for temperature and wind speed)	Performing measurement: by expert Ultragraphics. Judgement of results and compare the results against the set of KPIs: by expert Ultragraphics in consultation with supervisor.	Ultragraphic scan is more complex to perform. An extensive training is needed. Not only for the measurement itself, but also for analysing the Ultragraphic image. Threshold KPI is set up 20 dB.
Blowerdoor	Air leakage loss measured by bringing a building on over pressure and/or/ under pressure. (n50 / qv10-waarde)	Building envelop has to be closed and wind speed < 3 Bft.	Performing measurement: Expert Blower Door	
		1. For method B the airtightness of the building envelop is determined when building envelop is closed and depending on the situation there are possibilities to improve the air tightness.	Judgement of results and compare the results against the set of KPIs: by expert Blower Door in consultation with supervisor	Blower door test is more complex to perform. An extensive training is needed. KPI depends on demanded quality level.
		2. For method A the airtightness of the building envelop is determined when the building is complete ready.		
Thermographics for air tightness	Loss of warmth caused by air leakage made visible by IR camera.	In combination with Blower Door test. Only possible in case of a temperature difference between inside and outside (around 12 to 15 °C)	Performing measurement: Expert Thermographics Judgement of results: by expert Thermographics in consultation with supervisor	Thermographic scan is more complex to perform. An extensive training is needed. Not only for the measurement itself, but also for analysing the thermograhic image.

Table 2: Practical example based on guideline for inspection and decision making

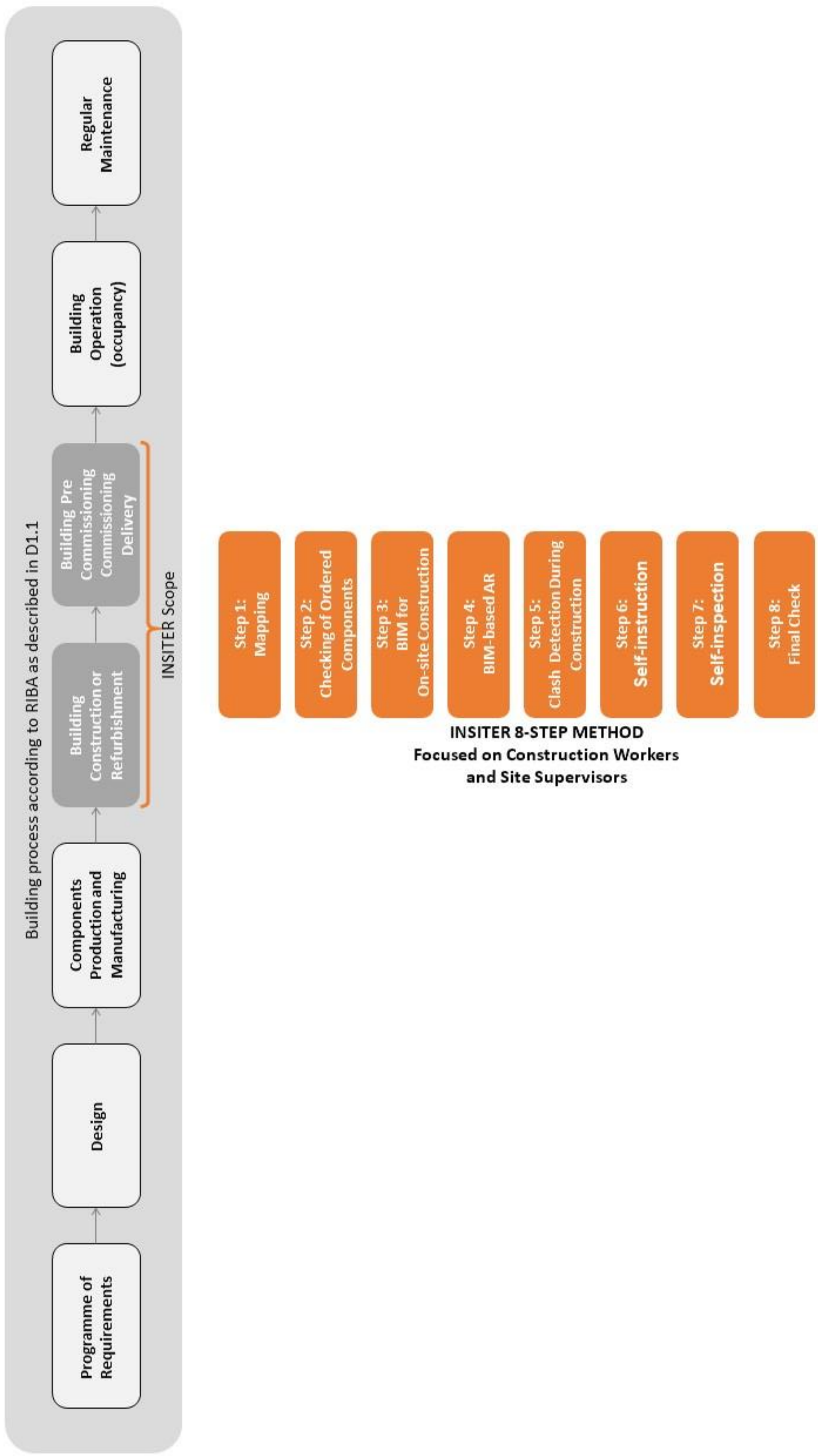
3.4 Construction workflows based on step-by-step INSITER methodology

After the description of the roles and duties of the main actors, the following schemes aim at defining the workflow of the construction process, on the basis of INSITER 8-step methodology.
The workflows show the interaction of the involved key-players, with the input to be acquired and the output to be produced at the end of each step. These schemes are sufficiently general in order to be flexible for different construction sites and projects, and they have been the basis to develop the “logic” of the INSITER App.

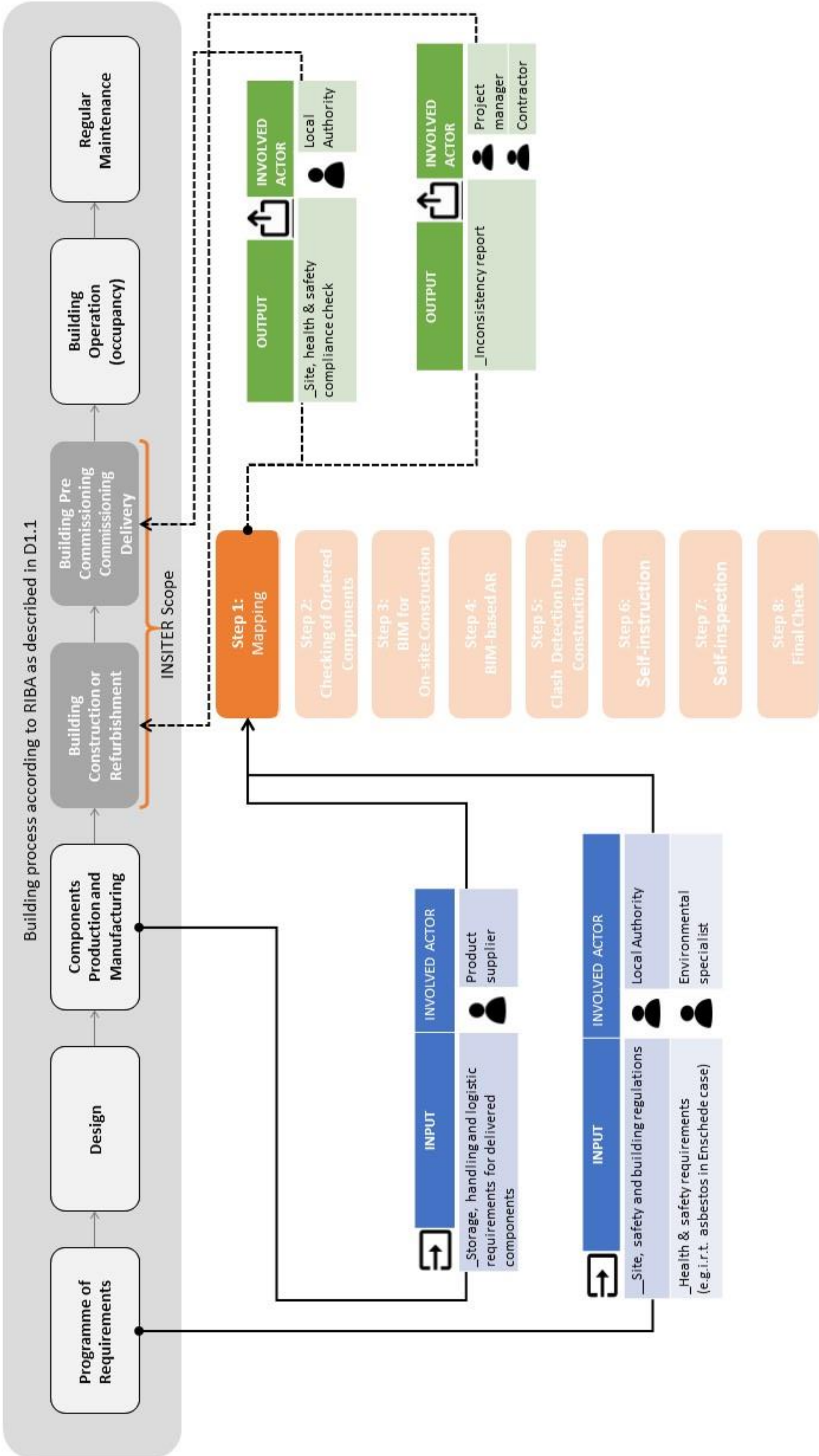
As already introduced in the previous deliverables, it is crucial to underline that the INSITER methodology (as also these specific guidelines) does not cover all building process but is dedicate only to 2 specific steps:

- Building **construction** and **refurbishment**;
- Building **pre-commissioning and commissioning**.

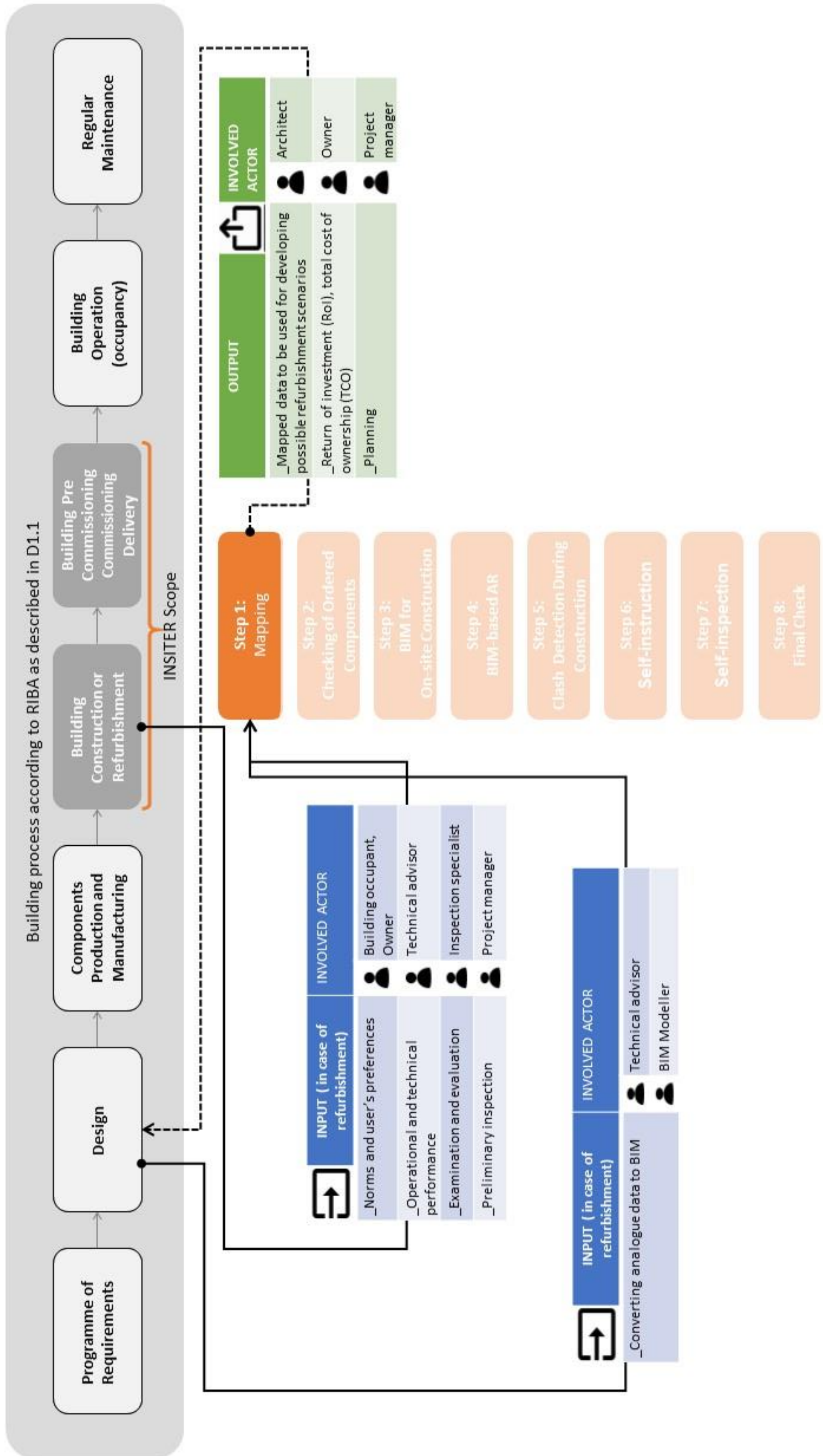
As introduced in the scheme proposed in the following page of this report, the design phase is dedicated to prepare all contents that will be stored on INSITER SharePoint and usable on-site using the INSITER App like the guidelines proposed in the datasheets of this report. The scheme “Overview of the construction process” summarizes these key concepts of the INSITER project.



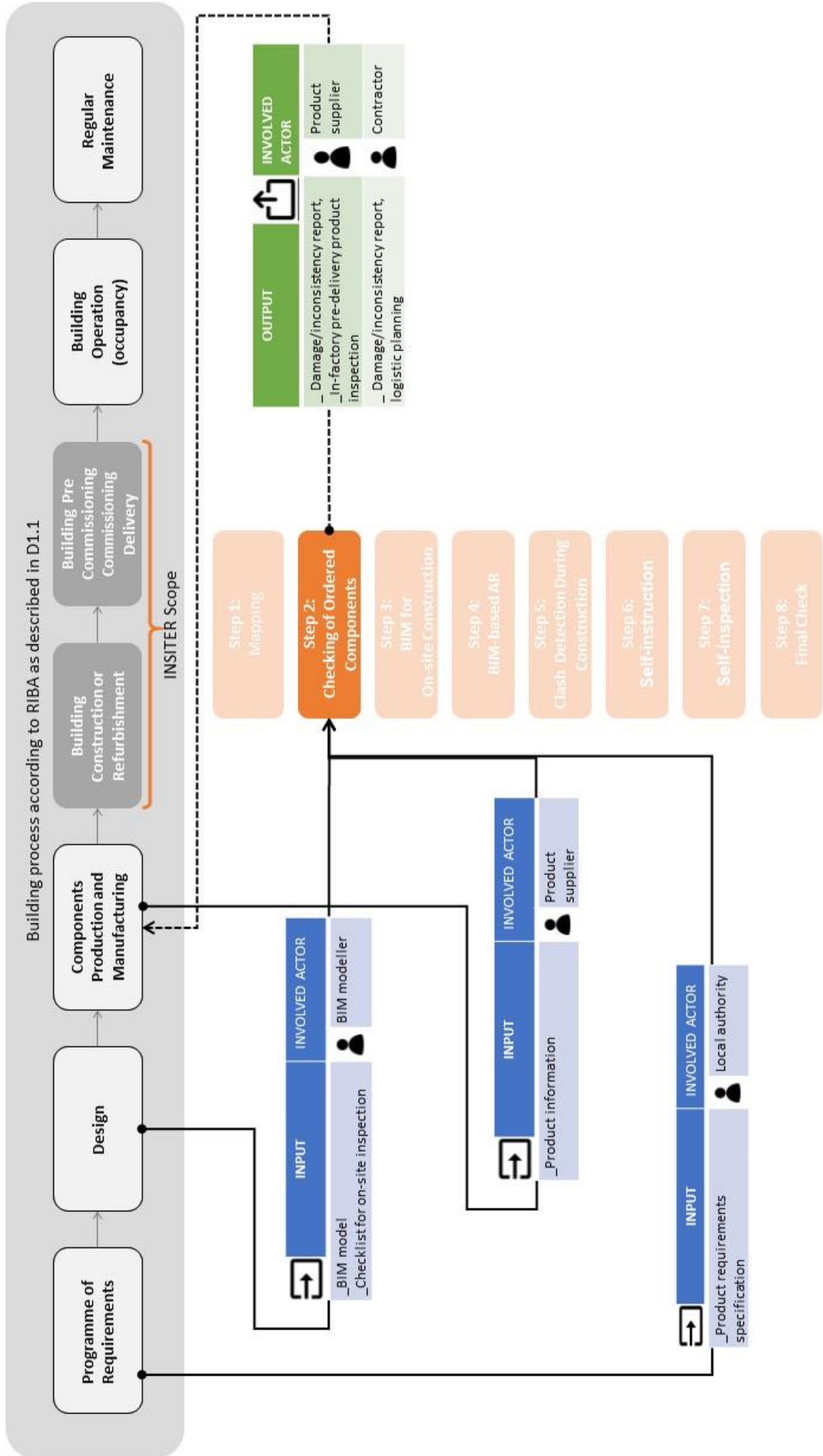
Overview of the construction process



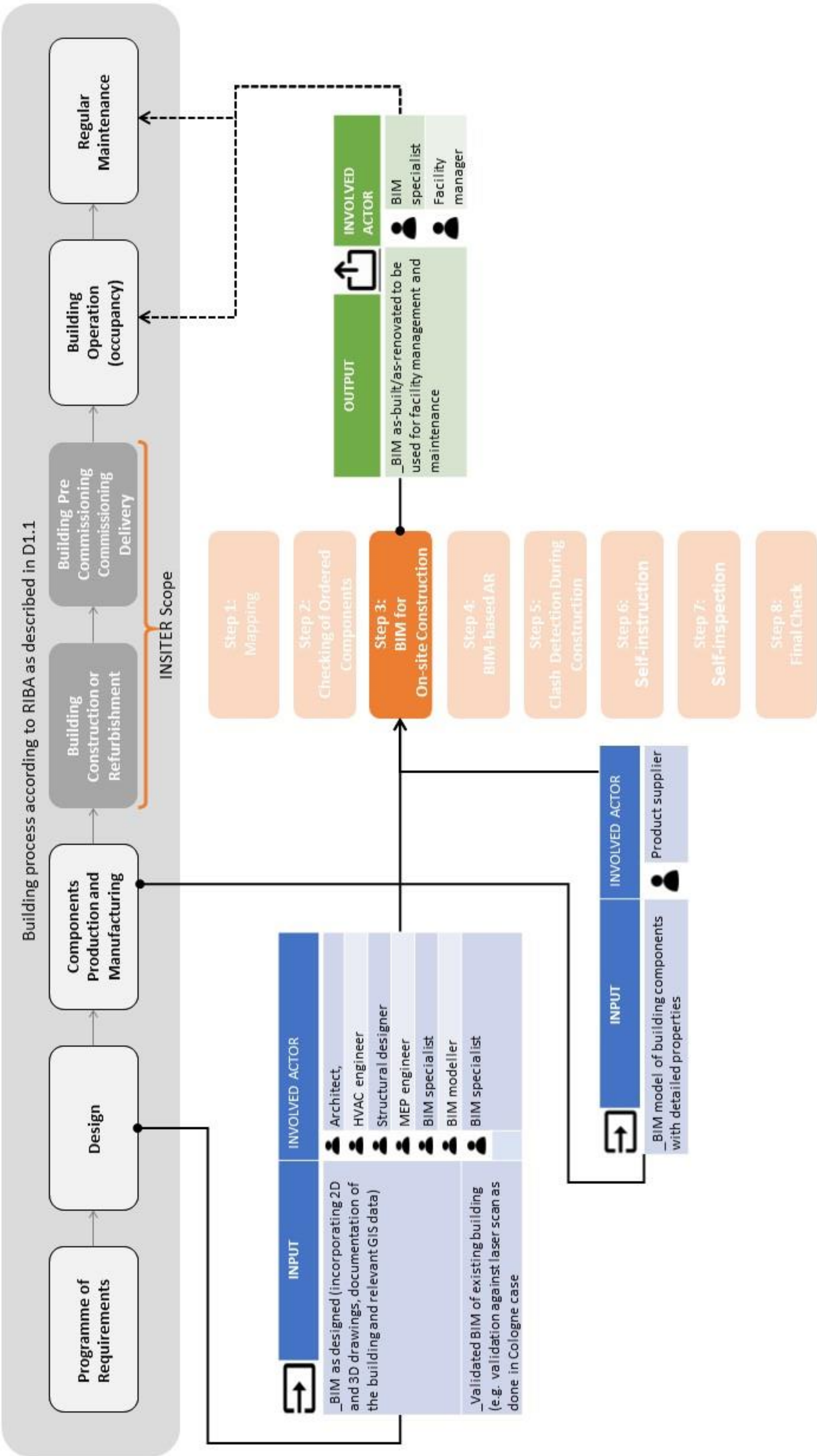
Step 1: Mapping Part A – Workflow, input, involved actors



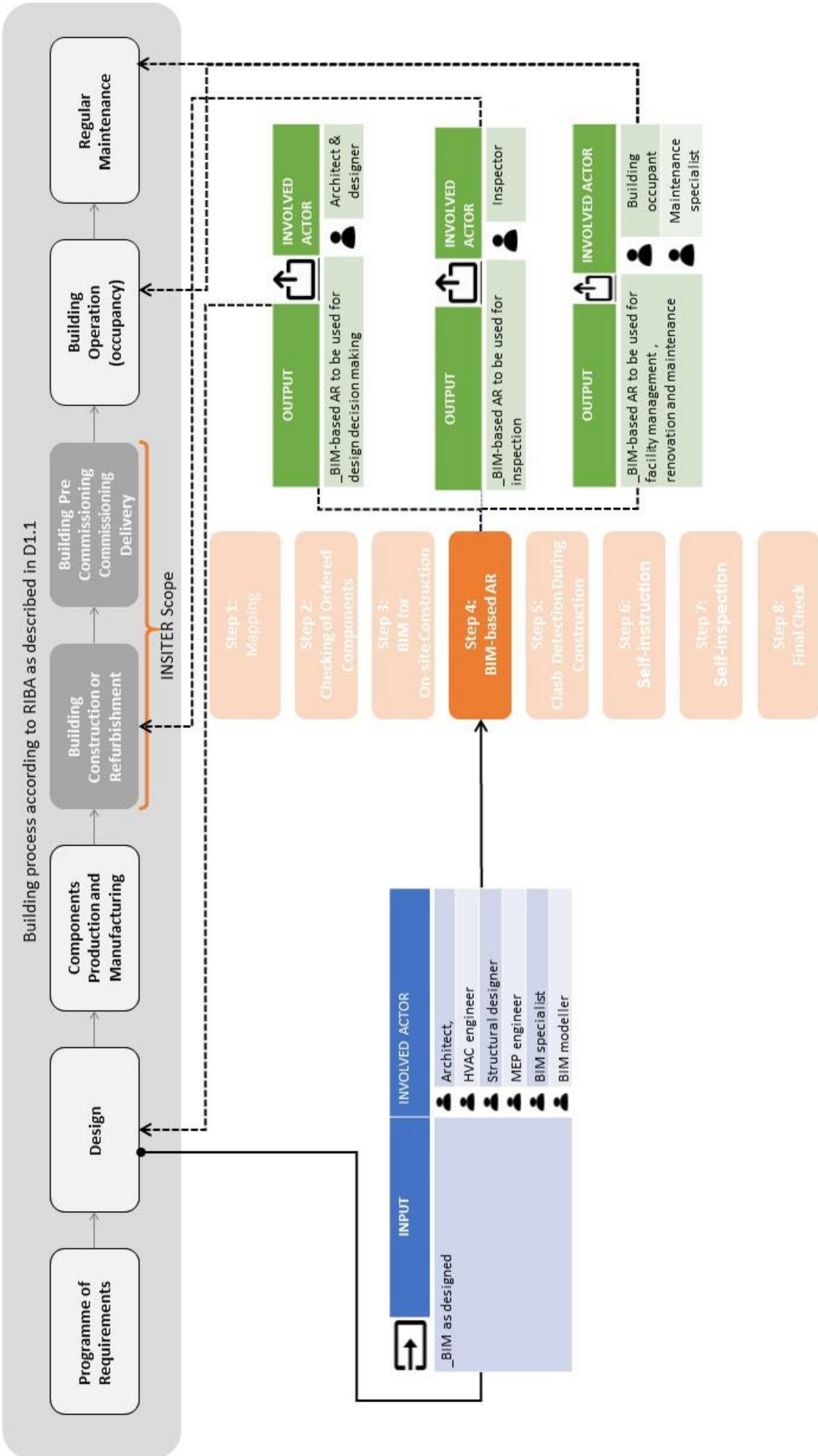
Step 1: Mapping Part B – Workflow, input, involved actors



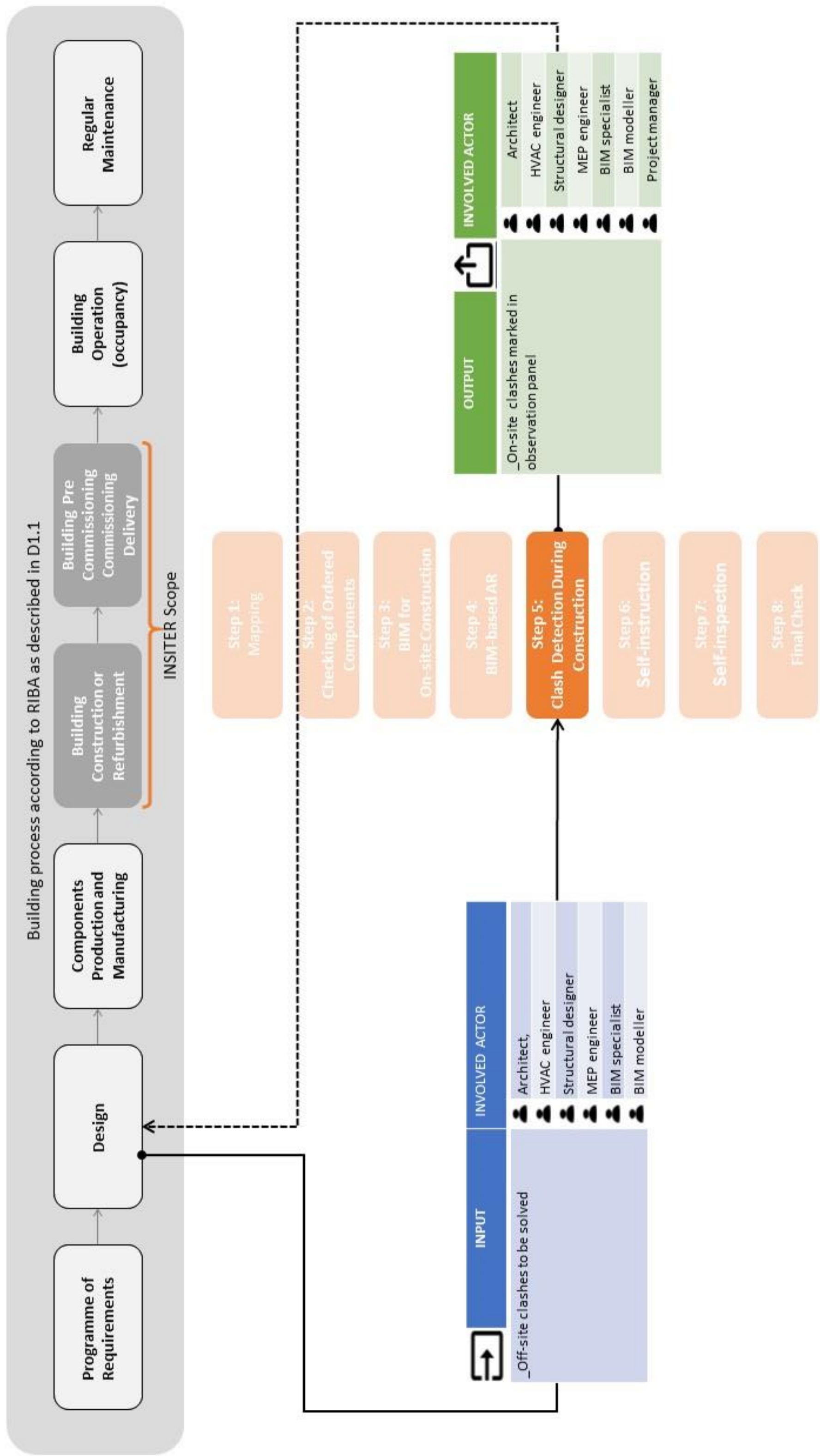
Step 2: Checking of ordered components – Workflow, input, involved actors



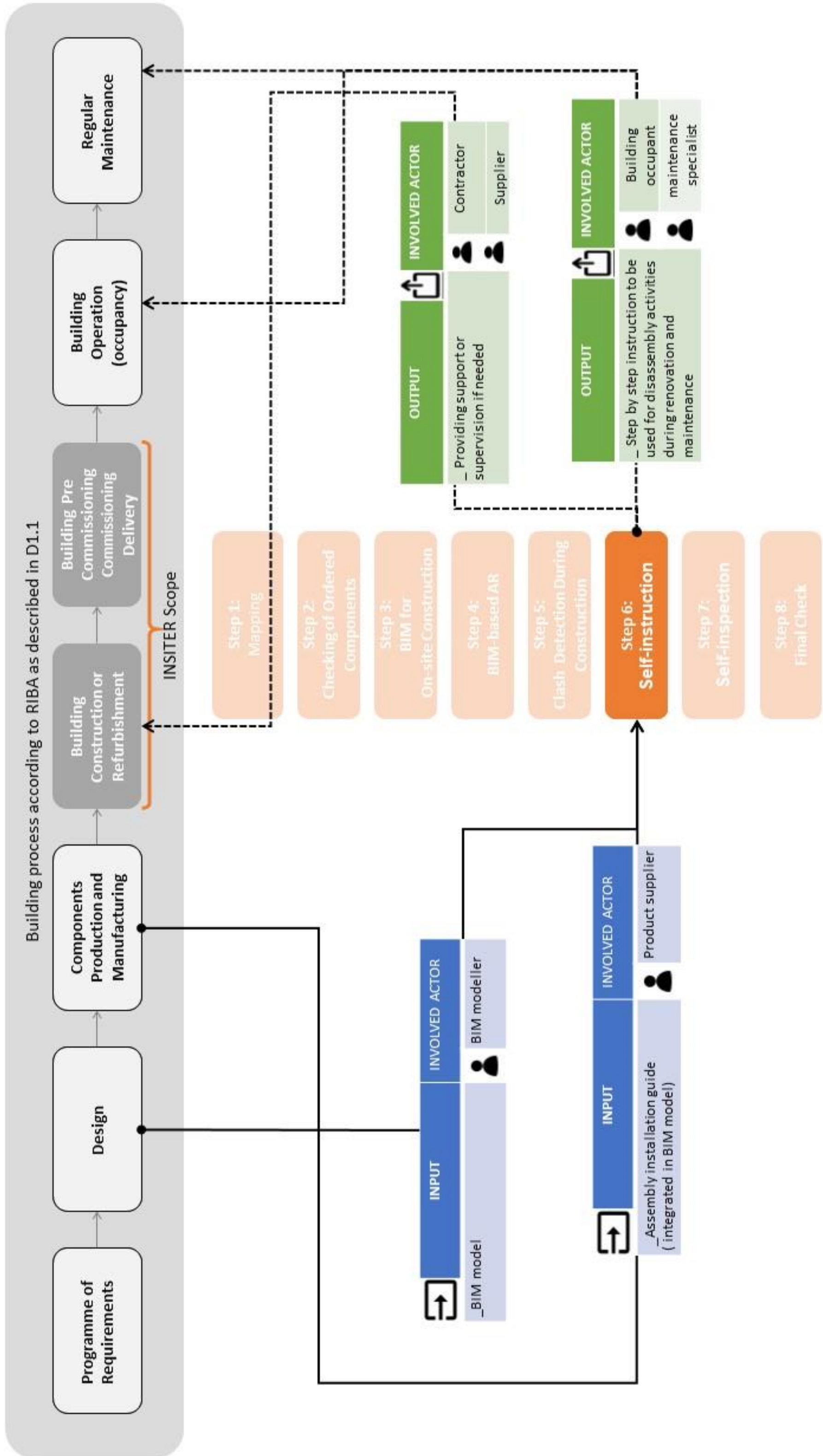
Step 3: BIM for on-site construction – Workflow, input, involved actors



Step 4: BIM based AR – Workflow, input, involved actors

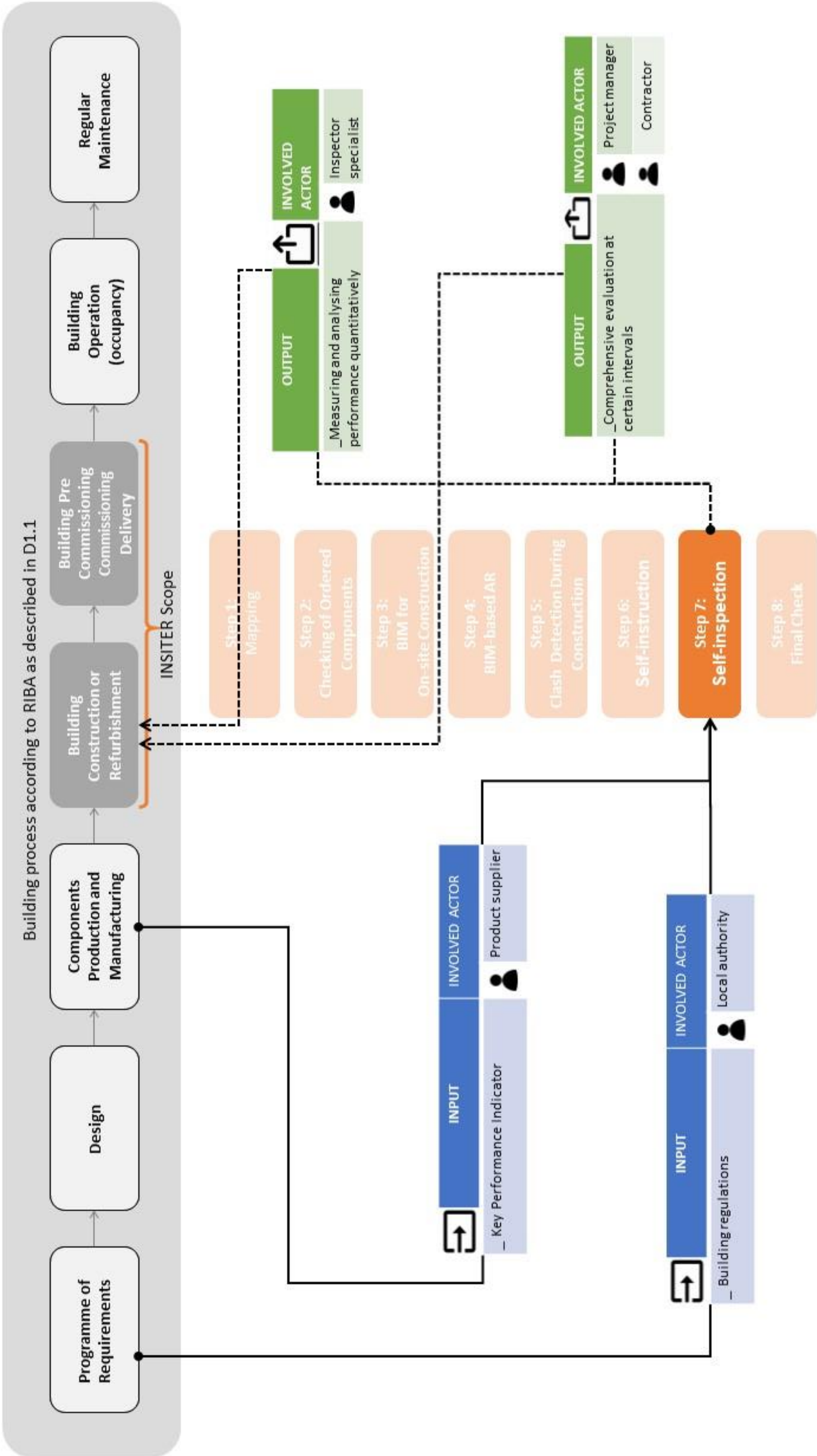


Step 5: Clash detection during construction – Workflow, input, involved actors

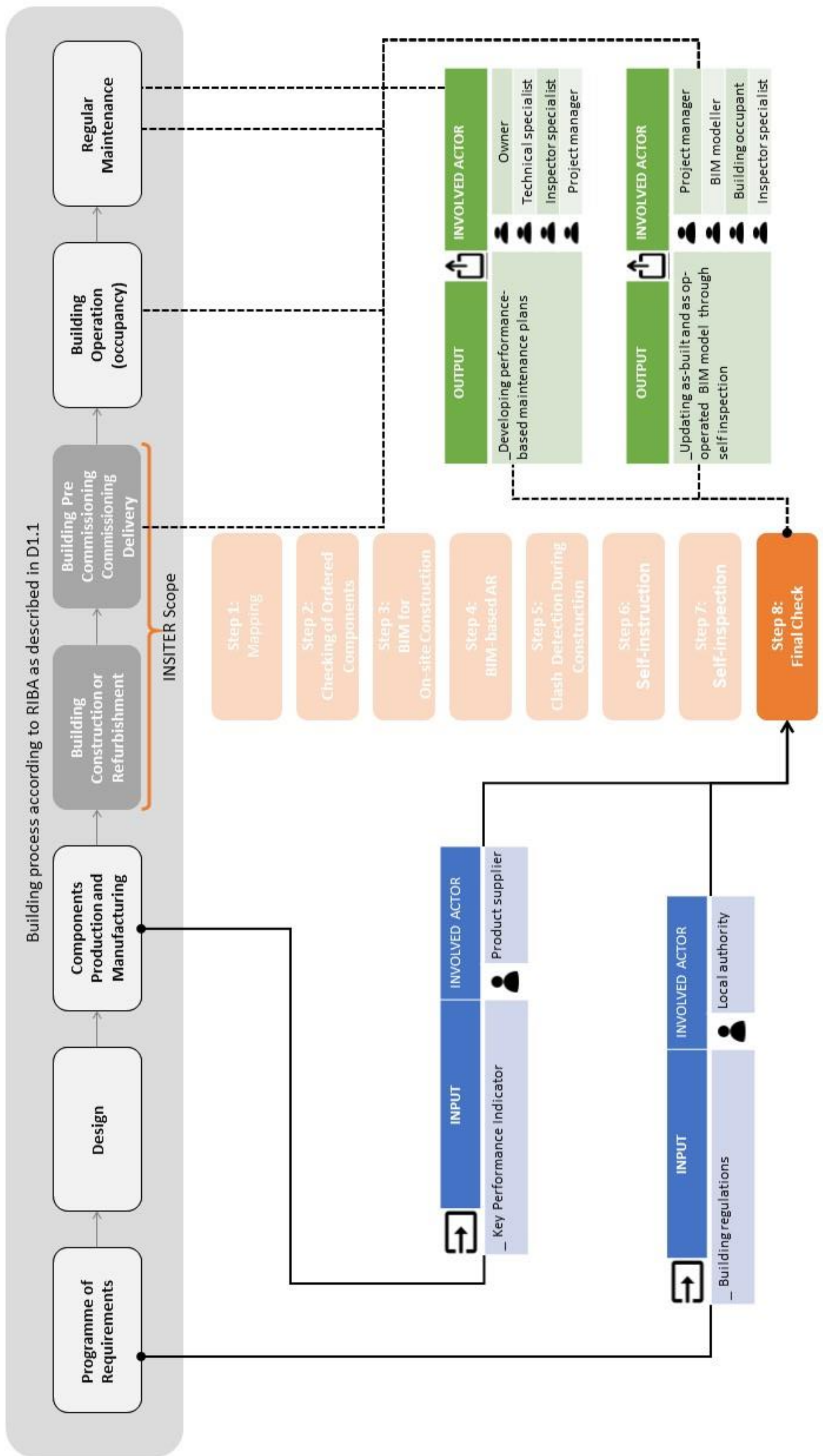


Step 6: Self-instruction – Workflow, input, involved actors

INSITER INTUITIVE SELF-INSPECTION TECHNIQUES



Step 7: Self-inspection – Workflow, input, involved actors



Step 8: Final Check – Workflow, input, involved actors

3.5 What comes next in this report

3.5.1 Positioning within WP1 deliverables

D1.2 and D1.3 are a follow-up of already produced deliverables in WP1 that analyse the construction errors and KPIs that should be avoided while applying the INSITER tool - see **D1.1 Best practices and existing shortcomings.**
The objective is to reduce the number and check the relevance of possible failures at a qualified level in order to reduce or even better avoid their impact especially on the quality of the building envelopes´ performance as these failures create a higher consumption of energy and might cause on-going problems affected by density leaks. Especially in lightweight prefab constructions consisting of well manufactured components the influence on total energy performance and indoor air quality and building physics is extremely high if the joints between the elements and supporting structures are not well closed in terms of expected air density. Leakages cause follow up damages and increasing bad performance of the total system.
Furthermore, in **D1.4 Calculation and analytical methods for building components** and **D1.6 Calculation and analytical methods for MEP/HVAC components** the critical components of the prefab building systems have been identified in order to assure the quality based on their special nature, constructive task and dependent on the position in the construction system and functionality expected.
The identified critical components are listed in D1.4 and D1.6 and will be treated following the INSITER 8-step approach of analysis in deliverables D1.4 and D1.6. Follow-up deliverables D1.5 and D1.7 will report in detailed measuring procedures and protocols for inspecting building components and *MEP/HVAC* respectively.

3.5.2 Structure and scope of D1.2 and D1.3

D1.2 Guidelines for self-inspection in new construction and **D1.3 Guidelines for self-inspection in refurbishment** explain how the holistically operating INISTER tool consisting of different components and organised by the INSITER software tool is applied practically on site in real time and in real life. Following the described scope of the INSITER guidelines, the main content of this report consists of the implementation guidelines of the INSITER 8-step methodology addressing critical architectural/structural and MEP/HVAC components respectively (in new buildings). The INSITER demonstrators of WP5 have been used as reference implementation examples within this context. Subsequently, each of the 8 steps for each component reflects on the real demonstration requirements of construction. Although, in this deliverable the holistic method is described following critical components demands, the results of the steps are not within the scope of this deliverable; these will be presented in WP5: following the defined use cases of each demonstrator. As a result, INSITER guidelines bridge the methods of WP1 and the tools of WP2 together with the real demonstration demands of WP5 within the described scope, while introducing a common framework based on the INSITER 8-steps methodology supported by WP3, without repeating the same information. The demonstrators that are introduced in D5.3 Case study elaboration, field validation protocols, and equipment calibration are relevant and further handled in this deliverable and the above-mentioned data sheets and additional guidelines following the defined scope of new buildings.

3.5.3 How to read the following chapters

D1.2 and D1.3 are composed by 4 main chapters. Chapter 1 defines and describes the INSITER Guidelines and the 8 steps methodology used on site by the main actors involved in the construction process. These 8 steps are implemented in the INSITER App, which preliminary user manual and demonstration are presented in chapter 1. In chapter 2 and 3

are describe the 8 steps methodology for the 9 identified critical components. In particular, chapter 2 presents the 8 steps for the critical architectural / structural components in new construction projects; chapter 3 addresses the critical MEP components, always in new construction projects. In *italic,* all the parts that are the same in each step are highlighted. In each step, the content presented within the table is the one shown in the app.
Outside the table, additional useful information for the same step is presented.

4. Implementation guidelines of INSITER 8-step methodology addressing critical architectural/ structural components in new construction projects

4.1 Connection foundation - ground floor

4.1.1 Explanation of EeB component

Connection between "foundations - ground floor" is considered as a critical EeB components, as tolerances created by inappropriate preparation of the foundation in terms of absolute measures, rectangular shape and horizontal flatness within acceptable tolerances is quite important. Tolerances out of scope cause connection problems not just at the foundation level but especially at the vertical gaps between pre-fab components. The gaps between the elements and the foundation have to be closed and sealed in order to ensure the air density of the envelope. Furthermore, tolerances influence the connection of HVAC components embedded in the pre-fab components. Improper installation of panels may harm operation or reduce the energy efficiency, by allowing excessive air, water and sound infiltration or condensation. This may promote the deterioration of the wall construction and its respective components.

Main energy-efficient and quality construction errors to be checked:

- geometrical accuracy:
  - geo-location
  - size
  - angular alignment
  - flatness alignment.

4.1.2 Explanation of Delft case for "new construction"

Sustainer Homes demonstrator is a reference critical EeB component example for new buildings as "connection foundation - ground floor". Reference material from the Office Lab has been used here to indicate an example of real criticalities to be faced on-site for this EeB component. In practice, what needs to be checked to avoid energy efficiency shortcomings during assembling refers mainly to: the positioning of the anchorage foundation; the correct placement of the water resistance layer, to secure the air density of the envelope; and the alignments between the anchorage of the foundation and the wooden modules of the ground floor. These criticalities with reference photos material address respectively to:

The position and the height of the foundation

According to the blocking point suggested tie-down locations, will be used for the positioning of the foundation.

Figure 16: Reference photos from the Sustainer Homes of the tie-down locations and the reference selected foundation system

The position of the water resistant layer

The placement of the sealing (recycled glass wool) to avoid gaps in the water proof-ness of the envelope.

Figure 17: Reference photo from the mounting between the foundation-ground floor and the sealing

The final position of the foundation

Figure 18: Reference photo from the final position between the foundation-ground floor

Category Intervention	New construction (Delft demonstration case)	
Critical EeB Component	Foundation and ground floor	
INSITER Methodology	☒	**Step 1: Mapping**
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Completeness and condition of the installation of the steel fundament elements before proceeding with the installation of the building elements. ***Key activities:*** • Check the site conditions; • Use as a reference the foundation plans to be sure that you are on the correct location where each ground floor element needs to be mounted; • Use the coding on the fundament elements and ground floor component as a reference to check that you are about to mount the correct fundament elements and ground floor components together; • Find a reference spot on site, to exactly position the elements in x, y and z coordinates. • Take pictures and note down ***Special attention:*** • Check if any fundament element is mounted at the wrong place; • Check if any damaged (transport) element is mounted to the ground; • Check if any fundament element is mounted in the wrong way.	
Technical data and information	• 2D foundation plan_Green Village • 3D foundation plan_Green Village • 2D site plan_ reference point_Green Village • 3D site plan_reference point_Green Village	

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction (Delft demonstration case)
Critical EeB Component	Foundation and ground floor
INSITER Methodology	☐ Step 1: Mapping ☒ **Step 2: Checking of ordered components** ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • Consistency of components and building materials; • Quality of the components and building materials; • The presence and the level of damage. ***Key activities:*** • Scan an attached QR or RFID code with an iPad; • Retrieve the components' ID; • Confirm whether these are the correct ones as specified in BIM and the technical specifications; • Note down remarks on the observation panel. ***Special attention:*** • Check the correctness of the ground floor components delivered on site; • Check whether these are the correct components as specified in the BIM model and technical documents; • Check if any materials or components have been damaged from transport; • Store all materials and delivered components according the logistics plan on-site.
Technical data and information	• 2D site plan_storage_Green Village • Manual_transportation and storage_Green Village • Specs_building elements_Green Village

Category Intervention	New construction (Delft demonstration case)	
Critical EeB Component	Foundation and ground floor	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☒	**Step 3: BIM for on-site construction**
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Completely and accurately follow the building design; • Having access through BIM to all parts and relevant technical details; • Having available the latest versions of the design details to be executed; • Avoid decreasing the overall building quality caused by ad-hoc solutions. ***Key activities:*** • Open BIM by using the scanned QR or RFID code from step 2. • The highlighted part corresponds to the exact location of each element to be installed; • Use the BIM model on the BIM viewer to observe how the foundations are modelled; • Use the component BIM model (if available) of the connection foundation ground flour to check the technical details; • Note down any remarks, questions or doubts on the observation panel.	
Technical data and information	• BIM model_Green Village • BIM screenshot01_Green Village • BIM screenshot02_Green Village • BIM screenshot03_Green Village • BIM screenshot04_Green Village • Dragados panels_Bottom slab	

Category Intervention	New construction (Delft demonstration case)
Critical EeB Component	Foundation and ground floor
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☒ **Step 4: BIM-based Augmented Reality** ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • Completely and accurately follow the building design; • Detailing to be followed. ***Key activities:*** • You can use here one of the BIM-based AR solutions for INSITER to visualize: 1. BIM and 3D objects on-site environment; 2. Self-instruction data with process sequences; 3. 3D animations; 4. Technical details; 5. Workflows; 6. Thermal images, acoustic measurements. • You can project on the top of the fundament elements the ground floor components to be installed, so that you can check visually the correct location and construction position; • You can retrieve and project through BIM the above information (2-6); • Please use this material as a reference and try to understand your tasks and the expected result; • Note down any remarks, questions or doubts on the observation panel; ***Special attention:*** • Be sure that all hardware and cameras are calibrated; • Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps; • AR markers should be visible around your working area; • Use the markers for the initialization of the applications and your navigation; • If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.
Technical data and information	• AR module on empty site_Green Village • AR module on right position_Green Village • AR module on site flying in_Green Village • AR right position detail_Green Village • AR video module positioning_Green Village • AR info movie

Category Intervention	New construction (Delft demonstration case)
Critical EeB Component	Foundation and ground floor
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☒ **Step 5: Visual clash detection during construction**
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Clashes correspond to potential inconsistencies between design and realization, such as: 1. Elements not given the required spatial or geometric tolerances; 2. Elements that its buffer zone is breached. ***Key activities:*** • You can use here one of the BIM-based AR solutions for INSITER; • Test AR on-site for visual comparisons between BIM model and realization of ground floor mounting on the fundament elements based on visualization of virtual clashes (super-imposed). • Refer to Step 4 whenever you have doubts about how to use the AR apps; • Note down remarks on the observation panel. ***Special attention:*** • Fundament elements that are mounted at the wrong place; • Fundament element that are mounted in the wrong way.
Technical data and information	• AR clash_Green Village

Category Intervention	New construction (Delft demonstration case)	
Critical EeB Component	Foundation and ground floor	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☒	**Step 6: Self-instruction**
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Ensure that all ground floor elements are mounted properly; • Accurately follow the manufacturer's assembly/installation manual. ***Key activities:*** • Open relevant technical drawings from previous steps for critical details to confirm the requirements; • Check directly on the BIM model the critical details; • Check the available manual from manufacturer and try to understand the mounting process stepwise; • Watch the relevant videos for ground floor elements mounting on foundation.	
Technical data and information	• Example_Assembly manual • BIM-based Self-Instruction model for mobile devices_Green Village	

Category Intervention	New construction (Delft demonstration case)
Critical EeB Component	Foundation and ground floor
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Ensure the quality of the so far assembled materials; • Correctness of the joints with regards to geometrical accuracy; • Pre-check the joints concerning avoidance of thermal or acoustic bridges or air leakages. • The worker needs to have the technical specifications of the building that are available as part of the BIM model (see steps 2 and 3). ***Key activities:*** • Fill-in the checklist; • Take at least one picture for each question of the checklist; • Add notes when needed and report your findings. ***Checklist*** • Are the right elements identified that should be tested (location ground floor elements)? • Have you protected your fundament elements from inappropriate weather during mounting or required drying time in case of concrete? • Are all the joints between framing of ground-floor components and foundation air-sealed? • Is there a scan of the identified elements (as- is ground floor elements) available? • Is there a BIM model (as –is BIM of ground floor elements from scan) available? • Was an overlay performed of BIM as designed with as-is BIM? • Was a deviation analysis (see picture) performed? • Are the deviations within the acceptable geometric tolerances? • If yes, was a report of the work completion done with time stamp and signature? • If not, is the site manager informed?
Technical data and information	• Laser scan image_Green Village • Deviation analysis_Green Village

The site-supervisor:

- Evaluates the results of the answers;
- Decides which measurement procedure to perform and checks their requirements;
- Co-ordinates, if needed the quick laser-scanning;
- Co-ordinates, if needed an acoustic test;
- Co-ordinates, if needed a thermal scan on the finished installation on selected locations;
- The measurement images can be superimposed to BIM or AR for visual evaluation.

Category Intervention	New construction (Delft demonstration case)	
Critical EeB Component	Foundation and ground floor	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☒	**Step 8: Final check**
Intervention description	***Main critical points:*** • Having access to all data and information from the previous steps. ***Key activities:*** • Make sure you have all your findings for steps 1-7 (images, notes, remarks); • Open the observation panel and note down your final remarks. In these please include: 1. deviations from initial planning; 2. deviations from designs; 3. any problem you have faced. • In the observation panel please answer the following questions: 1. To what extent have the tools contributed to properly performing the dedicated activity? 2. To what extent have the tools contributed to avoiding mistakes? 3. How many mistakes have been avoided by using the tools? • Sign and finalize your report.	
Technical data and information	• The App will automatically retrieve the reports and comments from previous steps.	

4.2 Exterior wall and opening

4.2.1 Explanation of EeB component

Reduction in energy consumption and an increase in energy efficiency are important prerequisites for a high-performing building stock and the exterior walls, including built-in elements (i.e. windows and openings).

Considering the same U value, the prefabricated façades have a thickness of 25% less than the traditional masonry walls, with a significant saving of space. It is therefore possible to complete the envelope adding a further external thermal insulation coating, ideal for reducing the primary energy requirements for heating and cooling the building. This involves the construction of a versatile façade system with high thermal insulation capacity and the possibility of benefiting from a high degree of prefabrication.

The construction of the structural works and the construction of the façade can thus take place almost at the same time, with considerable practical advantages, including the opportunity to immediately start the internal finishing works.

The low weight of the elements, usually made of thin steel profiles, significantly reduces the load on the load-bearing structure of the building and thus decisively affects the static structural work, contributing to the reduction of loads, especially in areas with high seismicity. The goal of the modular façade is the integration of functions, especially the integration of building services: in fact, the most recent construction techniques for prefab façade modules contain a complete façade element (inner cavity wall, insulation and cladding), openings (windows and doors) and integrated systems (HVAC, plumbing, electrical and special systems). Flexibility and upgradeability play a very important role.

Within INSITER context, the prefabricated façade elements can be distinguished between: lightweight façade modules (i.e. Aluminum facades, Timber frame, Steel frame, Sandwich façade elements) and heavy weight façade elements (i.e. Concrete, Brick façade elements). The main energy-efficient and quality construction errors to be checked: thermal insulation; sound insulation; protection against rain; protection against wind / airtightness.

The following characteristic points of junction are of interest:

- Geometrical accuracy of the bearing construction;
- Geometrical accuracy of the prefab façade elements;
- Joint between two prefab façade elements;
- Joint between façade elements and bearing construction.

4.2.2 Explanation of Cologne case for “new construction”

The reference demonstration case for “new construction” is the rooftop building addition on the Cologne Healthcare center. The addition is made of prefab light-weight elements on an existing facility built in 2012. The design choice to install an addition of t timber frame exterior walls is directly related to the fact that the new portion will be structurally connected to the existing one, without retrofitting it completely. The new rooftop addition can be considered a “new construction”. In particular, the exterior timber wall, for a total thickness of approx. 25.5 cm, consists of (from inside to outside):

- Interior wall lining made of OSB-3 panels, 15 mm thick, fastened with U-clamps, the plate joints airtight glued with an approved tape;
- Studs of 6/18cm made of construction wood, untreated, planed and fastened to provide the frame;
- Insulation made of mineral wool stands, 180mm thick;
- Exterior wall OSB panels, 60 mm thick;

- A hydrophobic plaster treatment.
- As regards the wall modules, the two critical joints are, respectively:
  - in plan, junction between panels, corner junction, connection between the new panels and the existing reinforced concrete elevator shaft;
  - in section, the ground connection and the connection between the floor and the perimeter wall.

Category Intervention	New construction (Cologne demo case)	
Critical EeB Component	Exterior wall and opening	
INSITER Methodology	☒	**Step 1: Mapping**
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • The completeness of the bearing structure; • The geometric accuracy as per design of the bearing structure; • The presence of any local damages on the horizontal/vertical structure on which the modules will be mounted; • The proper set-up of the benchmarking (GPS) for the mounting of the façade elements. ***Key activities:*** • Check the condition of the bearing structure around you; • Check for any local damages; • Check if benchmarking is set up; • Take pictures (minimum 3); • Note down your remarks on the observation panel. ***Special attention:*** • In case of detected inaccuracies as per design, check with the site supervisor to perform a quick laser-scanning of the existing conditions.	
Technical data and information	• Details_Plan_Cologne • Details_Section_Cologne • Existing condition_Cologne • Example_load bearing structure	

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction (Cologne demo case)
Critical EeB Component	Exterior wall and opening
INSITER Methodology	☐ Step 1: Mapping ☒ **Step 2: Checking of ordered components** ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • The completeness of delivered packages; • The correctness and adequacy for installation of components and building materials delivered on-site; • The presence of any damage due to transport; • Indication of handling and storage of components and building materials on-site. ***Key activities:*** • Scan an attached QR or RFID code on the packaging; • Retrieve the site storage plan, the lift plan and the requirements for fragile materials; • Compare the information from the delivered panels and the design requirements. The specific information relating to each individual component can be extracted; • Scan the attached QR or RFID code on each component; • Retrieve the specifications of each component linked to each component's ID; • Confirm whether these are the correct ones as specified in the BIM model and the specifications; • Specifically for each component information for storage is given, depending on the material and the characteristics of the product and how the panels shall be handled on-site; • Note down remarks on the observation panel. ***Special attention:*** • Check out the pick points where the panel or module will be lifted from the truck trailer by a crane and set on-site; • For wooden modules use a wraparound belt strap; • As a crane, use a truck mounted hydraulic crane, a crawler crane and, in special circumstances, a tower crane, following the given lifting plan. • If there is no area to store the panels on site, directly take them from the truck to the final position on the structure (Site Plan Logistics_Cologne).
Technical data and information	• Site Plan_Logistics_Cologne • Example_Wall Panel_AWP flex_Datasheet • Example_Ventilated facades_Catalogue • Example_Storage-on-site01 • Example_Storage-on-site02

Category Intervention	New construction (Cologne demo case)
Critical EeB Component	Exterior wall and opening
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☒ **Step 3: BIM for on-site construction**
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2.* • *The highlighted part corresponds to the exact location of each element to be installed;* • *Use the BIM model on the BIM viewer to observe how the façade elements are modelled;* • Use the component BIM model (if available) of the exterior wall and opening component to check the technical details; • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• BIM model_facade panels • Example_BIM_Connections

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Cologne demo case)	
Critical EeB Component	Exterior wall and opening	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☒	**Step 4: BIM-based Augmented Reality**
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER to visualize:* 1. *BIM and 3D objects on-site environment;* 2. *Self-instruction data with process sequences;* 3. *3D animations;* 4. *Technical details;* 5. *Workflows;* 6. *Thermal images, acoustic measurements.* • You can project on the bearing structure the exterior walls elements to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down any remarks, questions or doubts on the observation panel.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*	
Technical data and information	• AR_Cologne • Example_ AR on-site • AR info movie	

In italic are the common descriptions as per previous components (the reference component is “2.1. Foundation and ground floor”).

Category Intervention	New construction (Cologne demo case)
Critical EeB Component	Exterior wall and opening
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☒ **Step 5: Visual clash detection during construction**
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Clashes correspond to potential inconsistencies between design and realization, such as:* 1. *Elements not given the required spatial or geometric tolerances;* 2. *Elements that its buffer zone is breached.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of exterior walls elements installations based on visualization of virtual clashes (super-imposed); • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.* ***Special attention:*** • Connections between facade elements and the MEP systems to be integrated; • Interference between the load bearing structure and the panels; • Connections of two façade panels; • Corner junctions; • Roof connections; • Ground connections; • Air conditioning unit mounted on the façade.
Technical data and information	• Example_ clashes01 • Example_ clashes02 • Example_ clashes03

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Cologne demo case)
Critical EeB Component	Exterior wall and opening
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☒ **Step 6: Self-instruction** ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • Ensure that all façade panels are mounted properly; • Accurately follow the manufacturer's assembly/installation manual; • Focus on joints and sealing. ***Key activities:*** • Follow the manual documents / videos / animations where the mounting of the new facade components is described in a step-by-step process; • Mark fixing points on the wall or on the installation surface (control lines); • Check the layout, determining the exact position of the facade according to the technical drawings; • Drill/install fixing points as required by manuals, tech specs, videos; • Check the mounting/anchoring of profiles and fasten (screw brackets on the wall/installation surface); • Check the façade element and mount on the supporting structure; • Place and fix insulation material, sealants and finishing if required, especially on joints/corners. ***Special attention:*** • All frame joints are sealed properly during the construction/installation phase; • The manufacturer's installation instructions have been followed; • The work is done as per schedule; • Anchoring and fasteners; • Floor details and connection to the bearing structure; • Roof detailing.
Technical data and information	• Example_Installation manual_fibre cement • Example_Installation manual_timber • Facade-Section_Cologne • Lower-Detail_Cologne • Upper-Detail_Cologne • Plan-Connection-with-wall_Cologne • Plan-Corner detail_Cologne • Plan-Joints_Cologne • Example_Mounting modules • BIM-based Self-Instruction model for mobile devices_Green Village

Category Intervention	New construction (Cologne demo case)
Critical EeB Component	Exterior wall and opening
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Thermal bridges; • Air-leakages. ***Key activities:*** • *Fill-in the **checklist;*** • *Take at least one picture for each question of the **checklist**;* • *Add notes when needed and report your findings* • Check with your site supervisor the possibility to perform a quick laser-scanning of the existing condition; ***Checklist:*** • Is there congruence between the construction details and the approved shop drawings and the tested samples? • Are the finishes and quality of the installation, based on assembly requirements (stated by the Manufacturer and applicable standards), verified? • Are the flatness of the façade elements and the assembly tolerances verified? • Do the test results correspond to the performances required by the specific facade construction system? • Is the execution of the repairs required during the intermediate delivery verified? • Are the different acceptance tests executed? • Are there any local damages on the weather-stripping of window sashes? • Are there any closure problems (incomplete) on mounted windows and/or doors?
Technical data and information	• Example_ Quick laserscanning on-site • Example_Building exterior checklist

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

The site-supervisor:

- Evaluates the results of the answers;
- Decides which measurement procedure to perform and checks their requirements;
- Co-ordinates, if needed the quick laser-scanning;
- Co-ordinates, if needed an acoustic test;
- Co-ordinates, if needed a thermal scan on the finished installation on selected locations;
- The measurement images can be superimposed to BIM or AR for visual evaluation.

Category Intervention	New construction (Cologne demo case)	
Critical EeB Component	Exterior wall and opening	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☒	**Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* 1. *deviations from initial planning;* 2. *deviations from designs;* 3. *any problem you have faced.* • *In the observation panel please answer the following questions:* 1. *To what extent have the tools contributed to properly performing the dedicated activity?* 2. *To what extent have the tools contributed to avoiding mistakes?* 3. *How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*	
Technical data and information	The App will automatically retrieve the reports and comments from previous steps.	

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

4.3 Curtain wall / glazed façade

4.3.1 Explanation of EeB component

In addition to the similar issues as solid facades, in terms of air tightness and general performance (from acoustic, thermal points of view), glass façades present specific problems related to the presence of glass panes and sealing. The large transparent surfaces constitute a potential weak point of the envelope and have an impact on energy performance, acoustics, functionality, and Indoor Air Quality due to its potential for large heat gains and losses. Respectively, the main energy-efficient and quality construction errors to be prevented during construction (typical performance failures of glass façades) resulting to energy efficiency shortcoming, by facilitating BIM for (1) access to and integration of mounting information and knowledge; (2) building survey and as-built BIM; and (3) information exchange and interoperability refer to prevention of:

- Condensation and Frosting (typ. inadequate heat flow performance);
- Glare (typ. inadequate light control);
- Noise (typ. inadequate sound mitigation or generation of the inborn noise by the wall itself);
- Leakage (typ. inadequate rain water resistance);
- Glass breakage (typ. inadequate impact resistance, differential movement, or material failure);
- Free fall of wall fragments (typ. inadequate structural attachment);
- Aesthetic imperfections of glass and coatings (typ. miscellaneous reasons);
- Corrosion (typ. inadequate corrosion protection, galvanic action of dissimilar metals, etc.).

Main energy-efficient and quality construction errors to be checked:

- Water infiltration and condense assessment;
- Thermal bridge identification;
- Improper installation works.

4.3.2 Explanation of a typical case for new construction

No reference demonstrator is available within INSITER WP5 for glass façades in new constructions. General information from the literature will be used to describe this EeB component. Glass façades may incorporate a variety of materials and typologies of systems (refer to *"D1.4 Analytical methods for building components"*). Curtain walls are discussed here, as a type of glass façades and most specifically stick-built systems and utilized systems, as classified from their method of fabrication and installation.

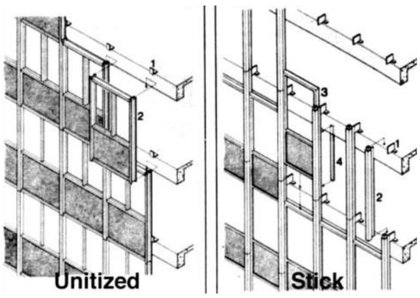


Figure 19: Utilized vs. stick curtain wall systems

In the stick system, the curtain wall frame and glass or opaque panels are installed and connected together piece by piece, as are fabricated as individual pieces and parts that should be assembled and erected on-site. Generally are supported from the face or top of the building floor structure. Vertical pieces (mullions) of aluminium extrusions go all along the face of the building creating a continue curtain wall system, out in front of the slab. Anchoring to floor slab is bolding back the system to the building, while pressure plates hold the glass into the system. In the unitized system, the curtain wall is composed of large units that are assembled and glazed in the factory, shipped to the site and erected on the building. The units are sealed together on-site. Cranes are most often used to install such systems. While curtain walls are likely to demonstrate movement caused by thermal changes, it is important to ensure that the connections that anchor the curtain wall are engineered to allow differential movement while resisting applied loads and pressures. In addition, to mitigate water penetration into the structure, water that enters the system at the gasket corners should ideally weep out through the snap cover weep holes. Both unitized and stick systems can be either interior or exterior glazed. Interior glazed systems are often specified for low-rise buildings or applications with limited interior obstructions for easy interior access. With exterior glazed systems, glass and spandrel components are installed from the exterior side of the curtain wall, requiring swing stage, scaffolding, or a man-lift to install such glaze.

<table>
<tr><td>Category Intervention</td><td colspan="2">New construction (Typical case)</td></tr>
<tr><td>Critical EeB Component</td><td colspan="2">Curtain wall / glazed façade</td></tr>
<tr><td rowspan="8">INSITER Methodology</td><td>☒</td><td>Step 1: Mapping</td></tr>
<tr><td>☐</td><td>Step 2: Checking of ordered components</td></tr>
<tr><td>☐</td><td>Step 3: BIM for on-site construction</td></tr>
<tr><td>☐</td><td>Step 4: BIM-based Augmented Reality</td></tr>
<tr><td>☐</td><td>Step 5: Visual clash detection during construction</td></tr>
<tr><td>☐</td><td>Step 6: Self-instruction</td></tr>
<tr><td>☐</td><td>Step 7: Self-inspection</td></tr>
<tr><td>☐</td><td>Step 8: Final check</td></tr>
<tr><td>Intervention description</td><td colspan="2">Main critical points:
• The completeness of the construction of the structural frames, preventing project management related implications and securing HSE on-site;
• The presence of damage on the already mounted slabs and joints between two prefab elements before starting anchoring;

Key activities:
• Visually inspect and evaluate the condition of the bearing structure;
• Take at least one picture from remarks for special attention below;
• Remember that you can always keep notes on the observation panel. You can also make notes on your photos.

Special attention:
• Check the condition of the slabs and the walls near the edges;
• Check if there are any broken parts of the bearing structure;
• Check if there are any gaps between the elements of the bearing structure;
• Check if there are any exposed, damaged or wet insulation material;
• Check if control lines for benchmarking are established;
• Check if edge protection and fall prevention systems have been installed.</td></tr>
<tr><td>Technical data and information</td><td colspan="2">• Example_2D and 3D curtain wall
• Example_edge protection
• Example_site plan and geolocation</td></tr>
</table>

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction (Typical case)
Critical EeB Component	Curtain wall / glazed façade
INSITER Methodology	☐ Step 1: Mapping ☒ **Step 2: Checking of ordered components** ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • The correctness of components and building materials delivered on-site; • The presence of damage from transport; • The handling and storage of components and building materials on-site. ***Key activities:*** • Scan an attached QR or RFID code on the packaging; • Retrieve the site storage plan, the lift plan and the requirements for fragile materials; • Scan the attached QR or RFID code on each component; • Retrieve the specifications of each component linked to each component's ID; • Confirm whether these are the correct ones as specified in the BIM model and the specifications; • Open in BIM the part of the building where each component has to be installed; • Lift and store the components and the building materials on each floor following the lift plan and the storage requirements; • Note down remarks the observation panel. ***Special attention:*** • Check if any materials or components have been damaged from transport; • Check the attached flow chart for identification of routine and non-routine *lifting operations;* • Check the video for *Storing and handling glass sheets*; • Store glass near the columns of each floor; • Check the general requirements for *storage of glass on-site*.
Technical data and information	• Example_Lifting operations • Example_Logistics • Example_Specs_FireframesSG • Example_Specs_wic_series_2012 • Example_Storage of glass on-site • Example_Storage • Storing and handling glass sheets

Category Intervention	New construction (Typical case)
Critical EeB Component	Curtain wall / glazed façade
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☒ **Step 3: BIM for on-site construction** ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2.* • *The highlighted part corresponds to the exact location of each element to be installed;* • Use the BIM model on the BIM viewer to observe how the curtain wall system is modelled; • Use the component BIM model (if available) of the curtain wall to check the technical details*;* • Observe the exact positioning of the gaskets and the way the modules and/or the bottoming out of individual module frames are engaged (intended “floating” between frames); • Observe the layout of the interlocking horizontals and vertical mullions at the perimeter of unitized panels; • Observe the layout of embeds in the structural slabs; • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• Example_BIM model_Screenshot • Example_Detailing_Screenshot1 • Example_Detailing_Screenshot2 • Example_Glass panels_Screenshot

In italic are the common descriptions as per previous components for new construction (the reference component is “2.1. Foundation and ground floor”).

Category Intervention	New construction (Typical case)
Critical EeB Component	Curtain wall / glazed façade
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☒ **Step 4: BIM-based Augmented Reality**
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER to visualize:* 1. *BIM and 3D objects on-site environment;* 2. *Self-instruction data with process sequences;* 3. *3D animations;* 4. *Technical details;* 5. *Workflows;* 6. *Thermal images, acoustic measurements.* • You can project on open bearing structure framing the curtain wall components to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down any remarks, questions or doubts on the observation panel.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*
Technical data and information	• Example_Curtain Wall_AR • AR info movie

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case)
Critical EeB Component	Curtain wall / glazed façade
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☒ **Step 5: Visual clash detection during construction** ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	**Main critical points:** • *Clashes correspond to potential inconsistencies between design and realization, such as:* 1. *Elements not given the required spatial or geometric tolerances;* 2. *Elements that its buffer zone is breached.* **Key activities:** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of curtain wall components installations based on visualisation of virtual clashes (super-imposed). • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.* **Special attention:** • Misalignment in laying out the structural framing systems; • Improper layout of imbeds that receive curtain walls anchors; • Improper or ineffective gasket engagement between modules; • Bottoming out of individual module frames; • Loss of engagement of the blind gaskets within the interlocking horizontal and vertical mullions at the perimeter of unitized panels; • Construction tolerances for the structural frame according to manufacturer (accepted based on best practices: +/- 2.54 cm over the height of the building); • Tolerance for the curtain wall according to manufacturer (accepted based on best practices:+/- 0.635 cm over the height of the building); • Misalignment problems encountered during erection of stick-built systems resulting to changes in the required glass size; • Reductions in the glass bite; • Changes in the required glass size; • Overlap the framing has on the glass.
Technical data and information	• Example_potential clashes_anchoring

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

INSITER INTUITIVE SELF-INSPECTION TECHNIQUES

Category Intervention	New construction (Typical case)
Critical EeB Component	Curtain wall / glazed façade
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☒ **Step 6: Self-instruction**
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Obtain the manufacturer's installation instructions; • Ensure that all frame joints are sealed properly; ***Key activities:*** • Use the control lines as reference points for measuring; • Check the layout, determining the exact position of the facade according to the technical drawings; • Check out the Assemby/Installation manual from manufacturer; • Use for each prefabricated assembly its unique identification number and its own individual QA/QC checklist. • Watch videos for mounting instruction; • Anchor the plates; • Erect mullions; • Install horizontals; • Seal the corners; • Glaze the wall; • Apply the exterior glazing caps and final sealants; • Install drywall caps and retainers in the interior. ***Special attention:*** • Focus on mullion intersections, splice joints in vertical mullions, and wall perimeter; • Check with the site-supervisor the possibility to perform a laser level survey of the building structure before mullions erection to determine misalignment problems of the anchoring; • For post tensioned slabs, special anchor conditions development is required to avoid interference with the slab pull points and tendons; • If the weather is not good, place plastic sheets supported by temporal wooden frames; • Install at least 7 grams of silicone sealant; • Check for any falling trim covers • Check for potential misalignments from terrace roofs or building interior at inside corners.

Technical data and information	• Example_Anchoring detail • Example_Assembly manual • Example_drilling • Example_Installation descriptions • Example_Installation instructions_400CW • Example_Installation instructions_im4500 • Example_Mullion transom • Example_Curtain wall installation

Category Intervention	New construction (Typical case)
Critical EeB Component	Curtain wall / glazed façade
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Thermal bridges; • Air-leakages. ***Key activities:*** • *Fill-in the checklist;* • *Take at least one picture for each question of the checklist;* • *Add notes when needed and report your findings.* ***Checklist:*** • Have you used the manuals for manufacturer for quality controls and checklists on specific points to be reviewed for every assembly fabricated and installed? • Have you fully cleaned the surfaces where caulking seals are required before installing sealing? • Are there any loose members in the aluminium/steel frames? • Are there any buckling or bending horizontal mullions? • Are there any missing/loose fasteners? • Are all weather seals of the internal perimeter sealing properly installed? • Have you filled the gasket pockets with silicone sealant? • Is sealing installed over weep holes? • Have you placed all shims in the correct location following the technical details?
Technical data and information	• Example_Checklist • Example_Field testing procedures

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

The site-supervisor:

- Evaluates the results of the answers;
- Decides which measurement procedure to perform and checks their requirements;
- Co-ordinates, if needed an acoustic test;
- Co-ordinates, if needed a thermal scan on the finished installation on selected locations;
- The measurement images can be superimposed to BIM or AR for visual evaluation.

Category Intervention	New construction (Typical case)	
Critical EeB Component	Curtain wall / glazed façade	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☒	**Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* *1. deviations from initial planning;* *2. deviations from designs;* *3. any problem you have faced.* • *In the observation panel please answer the following questions:* *1. To what extent have the tools contributed to properly performing the dedicated activity?* *2. To what extent have the tools contributed to avoiding mistakes?* *3. How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*	
Technical data and information	• The App will automatically retrieve the reports and comments from previous steps.	

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

4.4 Roof

4.4.1 Explanation of EeB component

The roof represents an important critical part of the building envelope considering that it protects and covers the indoor spaces from the weather condition as: rain, snow and wind. Nevertheless, the technological quality of the roofs is essential in order to minimize heat loss and waterproofing. Generally, the roof can be classified in two main typologies: 1) flat or 2) pitched. Roofs are composed by different elements (layers). The single elements influence the roof performance and its durability. In order to achieve the expected performance are important: 1) the different layers composition; 2) material quality; 3) roof design; 4) adequacy of assembly; 5) proper installation of single elements. An improper installation of the roof elements or integrity issues of the single elements may cause energy efficiency problem; water infiltration or interstitial condense. These problems may promote the deterioration of the structural elements of the roof and the different layers that compose the overall thickness.

The main energy performance of the roof is affected by the insulation quality and its proper installation. Heat loss through convection in roof elements of buildings can reach up to 25% of the total heat loses. When cold air enters the house through gaps in doors and windows for example, convection currents and is transferred heat energy into roof materials. Loses can be reduced significantly through proper insulation of the total roof surface. Regarding the waterproofing, is crucial to identify the best roofing slate in consideration of the local climate condition and to put in place the water sealing membranes. Flat roofs are vulnerable for accumulation of snow and water, whereas the pitched roofs have to deal with run-off water. The performance analysis of the roof elements also includes their connection to the vertical façade elements.

The construction market is characterized by several typologies of prefabricated roof covering elements to be directly supplied “just in time” to the building site ready for installation and complete with the necessary roofing components and transport wrapping. Nevertheless, it is possible to complete the roof construction directly on the factory assembling the prefab modular building on the construction site as in the “*Sustainer Homes demonstration case”*. The roof system will be completed by delivering all other important components: e.g. dome lights, continuous skylights, smoke extractors, plumbing vent.

Main energy-efficient and quality construction errors to be checked:

- Thermal bridge identification;
- Water infiltration and condense assessment;
- Damaged roof components.

4.4.2 Explanation of Delft demonstration case for new construction

Sustainer Homes demonstrator (NL) is a reference critical EeB component example for “new buildings” regarding the "roof construction" of totally prefab buildings. Sustainer Homes - Office Lab is a transportable prefab building based on wooden modules, built in a factory using renewable materials, assembled and finalized on construction site. Reference material from the Office Lab has been used here to indicate an example of real criticalities to be faced on-site for this EeB component. In practice, what needs to be checked to avoid energy efficiency shortcomings during assembling refers mainly to: the positioning of the different prefab modular buildings in order to close the roof joints connection; application of the correct insulation (material, thermal conductivity, thickness); the correct placement of the water resistance layer (sealing); the correct installation of smoke extractors and plumbing vent.

Category Intervention	New construction (Delft demo case)	
Critical EeB Component	Roof	
INSITER Methodology	☒	**Step 1: Mapping**
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Planning and organization of all work at height following the HSE; • The condition of the already mounted elements, before starting the installation of the roof. ***Key activities:*** • Check the site conditions; • Use as a reference the roof plans to be sure that you are on the correct location; • Find a reference spot on site, to exactly position the elements in x, y and z coordinates. (The position of this reference spot will be displayed at the site plan available on the mobile device); • Check the conditions of the installed modules at the exact location where the roof-works will take place; • Take pictures and note down your remarks on the observation panel. ***Special attention*** • Component is mounted at the wrong place; • Damaged (transport) component is mounted, • Component is mounted in the wrong way); • Check for any visible gaps between the cladding and the bottom roof deck layer of the installed modules and for any broken or damaged installed elements; • Check the condition of the hoisting corners.	
Technical data and information	• 2D foundation plan_Green Village • 2D ground floor plan_Green Village • 2D site plan_reference point_Green Village • 3D foundation plan_Green Village • 3D site plan_reference point_Green Village • Site plan_Green Village	

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted elements, before the start of the roof works.

<table>
<tr><td>Category Intervention</td><td colspan="2">New construction (Delft demo case)</td></tr>
<tr><td>Critical EeB Component</td><td colspan="2">Roof</td></tr>
<tr><td rowspan="8">INSITER Methodology</td><td>☐</td><td>Step 1: Mapping</td></tr>
<tr><td>☒</td><td>Step 2: Checking of ordered components</td></tr>
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<tr><td>☐</td><td>Step 7: Self-inspection</td></tr>
<tr><td>☐</td><td>Step 8: Final check</td></tr>
<tr><td>Intervention description</td><td colspan="2">Main critical points:
• Quality of the joint connections between external walls and roof;
• Consistency of the roof materials (Firestone Rubbencover, Xtratherm insulation, vapour barrier, OSB panel, MDF prime);
• Presence and the level of damages;
• Correctness of construction materials.

Key activities:
• Check the correctness of the roof components delivered on site scanning an attached QR or RFID code with an iPad;
• Retrieve the components' ID;
• Compare the information with technical specifications defined by the project manager;
• Check whether these are the correct components as specified in the BIM model and technical documents;
• Visually inspect in order to identify the integrities or damages of the roof elements: wood structural, thermal insulation and water sealing membranes;
• Verify if everything is correct and if all the materials, tools and accessories are on site.
• Note down remarks on the observation panel.

Special attention
• Check if the building materials are stored inside the modules to be protected from weathering;
• Check for any broken water sealing membranes or wet insulation.</td></tr>
<tr><td>Technical data and information</td><td colspan="2">• 2D site plan_storage_Green Village
• Specs_roof_Green Village
• Storage_Green Village
• Transportation and storage_Green Village</td></tr>
</table>

Category Intervention	New construction (Delft demo case)
Critical EeB Component	Roof
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☒ **Step 3: BIM for on-site construction**
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2;* • *The highlighted part corresponds to the exact location of each element to be installed;* • Use the BIM model on the BIM viewer to observe how the roof system is modelled; • Use the component BIM model (if available) of the roof system to check the technical details; • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• BIM_Dragados Panels_Top slab • BIM_Roof detail

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Delft demo case)	
Critical EeB Component	Roof	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☒	**Step 4: BIM-based Augmented Reality**
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER to visualize:* *1. BIM and 3D objects on-site environment;* *2. Self-instruction data with process sequences;* *3. 3D animations;* *4. Technical details;* *5. Workflows;* *6. Thermal images, acoustic measurements.* • You can project on top of the already installed building elements (floors underneath roof) the roof elements to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down on the observation panel any remarks, questions or doubts.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*	
Technical data and information	• AR info movie	

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

<table>
<tr><td>Category Intervention</td><td>New construction (Delft demo case)</td></tr>
<tr><td>Critical EeB Component</td><td>Roof</td></tr>
<tr><td rowspan="8">INSITER Methodology</td><td>☐ Step 1: Mapping</td></tr>
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<tr><td>☐ Step 7: Self-inspection</td></tr>
<tr><td>☐ Step 8: Final check</td></tr>
<tr><td>Intervention description</td><td>Main critical points:
• Clashes correspond to potential inconsistencies between design and realization, such as:
1. Elements not given the required spatial or geometric tolerances;
2. Elements that its buffer zone is breached.

Key activities:
• You can use here one of the BIM-based AR solutions for INSITER;
• Test AR on-site for visual comparisons between BIM model and realization of roof elements to be installed based on visualization of virtual clashes (super-imposed).
• Refer to Step 4 whenever you have doubts about how to use the AR apps;
• Note down remarks.

Special attention:
• Check for wrong slope;
• Check for incorrect flashings;
• Check for misalignments of the piping.</td></tr>
<tr><td>Technical data and information</td><td>• AR_Clash01_Green Village</td></tr>
</table>

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Delft demo case)	
Critical EeB Component	Roof	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☒	**Step 6: Self-instruction**
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Correct positioning of the piping; • Damaged insulation material. ***Key activities:*** • Open relevant technical drawings from previous steps for critical details to confirm the requirements; • Check directly on the BIM model the critical details; • Check the available manual from manufacturer and try to understand the mounting process stepwise; • Watch the relevant videos for roof installations. ***Special attention:*** • Place insulation material back into the in hoisting holes; • Fill any holes with PUR; • Repair the water resistant layer; • Repair damaged insulation material	
Technical data and information	• Assembly Manual_Green Village • Hoisting_PUR_Green Village • Module connection_Green Village • Section L_Green Village • Water resistance layer_Green Village • BIM-based Self-Instruction model for mobile devices_Green Village	

Category Intervention	New construction (Delft demo case)
Critical EeB Component	Roof
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • The correctness of the joints with regards to geometric accuracy of the construction; • The water sealing membranes and insulation continuity in all part of the roof; • The airtightness of the joints. ***Key activities:*** • *Fill-in the **checklist;*** • *Take at least one picture for each question of the checklist;* • *Add notes when needed and report your findings.* ***Checklist:*** • Are the right elements identified that should be tested (location of roof elements and components)? • Have you placed insulation material in the hoisting holes? • Are any of the fasteners missing or not attached to the purlins? • Does vent pipe flashing fit all over flues and pipes? • Is the BIM model (as designed) of the identified elements (roof) available and uploaded? • Is there a scan of the identified elements available (as-is roof elements)? • Is there a BIM model (as -is BIM of roof elements from scan) available? • Was an overlay performed of BIM as designed with as-is BIM? • Was a deviation analysis (see picture) performed? • Are the deviations within the acceptable geometric tolerances? • If yes, was a report of the work completion done with time stamp and signature? • If not, is the site manager informed?
Technical data and information	• Laser scan image_Green Village • Deviation analysis_Green Village

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

The site-supervisor:

- Evaluates the results of the answers;
- Decides which measurement procedure to perform and checks their requirements;
- Co-ordinates, if needed the quick laser-scanning;
- Co-ordinates, if needed an acoustic test;
- Co-ordinates, if needed a thermal scan on the finished installation on selected locations.

Category Intervention	New construction (Delft demo case)
Critical EeB Component	Roof
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☒ **Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* 1. *deviations from initial planning;* 2. *deviations from designs;* 3. *any problem you have faced.* • *In the observation panel please answer the following questions:* 1. *To what extent have the tools contributed to properly performing the dedicated activity?* 2. *To what extent have the tools contributed to avoiding mistakes?* 3. *How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*
Technical data and information	The App will automatically retrieve the reports and comments from previous steps.

In italic are the common descriptions as per previous components for new construction (the reference component is "2.1. Foundation and ground floor").

4.5 Connection between new and existing building

4.5.1 Explanation of EeB component

Connection between new and existing building is considered as a critical EeB components, as tolerances in the existing building in terms of absolute measures, rectangular shape and horizontal flatness within acceptable tolerances is quite important. Tolerances out of scope cause connection problems at walls, roofs and ground floors especially at the vertical and horizontal joints between new pre-fab components and existing constructions. The gaps between the new elements and the existing construction have to be closed and sealed in order to ensure the air and steam density of the envelope. Furthermore tolerances can influence the connection of HVAC components embedded in the pre-fab components. Improper installation of panels may harm operation or reduce the energy efficiency, by allowing excessive air, water and sound infiltration or condensation. This may promote the deterioration of the wall or roof construction and its respective components. Main energy-efficient and quality construction errors to be checked:

- geometrical accuracy:
  - geo-location;
  - size;
  - angular alignment;
  - flatness alignment.

4.5.2 Explanation of Cologne case

In the Cologne Demonstrator a new storey is added to an existing roof. When the existing building was planned and built in 2012, a potential later roof top extension was already prepared by already calculating additional loads to the top floor slab and the exterior walls. The elevator shaft was already built higher to enable a stop at a later roof extension without too much construction work. So the connection of the new roof storey to the existing building affects the ground floor, the wall and roof connection to the elevator shaft and of course the MEP/HVAC systems that have to be connected with the existing building. The building envelope of the new storey will be completed with the installation of double glazed windows with PVC or wood frames. Considering the building envelope, the new storey will be realized with wood prefab technologies as follow:

- Walls timber frame exterior wall - Certified timber frame exterior walls factory prefabricated (including the required quality control):
  - Interior planking with OSB-3 panels, 15 mm thick, Egger or glw., fastened with U-clamps, the plate joints airtight glued with an approved tape;
  - Ständerwerk acc. Statics (posts, threshold, Rähm) off 6 / 18cm Fi / Ta construction wood, untreated, planed and fasted, techn. dried, in a pitch of 62.5cm;
  - The insulation within the mineral wool stands WLG 035, 180mm thick, ISOVER Ultimate A1 or glw. with 10mm;
  - An external, diffusion-open plasterboard fibreboard, 60mm thick, Egger or glw;
  - A hydrophobing of the plaster support plate with a plaster base;
  - STO plaster base or glw.
- Roof - Certified timber frame ceiling elements factory prefabricated (including required quality control):
  - bottom counter battens from 4 / 6cm Fi / Ta solid construction in a pitch of about 62.5cm;
  - A climate membrane, per clima Intello plus or glw., glued airtight;

- Beam position acc. Statics (bars and edge beams) from 8/20 Fi / Ta Solid construction wood, untreated, planed and bevelled, techn. dried, in a pitch of 62.5cm;
- The insulation within the framework of mineral wool insulation, WLG 035, 200mm thick, ISOVER Ultimate or glw., With 10 mm;
- Upper planking with an untreated rough-skin formwork, 23.5 mm.

Category Intervention	New construction and refurbishment (Cologne demo case)
Critical EeB Component	Connection between new and existing building sections
INSITER Methodology	☒ **Step 1: Mapping** ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • The condition of the existing building before starting with the installation of the new elements (new building storey); • To compare the existing condition with the information defined during the project plan. ***Key activities:*** • Use the BIM model of the existing building before the addition of the new building level realized with prefab technologies for visual comparisons; • Check around if all conditions are confirmed; • Check the building geometry and the structural technologies; • Check with the site supervisor the possibility to perform laser scanning for data acquisition of the geometric building • Take pictures; • Note down remarks on the observation panel. ***Special attention:*** • Geometric and technical conditions of the existing building; • Identify the real environment condition of the roof "on-site" where the new building story will be realized. • Detailing of the structural frame and roof conditions.
Technical data and information	• Site Plan_Cologne • Roof plan_Cologne

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the actual condition.

Category Intervention	New construction and refurbishment (Cologne demo case)
Critical EeB Component	Connection between new and existing building sections
INSITER Methodology	☐ Step 1: Mapping
	☒ **Step 2: Checking of ordered components**
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • The correctness of components and building materials delivered on-site; • The presence of damage from transport; • The handling and storage of components and building materials on-site. ***Key activities:*** • Scan an attached QR or RFID code on the packaging; • Retrieve the site storage plan, the lift plan and the requirements for fragile materials; • Scan the attached QR or RFID code on each component; • Retrieve the specifications of each component linked to each component's ID; • Check the technical characteristics of the delivered elements on-site with the information of the specs (e.g. U value of the wood panels; geometric dimension and thickness of the façade and roof panels; consistency of materials and elements that make up prefabricated panels -wood, insulation, waterproofing membranes). • Confirm whether these are the correct ones as specified in the BIM model and the specifications; • Open in BIM the part of the building where each component has to be installed; • Note down remarks on the observation panel. ***Special attention:*** • Walls prefab timber frame (including complementary elements as insulation and surface finish); • Roof prefab timber frame (including complementary elements as insulation, waterproof membrane, surface finish); • Building façade cladding; • Loading and storage of double glazed windows with PVC or wood frames.
Technical data and information	• Logistics_Cologne

Category Intervention	New construction and refurbishment (Cologne demo case)	
Critical EeB Component	Connection between new and existing building sections	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☒	**Step 3: BIM for on-site construction**
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2.* • *The highlighted part corresponds to the exact location of each element to be installed;* • Use the BIM model on the BIM viewer to observe how the wood prefab panels and windows elements are modelled; • Use the component BIM model (if available) of the roof extension to check the technical details; • Observe how the roof extension is modelled and integrated within the existing building; • *Note down any remarks, questions or doubts on the observation panel.*	
Technical data and information	• BIM model_Cologne • BIM model_dragados panel	

Category Intervention	New construction and refurbishment (Cologne demo case)
Critical EeB Component	Connection between new and existing building sections
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☒ **Step 4: BIM-based Augmented Reality**
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER to visualize:* 1. *BIM and 3D objects on-site environment;* 2. *Self-instruction data with process sequences;* 3. *3D animations;* 4. *Technical details;* 5. *Workflows;* 6. *Thermal images, acoustic measurements.* • You can project on the roof of the existing building the extension elements to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down any remarks, questions or doubts on the observation panel.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*
Technical data and information	• AR info video

Category Intervention	New construction and refurbishment (Cologne demo case)	
Critical EeB Component	Connection between new and existing building sections	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☒	**Step 5: Visual clash detection during construction**
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • *Clashes correspond to potential inconsistencies between design and realization, such as:* 1. *Elements not given the required spatial or geometric tolerances;* 2. *Elements that its buffer zone is breached.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of roof extension installations based on visualisation of virtual clashes (super-imposed). • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.* ***Special attention:*** • *Misalignments in installation of prefab external walls;* • *Misalignments in wood prefab roof installation;* • *Inconsistencies in windows installations.*	
Technical data and information	• AR_Clash01_Cologne	

Category Intervention	New construction and refurbishment (Cologne demo case)	
Critical EeB Component	Connection between new and existing building sections	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☒	**Step 6: Self-instruction**
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Ensure that all wall and roof panels are mounted properly at the right place in the right direction; • Focus on joints and sealings between new wall elements and existing elements; • Focus on joints and sealings between new roof elements and existing elements. ***Key activities:*** • Check the BIM model to focus on critical details; • Follow the step-by step user manual from the manufacturer to correctly mount and seal the wall and roof elements; • Use markers to control the geometry of the construction. ***Special attention:*** • All connections between existing structure and new building elements have to be airtight and waterproof; • All joints between existing and new building elements have to be filled with PUR to avoid thermal bridges or air leakages; • Follow precisely the (video) manual of the manufacturer; • Check anchoring and fasteners to the bearing construction.	
Technical data and information	https://www.youtube.com/watch?v=MFEvE6OI5T4 • BIM-based Self-Instruction model for mobile devices_Green Village	

Category Intervention	New construction and refurbishment (Cologne demo case)
Critical EeB Component	Connection between new and existing building sections
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Having the technical specifications of the building that are available as part of the BIM model (see steps 2 and 3); • Ensure the quality of the so far assembled materials; • Ensure the correctness of the joints with regards to geometrical correctness; • Pre-check the joints concerning avoidance of thermal or acoustic bridges or air leakages. ***Key activities:*** • *Fill-in the **checklist**;* • *Take at least one picture for each question of the **checklist**;* • *Add notes when needed and report your findings.* ***Checklist:*** • *Are the right elements identified that should be tested (location of new roof elements)* • *Is there enough overlap (as per installation requirements) on the insulation layers between the new and existing exterior wall components?* • *Are the assembly tolerances between the new and existing exterior wall components verified?* • *Is there a scan of the identified elements available (as-is new roof elements)* • *Is there a BIM model (as –is BIM of new roof elements from scan) available?* • *Was an overlay performed of BIM as designed with as-is BIM?* • *Was a deviation analysis (see picture) performed?* • *Are the deviations within the acceptable geometric tolerances?* • *If yes, was a report of the work completion done with time stamp and signature?* • *If not, is the site manager informed?*
Technical data and information	• Deviation analysis_screenshot

The site-supervisor:

- Receives the filled-in checklist from the construction worker;
- Evaluates the answers of the construction worker from the checklist;
- Opens the available measurement procedures and selects what testing he needs to apply and where;
- Co-ordinates, if needed the quick laser-scanning;
- Co-ordinates, if needed a thermal scan on the finished installation on selected locations;
- Scans with the mobile app the QR code of the building component where the measurement has been performed and retrieves the components ID;
- Stores the results of the measurements on the SharePoint and uses them later for evaluation of the as-built situation.

Category Intervention	New construction and refurbishment (Cologne demo case)
Critical EeB Component	Connection between new and existing building sections
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☒ **Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* 1. *deviations from initial planning;* 2. *deviations from designs;* 3. *any problem you have faced.* • *In the observation panel please answer the following questions:* 1. *To what extent have the tools contributed to properly performing the dedicated activity?* 2. *To what extent have the tools contributed to avoiding mistakes?* 3. *How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*
Technical data and information	• The App will automatically retrieve the reports and comments from previous steps.

5. Implementation guidelines of INSITER 8-step methodology addressing critical MEP components in new construction projects

5.1 Heat pump

5.1.1 Explanation of EeB component

Heat pumps are one of the most efficient heating and cooling systems on the market today. A high efficiency is reached through the principle that in a heat pump most of the heat or cold is moved rather than generated. Moving heat requires a source to move this heat from. To give a complete description of key components and their functionality independent of the manufacturer the critical components inside the sub systems are described separately. The main components are:

- Heat pump (Compressor, evaporator, expansion valve and Condenser);
- ATES (Well, source pump, heat exchanger);
- Gas-fired boiler;
- Distribution circuit;
- Buffer tank;
- Control system.

5.1.2 Explanation of a typical case for new construction

Due to its high energy efficiency, heat pump is very sensitive for design, installing and setting errors. Especially the distribution circuit and control system are very sensitive to errors. These components are one-of-a-kind custom-made components for each specific building. To avoid errors it is highly recommended to carefully design the whole heat pump systems integrally considering HVAC and MEP systems as well as building elements. Low quality building elements, air leakage and heat losses, can negatively influence the performance of the heat pump. The most common errors regarding this system are (for the complete list please read D1.6):

- H03: The heat pump is installed incorrectly, supply and return flows are interchanged
- H03: Construction errors in the distribution circuit
- H04: Incorrect settings of the controller parameters
- H04: Settings are applied incorrectly, or sub-optimally
- H03: Connections of different sensors are mixed up
- H02: Default sensors.
- Such errors can affect the performance of the heat pump; especially the following KPI's:
- Efficiency of a heat pump / chiller;
- Vertical air temperature;
- Delivered temperature (warm and cool floors).

Self-instruction processes can therefore contribute to properly installing the heat pump system and avoiding low performance. Self-inspection processes, on the other hand, can strangely contribute to project management KPI's (time, cost and quality); the first-time-right principle. In this guidance, the self-inspection of the heat pump system will be presented. Due to the complexity of the system, the following considerations have been taken:

- The self-inspection process is based on recommended inspection guidance (provided by the manufacturer);

- Different manufacturers may demand/recommend own inspection instructions. In this guidance, inspection guidance of TRANE has been followed.
- Guidance has been complemented by inspection instructions of Carrier.

Category Intervention	New construction (Typical case)
Critical EeB Component	Heat pump
INSITER Methodology	☒ **Step 1: Mapping**
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Condition of the building interior and exterior parts where the heat pump units will be mounted; ***Key activities:*** • Check the building conditions around the mounting area; • Check if mounting points have been established; • Take pictures and note down your remarks on the observation panel. ***Special attention:*** • The building can sustain the weight of the heat pump unit; • The mounting area is undamaged; • The availability and suitability of the concrete footings and mounting points; • The mounting area cannot be flooded.
Technical data and information	• Example_Heat Pump layout

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)	
Critical EeB Component	Heat pump	
INSITER Methodology	☐	Step 1: Mapping
	☒	**Step 2: Checking of ordered components**
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • The correctness of heat pump units and components delivered on-site; • The presence and the level of damage from transport; • The handling and storage of components and building materials on-site. ***Key activities:*** • Scan an attached QR or RFID code with an iPad on the packaging; • Retrieve the specifications of each component linked to each component's ID; • Check for the right quality certificates if available; • Retrieve the site storage plan; • Check whether these are the correct ones as specified in the BIM model and the specifications; • Store the heat pump according to the manufacturer instructions; • Follow steps in Checklist Pre-start Checkout reference material attached. ***Special attention:*** • Check if any materials or components have been damaged from transport; • The heat pump is free of damages and corrosion; • All components and pipes are not-moved (check manufacturer instruction); • Presence of the interior and exterior nameplates; • If information on the nameplates corresponds to the order; • If information on the nameplates corresponds to the manufacturer information.	
Technical data and information	• Checklist Pre-start checkout • Checklist Storage instruction • Example_Pre-Installation • Example_RLC SLB018	

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)	
Critical EeB Component	Heat pump	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☒	**Step 3: BIM for on-site construction**
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2.* • *The highlighted part corresponds to the exact location of each element to be installed;* • Use the BIM model on the BIM viewer to observe how the heat pump is modelled; • Use the component BIM model (if available) of the heat pump and other related systems (piping, pumps…) to check the technical details; • *Note down any remarks, questions or doubts on the observation panel.*	
Technical data and information	• Example_BIM condenser_screenshot01 • Example_BIM piping_screenshot02	

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Heat pump
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☒ **Step 4: BIM-based Augmented Reality**
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** *You can use here one of the BIM-based AR solutions for INSITER to visualize:* *1. BIM and 3D objects on-site environment;* *2. Self-instruction data with process sequences;* *3. 3D animations;* *4. Technical details;* *5. Workflows;* *6. Thermal images, acoustic measurements.* • You can project on real environment the heat pump system to be installed, so that you can check visually the correct location and position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down any remarks on the observation panel, questions or doubts.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*
Technical data and information	• AR info movie

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Heat pump
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☒ **Step 5: Visual clash detection during construction**
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Clashes correspond to potential inconsistencies between design and realization, such as:* 1. *Elements not given the required spatial or geometric tolerances;* 2. *Elements that its buffer zone is breached.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of Heat pump components installations based on visualisation of virtual clashes (super-imposed). • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.* ***Special attention:*** • Mounting/levelling errors and inconsistencies; • The suitability of the building structure for the HP system (regarding weight); • The suitability of the mounting place for the HP system (regarding place); • Check the levelling of the mounting place.
Technical data and information	• Example_AR Clash01_Heat Pump

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Heat pump
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☒ **Step 6: Self-instruction** ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • Accurately follow the manufacturer's assembly/installation manual; • Collaboration between mounting team members (mechanical, technical….). ***Key activities:*** (**mechanical**): • Start the foundation steps following the manufacturer instruction; • Prepare the mounting area considering clearances issues according to manufacturer instructions; • Start unpacking procedures considering rigging and lifting issues; • Start mounting procedures considering levelling and isolation instructions provided by the manufacturer: 1. Mounting the evaporator water piping; 2. Condenser Water Piping 3. System Configuration (**electrical**): • Start reading general recommendations provided by the manufacturer • Start installing: 1. Installer-supplied component; 2. Interconnecting wiring 3. Communication interface
Technical data and information	• Manufacturers manuals *available* • Example_RLC SVX09K_Manual • Example_RLC SVX09H_Manual

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Heat pump
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Acoustic issues; • Hazardous voltage issues; • Pressure issues; • Configuration issues. ***Key activities:*** • *Fill-in the* **checklist***;* • *Take at least one picture for each question of the checklist;* • *Add notes when needed and report your findings.* ***Checklist:*** • Are all FAT issues already solved? • Is the place of the heat pump inspected by the supplier? • Is the heat pump mounted according to the design (drawing)? • Is the heat pump properly connected to the piping system and according to the design (drawing)? • Is the piping unit provided with compensators according to the design (drawing)? • Is the evaporator unit properly insulated? • Is the heat pump free of corrosions or mechanical damages? • Are the lamellae free of damage? • Are all manometers provided with the right pressure step? • Are all keys of the control interface available?
Technical data and information	• Example_Checklist 1 • Example_Checklist 2 • Example_Inspection list

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)	
Critical EeB Component	Heat pump	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☒	**Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* 1. *deviations from initial planning;* 2. *deviations from designs;* 3. *any problem you have faced.* • *In the observation panel please answer the following questions:* 1. *To what extent have the tools contributed to properly performing the dedicated activity?* 2. *To what extent have the tools contributed to avoiding mistakes?* 3. *How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*	
Technical data and information	• The App will automatically retrieve the reports and comments from previous steps.	

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

5.2 Mechanical ventilation

5.2.1 Explanation of EeB component

Proper ventilation keeps the air fresh and healthy indoors. Like the lungs, buildings need to be able to breathe to make sure that fresh air comes in and dirty air goes out. Air indoors can build up high levels of moisture, odours, gases, dust, and other air pollutants-even exhaled breaths. To keep the air safe indoors, the air needs to circulate with fresh outdoor air. The building's windows and structural elements circulate fresh air (infiltration). By improving the energy efficiency of buildings, the amount of infiltration is reduced. Therefore many buildings have additional mechanical systems to add to the flow. Because outdoor air is hardly ever perfectly conditioned for indoor use, it generally takes a lot of energy to adapt the outdoor air to the desired indoor air conditions. So it’s important that the ventilation system is effective and efficient at the same time. INSITER’s goal is to reduce the amount of energy losses due to inefficient operation and shortcomings of the ventilation system.

Main energy-efficient and quality construction errors to be checked

- Air leakage due to ventilation (tightness of the duct system);
- Heat recovery system efficiency;
- Energy use of fans and drives;
- Draught rate;
- Air velocity;
- Vertical air temperature;
- Relative Humidity;
- Sound intensity;
- Sound pressure level;
- Air supply rates.

5.2.2 Explanation of a typical case for new construction

No reference demonstrator is available within INSITER WP5 for mechanical ventilation. The following table has been developed considering new construction best practices cases.

Category Intervention	New construction (Typical case)	
Critical EeB Component	Mechanical ventilation	
INSITER Methodology	☒	**Step 1: Mapping**
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Condition of the mounted building elements; • Condition and cleanliness of the place where the ventilation units will be installed. ***Key activities:*** • Check the condition of the building interior and exterior on the locations where the ventilation units will be installed; • Check for any presence of local damages and debris; • Take pictures and note down your remarks on the observation panel. ***Special attention:*** • Ensure that the locations of outdoor air intakes are clear of obstructions, debris, clogs, or covers.	
Technical data and information	• Example_Ventilation layout	

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Mechanical ventilation
INSITER Methodology	☐ Step 1: Mapping
	☒ **Step 2: Checking of ordered components**
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Consistency of ventilation components and materials; • Quality of the ventilation components and materials; • The presence and the level of damage. ***Key activities:*** • Before storing the components, scan the QR code and get specific information on how to handle and store the components on site; • Scan the attached QR or RFID code with a smart device; • Retrieve the components' ID; • Check whether these are the correct components as specified in the BIM model and technical documents; • Verify if everything is correct and if all the materials, tools and accessories are on site. ***Special attention:*** • Check the correctness of the ventilation components delivered on site; • Check for the right quality certificates if available; • Check for damages and pollution of the component.
Technical data and information	• Example_Specs • Example_Storage requirements

<table>
<tr><td>Category Intervention</td><td colspan="2">New construction (Typical case) / Refurbishment (Enschede demo case)</td></tr>
<tr><td>Critical EeB Component</td><td colspan="2">Mechanical ventilation</td></tr>
<tr><td rowspan="8">INSITER Methodology</td><td>☐</td><td>Step 1: Mapping</td></tr>
<tr><td>☐</td><td>Step 2: Checking of ordered components</td></tr>
<tr><td>☒</td><td>Step 3: BIM for on-site construction</td></tr>
<tr><td>☐</td><td>Step 4: BIM-based Augmented Reality</td></tr>
<tr><td>☐</td><td>Step 5: Visual clash detection during construction</td></tr>
<tr><td>☐</td><td>Step 6: Self-instruction</td></tr>
<tr><td>☐</td><td>Step 7: Self-inspection</td></tr>
<tr><td>☐</td><td>Step 8: Final check</td></tr>
<tr><td>Intervention description</td><td colspan="2">Main critical points:
• Completely and accurately follow the building design;
• Having access through BIM to all parts and relevant technical details;
• Having available the latest versions of the design details to be executed;
• Avoid decreasing the overall building quality caused by ad-hoc solutions.

Key activities:
• Open BIM by using the scanned QR or RFID code from step 2.
• The highlighted part corresponds to the exact location of each element to be installed;
• Use the BIM model on the BIM viewer to observe how the ventilation system is modelled;
• Use the component BIM model (if available) of the ventilation system and other related systems (ventilation unit, ducts, terminal devices) to check the technical details;
• Note down any remarks, questions or doubts on the observation panel.</td></tr>
<tr><td>Technical data and information</td><td colspan="2">• Example_BIM screenshot01</td></tr>
</table>

In itailc are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Mechanical ventilation
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☒ **Step 4: BIM-based Augmented Reality**
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Completely and accurately follow the building design; • Detailing to be followed. ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER to visualize:* *1. BIM and 3D objects on-site environment;* *2. Self-instruction data with process sequences;* *3. 3D animations;* *4. Technical details;* *5. Workflows;* *6. Thermal images, acoustic measurements.* • You can project on real environment the ventilation system to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down on the observation panel any remarks, questions or doubts.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*
Technical data and information	• AR info movie

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Mechanical ventilation
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☒ **Step 5: Visual clash detection during construction**
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Clashes correspond to potential inconsistencies between design and realization, such as:* 1. *Elements not given the required spatial or geometric tolerances;* 2. *Elements that its buffer zone is breached.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of mechanical ventilation components based on visualization of virtual clashes (super-imposed). • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.*
Technical data and information	• Example_AR Clash01

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Mechanical ventilation
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☒ **Step 6: Self-instruction**
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • To ensure that the right component is installed. Disparities of model, type or versions can lead to critical deviations of performance; • To ensure the component is free of damages and pollution. This is a second check, after the component has been transported from the storage location on-site to the place of mounting; • To make sure the component will be installed as intended. ***Key activities:*** • Scan the attached QR-code with the mobile device. A link containing information (objects in the BIM model or pdf files, other information) will open with the technical data of the component, accessories and auxiliary materials; • Install the ventilation component, using the assembly/installation manual of the manufacturer and general rules of craftsmanship; • Where available, follow specific instruction protocols for ventilation components. ***Special attention*** • Use the manufacturer's installation instructions, general rules of craftsmanship and, if available, specific instruction protocols apply; • Check that the right component is delivered; • Check that the component is clear of pollution and undamaged.
Technical data and information	• Example_Instruction activities

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Mechanical ventilation
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☒ **Step 7: Self-inspection** ☐ Step 8: Final check
Intervention description	***Main critical points:*** • Air leakage due to ventilation (tightness of the duct system) ***Key activities:*** • *Fill-in the **checklist**;* • *Take at least one picture for each question of the **checklist**;* • *Add notes when needed and report your findings.* ***Checklist:*** • Are lockable work switches fitted? • Is the air handling unit earthed? • Is the power cable for the frequency-controlled motor in a symmetrical shielded cable? • Is the overpressure siphon correctly installed (including siphon height)? • Is the vacuum siphon correctly applied (including siphon height)? • Is the air handling unit protected against rain and dust penetration before being connected to the air ducts? • Is air handling unit protected against the effects of the weather and the entrance of vermin and the like? • Is there storage of materials and tools in the air handling unit during the construction process? • Are air ducts supported on the construction of the air handling unit? • Are there any specific measurements needed (Energy use of fans and drivers, draught rate, air velocity, vertical air temperature, relative humidity, sound intensity, sound pressure level, air supply rates)?
Technical data and information	• Example_Self-inspection activities • Example_Common errors

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

The site supervisor:

Upon notification of the worker, requests for specific measurements in case of doubt of performances of:

1. Energy use of fans and drives;
2. Draught rate;
3. Air velocity;
4. Vertical air temperature;
5. Relative Humidity;
6. Sound intensity;
7. Sound pressure level;
8. Air supply rates.

Category Intervention	New construction (Typical case) / Refurbishment (Enschede demo case)
Critical EeB Component	Mechanical ventilation
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☒ **Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* *1. deviations from initial planning;* *2. deviations from designs;* *3. any problem you have faced.* • *In the observation panel please answer the following questions:* *1. To what extent have the tools contributed to properly performing the dedicated activity?* *2. To what extent have the tools contributed to avoiding mistakes?* *3. How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*
Technical data and information	The App will automatically retrieve the reports and comments from previous steps.

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

5.3 Solar hot water systems

5.3.1 Explanation of EeB component

A solar hot water facility is composed by three main subsystems and the corresponding hydraulic connections between them, namely: (i) solar thermal collectors, (ii) storage system and (iii) pumping stations.

By nature, solar collectors are the most visible of all components within a solar thermal system – they are typically mounted on the roof of a building, but can also be placed on the façade, on balconies or mounted on ground structures. All collector types have in common that solar irradiation is absorbed by a dark – often black or dark-blue – surface, which heats up and from which the heat is transferred directly or indirectly to water. For lower temperatures (ca. up to 100°C) three different collector types are the most common ones:

- Evacuated tube collectors;
- Flat plate collectors;
- Unglazed absorbers.

Due to the temperature levels they can usually provide, the unglazed absorbers are used almost exclusively used for swimming pool heating, while the former are used for a wide variety of applications. Typical evacuated tube or flat plate collectors are rectangular, covering an area of 1.5 - 2.5 m^2 but much larger sizes are available (12-15 m^2), sometimes even custom built for individual projects. Their height is usually between 80-120mm for flat plate collectors and 120-200mm for vacuum tubes, depending on the manufacturer and model. Multiple collectors can be combined to form a collector array. (Trenkner & Dias, 2014)

The good practice lies in the effectiveness of the solar thermal system in terms of energy efficiency that depends upon the proper installation of the elements, as well as the operation and maintenance. This last term also applies in the case of durability. A non-proper installation may originate water losses and, therefore, energy losses in the distribution systems, which reduces the energy efficiency.

Main energy-efficiency defects and quality construction errors to be checked are:

- Geometrical correctness and fitting;
- Water leakages;
- Undesired operation parameters such as (see D1.6):
    1. Unmet flow rate setpoints;
    2. Low heat exchanger efficiency;
    3. Too high collector temperatures;
    4. Too high pumping electric consumption;
    5. Unmet supply temperature setpoint;
    6. Too low storage temperature.

Category Intervention	New construction (Typical case)	
Critical EeB Component	Solar hot water system	
INSITER Methodology	☒	**Step 1: Mapping**
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Condition of the building roof. ***Key activities:*** • Check the condition of the building roof to ensure that it is structurally sound; • Check for any presence of local damages and debris; • Check the compatibility of the electrical panel (Ampere capacity) – grey box – with the new solar hot water system to be installed; • Take pictures and note down your remarks on the observation panel.	
Technical data and information	• Example_Roof plan • SolarSystemLayout_01_CARTIF3	

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	Solar hot water system
INSITER Methodology	☐ Step 1: Mapping
	☒ **Step 2: Checking of ordered components**
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Consistency of solar hot water collectors and auxiliary components. • Presence of damage on system components prior to procurement • Handling and storage of components on-site ***Key activities:*** • Scan QR code attached on the packaging of each component • Retrieve components' ID and check consistency of each one according to invoiced order • Retrieve components' specifications and documentation (e.g. recommendations and instructions from manufacturer) • Unpack the verified components • Revise that correct QR codes (to track back components' ID and characteristics) and quality certificates for each component are available • Store the solar collectors and auxiliary components according to manufacturer instructions and storage plan. ***Special attention:*** • Correctness of components and quality certificates; • Possible damage on system components caused by manufacturing failures, handling and/or transport; • Reporting of any potential fault detected within this step.
Technical data and information	• Example_vitosol 300_specs • Handling the procured components • Checklist for damage verification

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	Solar hot water system
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☒ **Step 3: BIM for on-site construction** ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☐ Step 6: Self-instruction ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2.* • *The highlighted part corresponds to the exact location of each element to be installed;* • Use the BIM model on the BIM viewer to observe how the solar thermal facility is modelled and check available space, possible shadings, adequate access; • Use the component BIM model (if available) of the solar hot water system and other related to check the technical details; • Observe how main connection pipes for the solar thermal system are modelled; • Surf the model and observe connection details between panels, position of valves and other auxiliary components; • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• Cartif3_solar01 • Cartif3_solar 02 • Cartif3_solar 03

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	Solar hot water system
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☒ **Step 4: BIM-based Augmented Reality**
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER to visualize:* 1. *BIM and 3D objects on-site environment;* 2. *Self-instruction data with process sequences;* 3. *3D animations;* 4. *Technical details;* 5. *Workflows;* 6. *Thermal images, acoustic measurements.* • You can project on the roof the solar heat water system to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down on the observation panel any remarks, questions or doubts.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*
Technical data and information	• AR info movie

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	Solar hot water system
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☒ **Step 5: Visual clash detection during construction**
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Clashes correspond to potential inconsistencies between design and realization, such as:* *1. Elements not given the required spatial or geometric tolerances;* *2. Elements that its buffer zone is breached.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of solar heat water components based on visualisation of virtual clashes (super-imposed). • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.* ***Special attention:*** • Levelling of the mounting place; • Slope of the installed solar thermal collectors.
Technical data and information	• Example_AR Clash01

In italic are the common descriptions as per previous components (the reference component is “2.1. Foundation and ground floor”).

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	Solar hot water system
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☒ **Step 6: Self-instruction**
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Accurately follow the manufacturer's installation manual and tutorials; • Focus on pipe connections and sealing. ***Key activities:*** (**mechanical**): • Retrieve the installation manual from the manufacturer; • Identify key reference positions on the roof; • Anchor the mounting system to the structural elements of the building; • Fit the mounting system (mounting rails, brackets) and collector frames; • Route the pipe lines; • Make the hydraulic connections; • Install auxiliary components: heat dissipater, valves, thermal storage and pump station, and expansion tanks according to manufacturer's recommendations. (**electrical**): • Retrieve the installation manual from the manufacturer (electrical); • Assemble and interconnect wiring; • Mount sensors and controllers; • Start installing communication interface.
Technical data and information	• SolarSystemLayout_02_CARTIF3 • Example_Installation instructions • Tutorial video

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	Solar hot water system
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Proper supporting systems, insulation and location/orientation of different components; • Fill sequence for the water loops and storage tanks; • Water leaks; • Control and monitoring equipment being operative. ***Key activities:*** • *Fill-in the **checklist**;* • *Take at least one picture for each question of the **checklist**;* • *Add notes when needed and report your findings.* ***Checklist:*** • Are all pipes properly supported? • Is any component (pipes, pumps, tanks) not correctly insulated? • Are air vents, valves and gauges properly located, aligned and/or oriented? • Is there any missing pressure and temperature relief valve? • Are all collectors properly tightened? • Are all collectors oriented and with the correct slope angle (as designed)? • Are collector glass covers clean and without any crack? • Is there any sign of corrosion in the absorber? • Is electrical wiring properly installed (including support, protections)? • Are collectors cool or properly covered before the initial flush? • Does the water come out clean from the drain port after the initial flush? • Is the pressure test satisfactory for each component? • During fill sequences, are all pumps properly primed? • Are all sensors correctly calibrated? • Are all control equipment including relays correctly operating? • Are mass flow rates in agreement with design?
Technical data and information	• Example_Recommended measurement devices • Commissioning checklist

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)	
Critical EeB Component	Solar hot water system	
INSITER Methodology	☐	Step 1: Mapping
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☒	**Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* 1. *deviations from initial planning;* 2. *deviations from designs;* 3. *any problem you have faced.* • *In the observation panel please answer the following questions:* 1. *To what extent have the tools contributed to properly performing the dedicated activity?* 2. *To what extent have the tools contributed to avoiding mistakes?* 3. *How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*	
Technical data and information	• The App will automatically retrieve the reports and comments from previous steps.	

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

5.4 LED lighting

5.4.1 Explanation of EeB component

Lighting is important for the visual comfort of building occupants. Visual comfort is usually defined through a set of criteria based on the level of light in a room, the balance of contrasts, the colour 'temperature' and the absence or presence of glare. Everybody's perception of light is different, but for frequent circumstances or activities there are some recommended light levels, defined as illumination values (in lux).

Because light is an important element of expenditure in a building, late technology with the Light Emitting Diode (LED) has brought many perspectives in this field due to its high energy efficiency. The choice of LED systems is guided by the required performance in terms of light quality and energy consumption of the lighting system. Quality of the lighting systems depends, for a greater part, on the design. But also during installation, many mistakes are being made, resulting in inefficient light systems or poor quality. INSITER's goal is to reduce the amount of energy losses and poor visual comfort due to inefficient operation and shortcomings of the lighting system.

Main energy-efficient and quality construction errors to be prevented:

- Energy use of lighting;
- Illuminance;
- Colour temperature;
- UGR value;
- Daylight factor.

During the assembly, the MEP worker performs inspections, related to correct assembly in order to close the possible gap between design and realisation. The KPIs can only be determined by experts, using suitable measuring instruments.

5.4.2 Explanation of a typical case

In order to determine that the LED lighting components have been installed and function as intended, in different phases after installation specific inspection protocols need to be enrolled. The phases are:

- After installation (first check);
- After pre-commissioning (adjusting);
- After commissioning (start-up);
- Before delivery (final check).

The checks in different phases are needed to ensure the quality of the assembled components at the right moment, in order to avoid critical errors to be obscured by other executions or being discovered too late.

Category Intervention	New construction (Typical case)	
Critical EeB Component	LED lighting	
INSITER Methodology	☒	**Step 1: Mapping**
	☐	Step 2: Checking of ordered components
	☐	Step 3: BIM for on-site construction
	☐	Step 4: BIM-based Augmented Reality
	☐	Step 5: Visual clash detection during construction
	☐	Step 6: Self-instruction
	☐	Step 7: Self-inspection
	☐	Step 8: Final check
Intervention description	***Main critical points:*** • Condition of the mounted building element; • Condition and cleanliness of the location where the LED lighting units will be installed. ***Key activities:*** • Check the condition of the building interior on the place where lighting units will be installed; • Check if marks for the whole placement for the LED lighting have been established, so that you know exactly where the wiring will have to be; • Use the lighting layout as a reference; • Take pictures and note down your remarks on the observation panel.	
Technical data and information	• Example_lighting layout	

The site-supervisor:

- Receives the findings from the construction worker;
- Evaluates the answers;
- Checks the available measurement procedures and selects what testing he needs to apply and where;
- Checks the requirements for laser scanning to capture the exact positioning of the mounted fundament elements, before the start of the ground floor installations.

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping
	☒ **Step 2: Checking of ordered components**
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Consistency of lighting components and materials; • Quality of the lighting components and materials; • The presence and the level of damage. ***Key activities:*** • Scan the attached QR or RFID code with a smart device; • Retrieve the components' ID; • Check whether these are the correct components as specified in the BIM model and technical documents; • Check if everything is correct and if all the materials, tools and accessories are on site; • Note down remarks on the observation panel. ***Special attention:*** • Check for damages and pollution of the component; • Check for the right quality certificates if available.
Technical data and information	• Example_Storage requirements

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☒ **Step 3: BIM for on-site construction**
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Having access through BIM to all parts and relevant technical details;* • *Having available the latest versions of the design details to be executed;* • *Avoid decreasing the overall building quality caused by ad-hoc solutions.* ***Key activities:*** • *Open BIM by using the scanned QR or RFID code from step 2.* • *The highlighted part corresponds to the exact location of each element to be installed;* • *Use the BIM model on the BIM viewer to observe how the LED lighting system is modelled;* • Use the component BIM model (if available) of the LED lighting system to check the technical details; • Observe the technical details of the light fixture, cables and cable trays and the lighting control system • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• Example_BIM LED_screenshot1

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☒ **Step 4: BIM-based Augmented Reality**
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Completely and accurately follow the building design;* • *Detailing to be followed.* ***Key activities:*** *You can use here one of the BIM-based AR solutions for INSITER to visualize:* *1. BIM and 3D objects on-site environment;* *2. Self-instruction data with process sequences;* *3. 3D animations;* *4. Technical details;* *5. Workflows;* *6. Thermal images, acoustic measurements.* • You can project on real environment the LED lighting components to be installed, so that you can check visually the correct location and construction position; • *You can retrieve and project through BIM the above information (2-6);* • *Please use this material as a reference and try to understand your tasks and the expected result;* • *Note down on the observation panel any remarks, questions or doubts.* ***Special attention:*** • *Be sure that all hardware and cameras are calibrated;* • *Be sure that AR markers are placed and will remain in the same position as long as you are using the AR apps;* • *AR markers should be visible around your working area;* • *Use the markers for the initialization of the applications and your navigation;* • *If AR markers are combined with marker-less tracking make sure that supplementary markers are introduced to the screen.*
Technical data and information	• AR info video

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☒ **Step 5: Visual clash detection during construction**
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • *Clashes correspond to potential inconsistencies between design and realization, such as:* 1. *Elements not given the required spatial or geometric tolerances;* 2. *Elements that its buffer zone is breached.* ***Key activities:*** • *You can use here one of the BIM-based AR solutions for INSITER;* • Test AR on-site for visual comparisons between BIM model and realization of LED lighting components installations based on visualization of virtual clashes (super-imposed). • *Refer to Step 4 whenever you have doubts about how to use the AR apps;* • *Note down remarks on the observation panel.*
Technical data and information	• Example_AR clash01

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping ☐ Step 2: Checking of ordered components ☐ Step 3: BIM for on-site construction ☐ Step 4: BIM-based Augmented Reality ☐ Step 5: Visual clash detection during construction ☒ **Step 6: Self-instruction** ☐ Step 7: Self-inspection ☐ Step 8: Final check
Intervention description	***Main critical points:*** • To ensure that the right component is installed. Disparities of model, type or versions can lead to critical deviations of performance; • To ensure the component is free of damages and pollution. This is a second check, after the component has been transported from the storage location on-site to the place of mounting; • To make sure the component will be installed as intended. ***Key activities:*** • The MEP worker scans the attached QR-code with the mobile device. A link containing information (objects in the BIM model or pdf files, other information) opens with the technical data of the component with accessories and auxiliary materials; • The MEP worker then installs the lighting component, using the assembly/installation manual of the manufacturer and general rules of craftsmanship. Where available, also specific instruction protocols for lighting components will be used. ***Special attention:*** • Use the manufacturer's installation instructions, general rules of craftsmanship and, if available, specific instruction protocols apply; • Check that the right component is delivered; • Check that the components are clear of pollution and undamaged.
Technical data and information	• Example_Proposed activities • Example_Installation guide

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☒ **Step 7: Self-inspection**
	☐ Step 8: Final check
Intervention description	***Main critical points:*** • Energy use of lighting; • Illuminance; • Color temperature; • UGR value; • Daylight factor. ***Key activities:*** • *Fill-in the* ***checklist****;* • *Take at least one picture for each question of the* ***checklist****;* • *Add notes when needed and report your findings.* ***Checklist:*** • If applies, is an earthen system connected? • Are the right cables used? • Are the cables connected with the correct polarity? • Is the correct closure applied at the end of the cable? • If applies, are all luminaires addressed individually? • If infrared transmitters and receivers are applied, is there no barrier in between with normal use of the room? • Is the suspension structure suitable for the mass hanging from it? • Is the LED luminaire free of damage?
Technical data and information	• Example_Self-inspection procedures

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

Category Intervention	New construction / Existing building (Typical case)
Critical EeB Component	LED lighting
INSITER Methodology	☐ Step 1: Mapping
	☐ Step 2: Checking of ordered components
	☐ Step 3: BIM for on-site construction
	☐ Step 4: BIM-based Augmented Reality
	☐ Step 5: Visual clash detection during construction
	☐ Step 6: Self-instruction
	☐ Step 7: Self-inspection
	☒ **Step 8: Final check**
Intervention description	***Main critical points:*** • *Having access to all data and information from the previous steps.* ***Key activities:*** • *Make sure you have all your findings for steps 1-7 (images, notes, remarks);* • *Open the observation panel and note down your final remarks.* *In these please include:* 1. *deviations from initial planning;* 2. *deviations from designs;* 3. *any problem you have faced.* • *In the observation panel please answer the following questions:* 1. *To what extent have the tools contributed to properly performing the dedicated activity?* 2. *To what extent have the tools contributed to avoiding mistakes?* 3. *How many mistakes have been avoided by using the tools?* • *Sign and finalize your report.*
Technical data and information	• The App will automatically retrieve the reports and comments from previous steps.

In italic are the common descriptions as per previous components (the reference component is "2.1. Foundation and ground floor").

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- http://www.carrier.com/
- http://www.trane.com/Index.aspx
- http://www.rdosmaps.bc.ca/min_bylaws/building_inspect/forms/Mechanical_Ventilation_Checklist.pdf
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- http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad%2C27963%2Cen.pdf
- https://consumer-nz-assets.s3.amazonaws.com/assets/2065/Good_practice_heat_pump_installation.pdf
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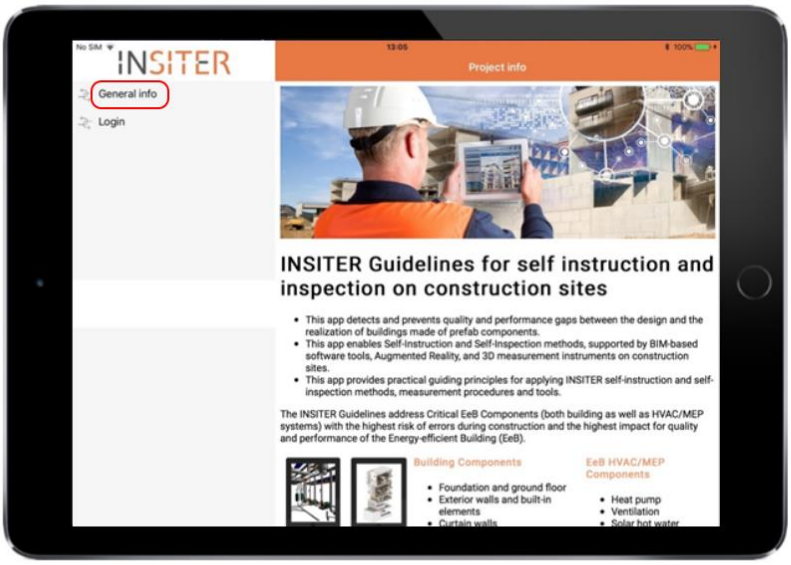
Appendixes

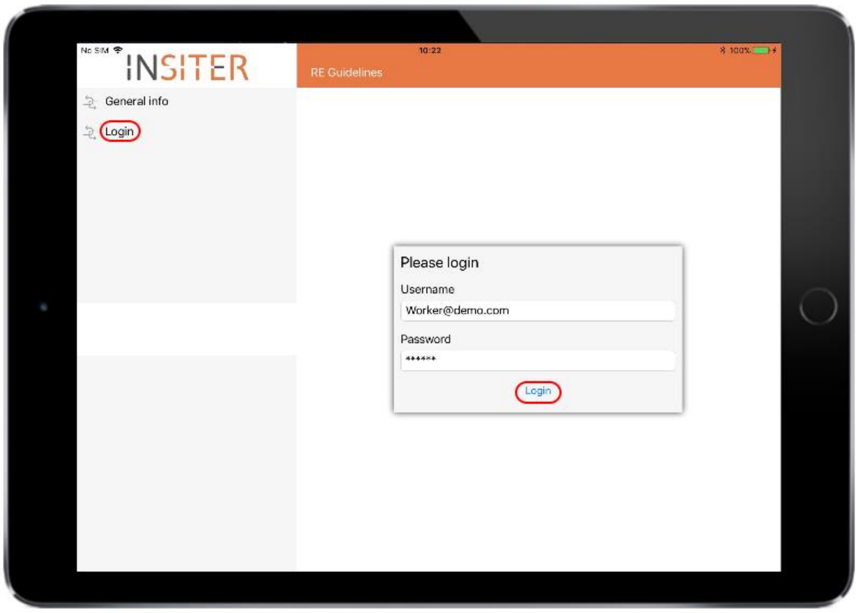
Appendix 1 - USER DEMO OF THE MOBILE INSITER APP

1. Start the app by clicking on its icon as it appears on the spring board (home).

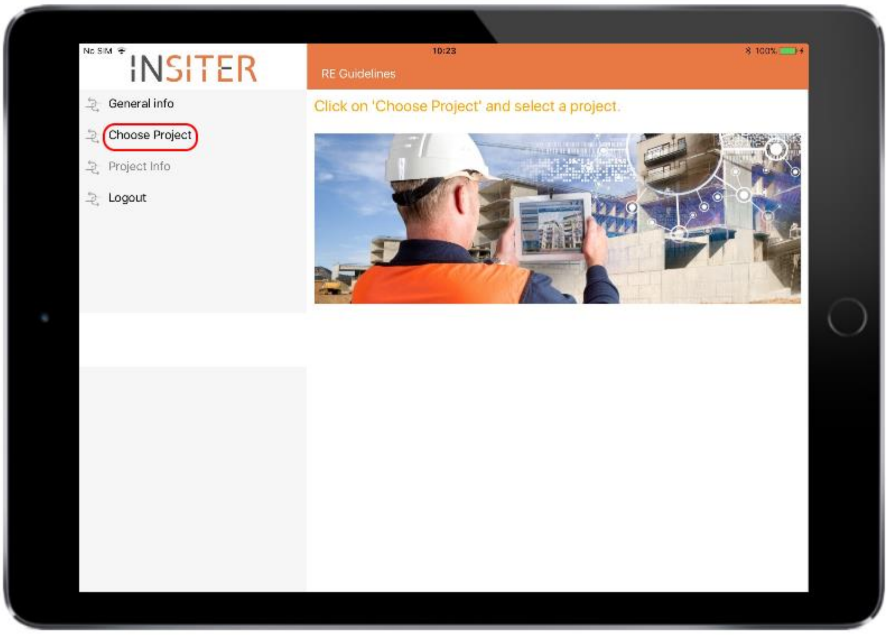
2. View General information, which does appear instantly at the start of the app or when you click on the General Info item in the menu on the left.



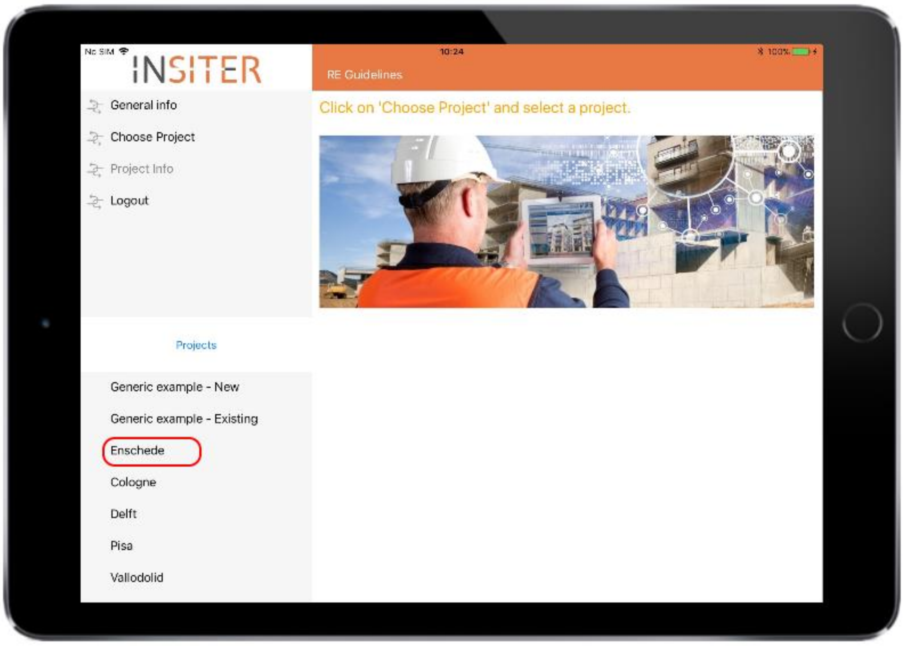
3. Choose **Login**, use the provided credentials (user name and password)



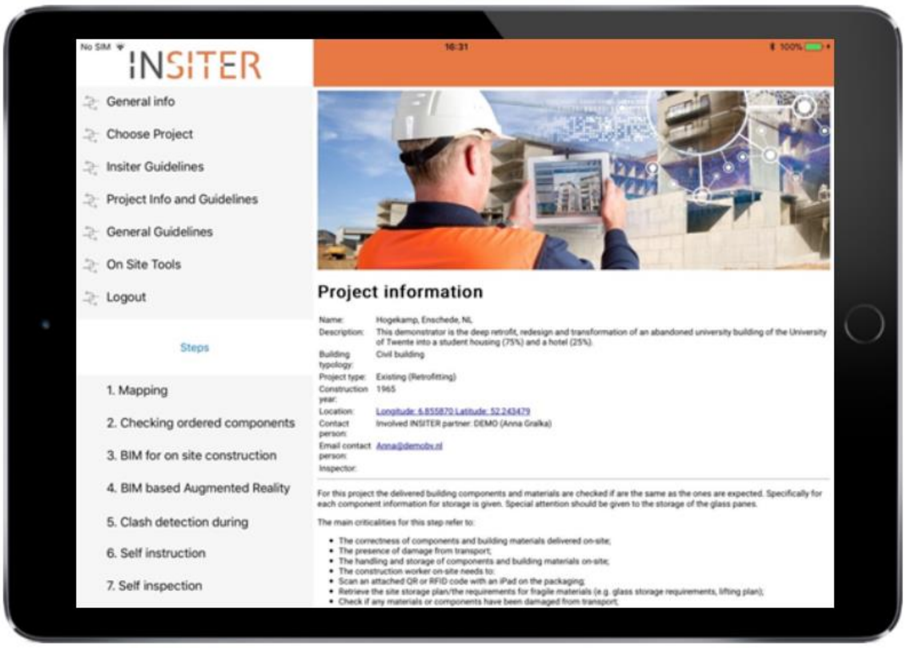
4. Select the menu option ‘Choose project’



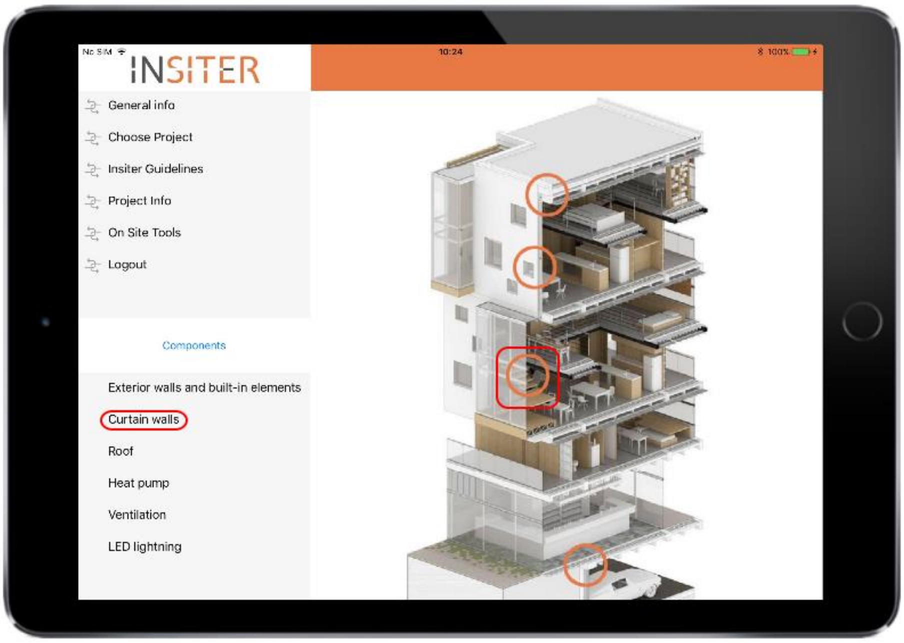
5. Select a project from the projects list, for example 'Enschede'



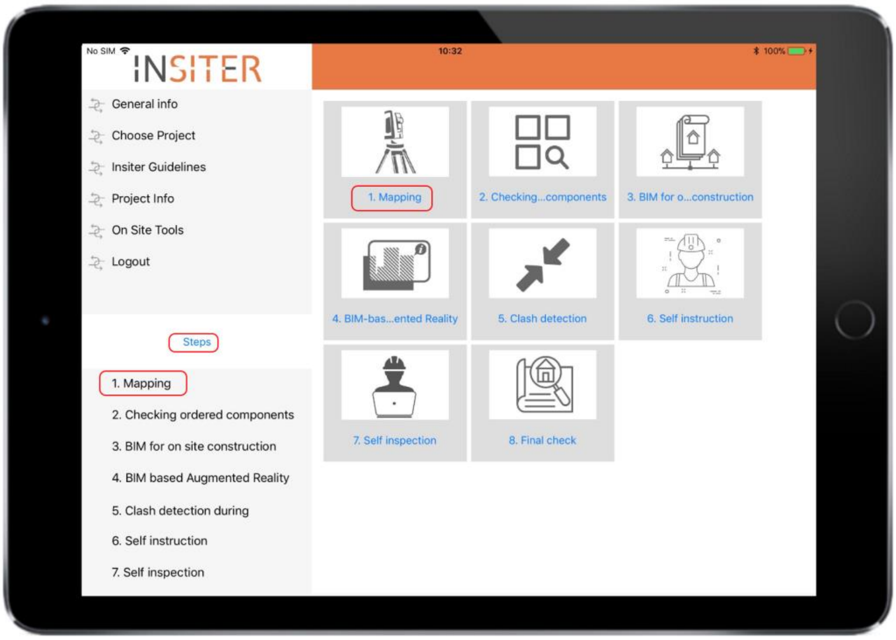
6. After selecting a project on the left the project information will be shown on the right.



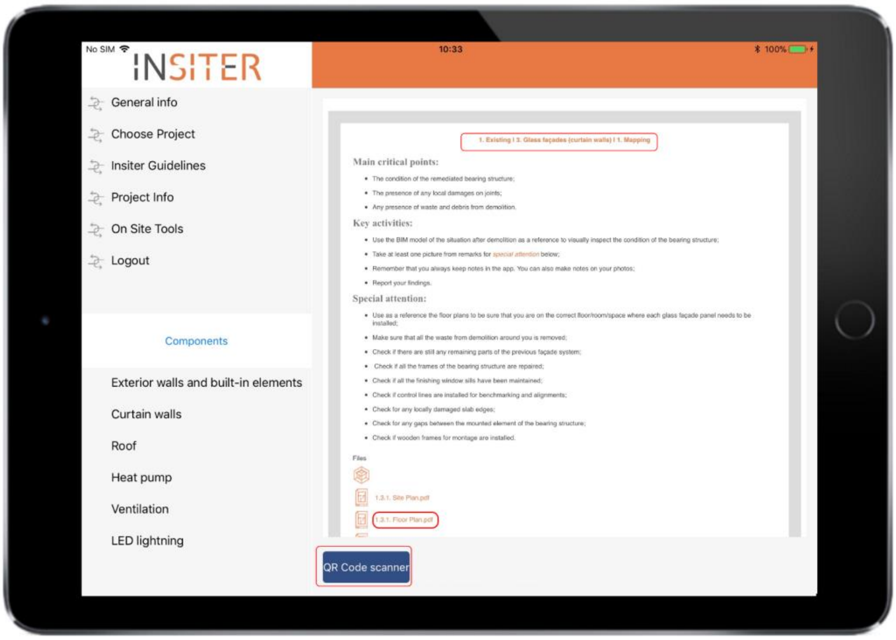
7. Select a component, for example 'Curtain walls'. You can also choose to click on one of the hotspots as seen on the picture on the right. Only the project relevant components will be visible.



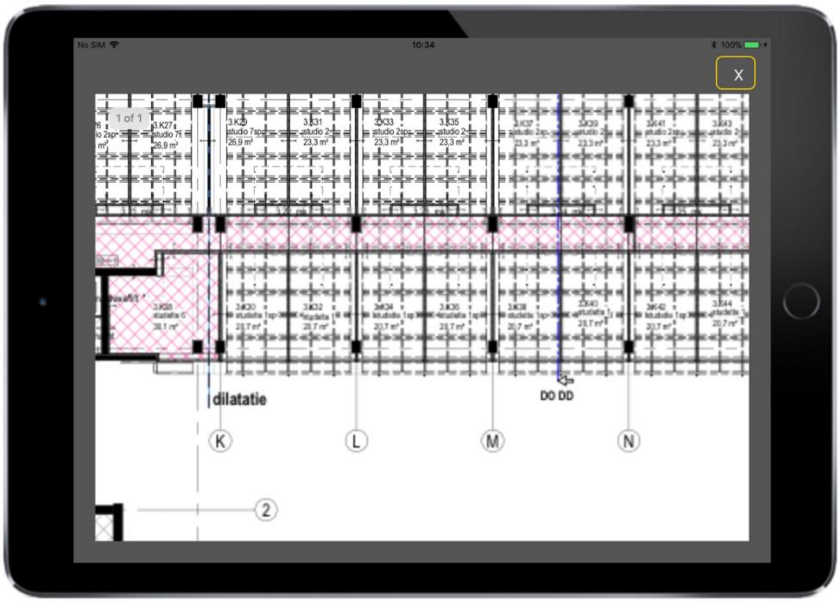
8. Next, select a step. You can select a step from the list on the left or choose one from the grid shown on the right. For example, choose **Mapping**. Later you can click on the blue '**Steps'** or '**Component'** button to toggle between the two of them so you can select another guideline, related to a specific step and a specific component.



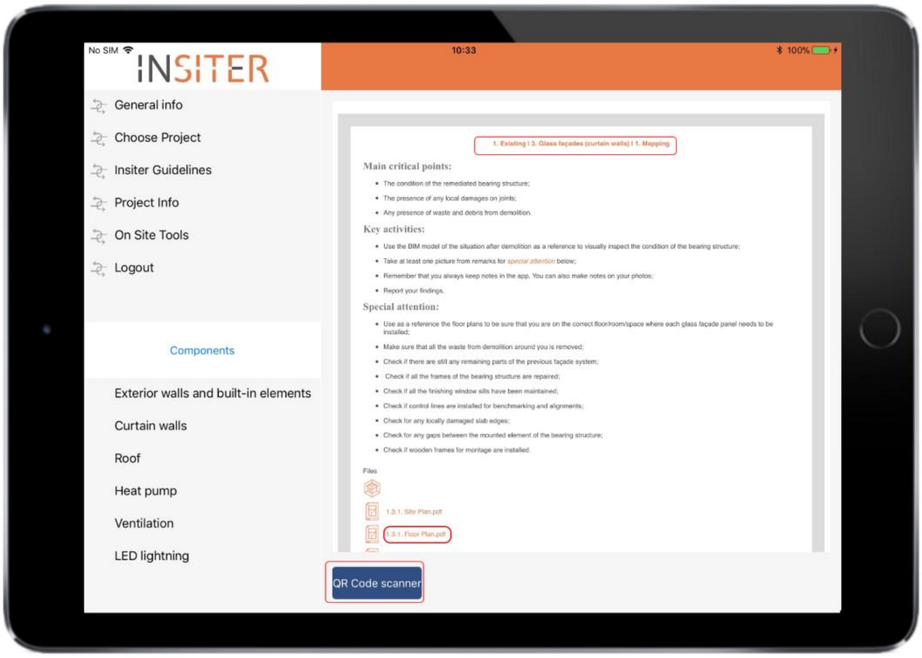
9. After you have selected a step and component the guidelines related to that step and component that you have just selected are shown. Notice the 'crumble path' displaying the project type, component and step. Click on a link to view any of the attached documents shown below the guidelines.



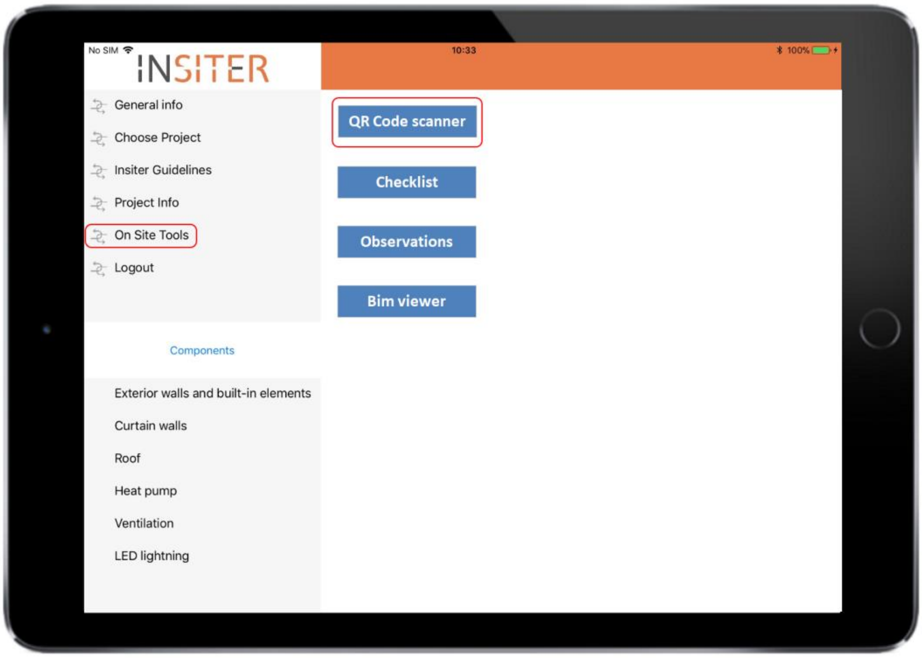
10. After clicking on any of the links you can view the content of it in a modal popup window. This allows you to view the document full screen and to easily navigate away from it by clicking on the X button as shown on the top right. Using pinch gestures one can zoom in or out on the currently visible document. In this example a PDF document, representing a floor plan, is shown.



11. The associated tool or tools, related to the selected step, are shown as buttons at the bottom of the screen, displaying the guidelines. In this example and for this step the ‘QR Code scanner’ button is available. By clicking on this button, the QR Code scanner will be shown.



You can also choose the menu option On Site tools. By clicking on this menu option, you will see the collection of all available tools, not just those related to a selected step.
Select a tool and, if required, choose a component. Here you can also click on the QR code scanner button.

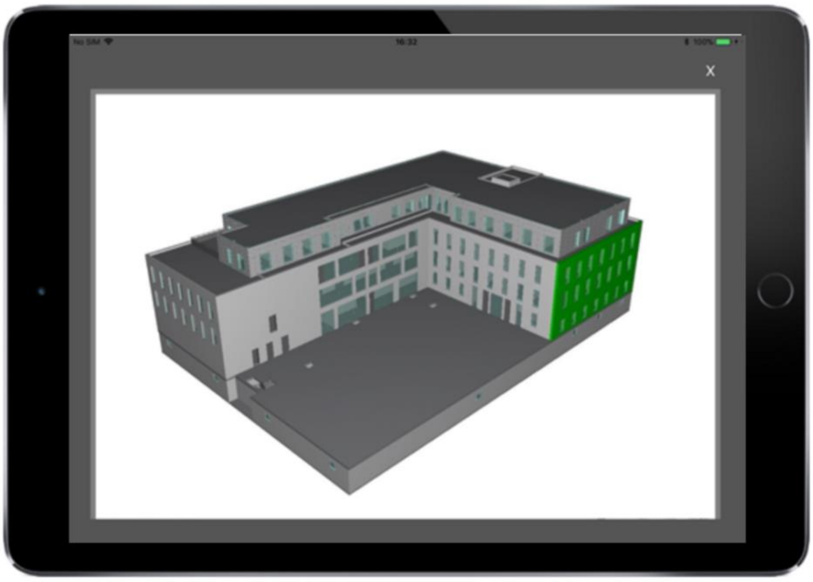


12. At the construction site, when the Construction Worker uses the mobile app, by clicking on the menu option **On Site tools** and choosing the **QR Code scanner** button (available at the On Site tools view or at *step 2)*, the QR code scanner functionality can be utilized.

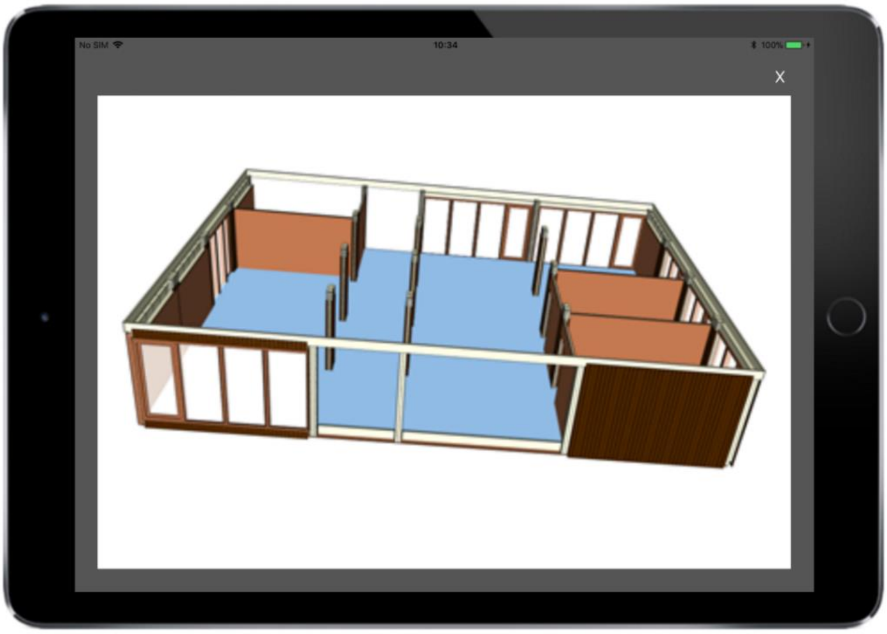
Note: In the Desktop / Client application, a **QR Code generator tool** is available to create a QR code for the selected component in the BIM model. The QR code can be printed and attached to the real (physical) building / MEP component that will be delivered to the construction site.

After scanning the QR code at step 2, the app will open the mobile BIM viewer showing the location / position of the component in the BIM model at step 3.

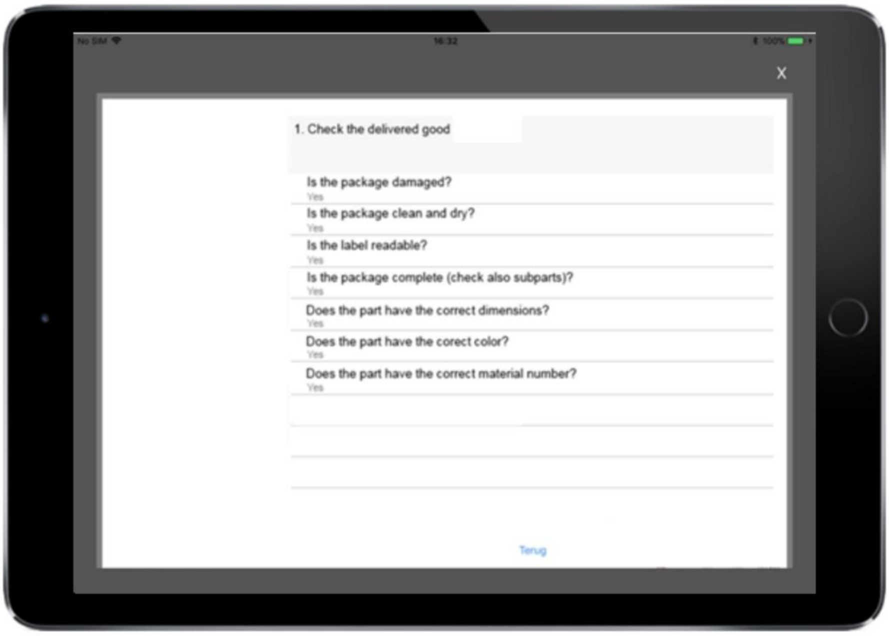
13. By clicking on the button BIM Viewer, the BIM Model functionality can be utilized. The 3D model will be shown and one can select an element - or more relevant for the app - a critical component.



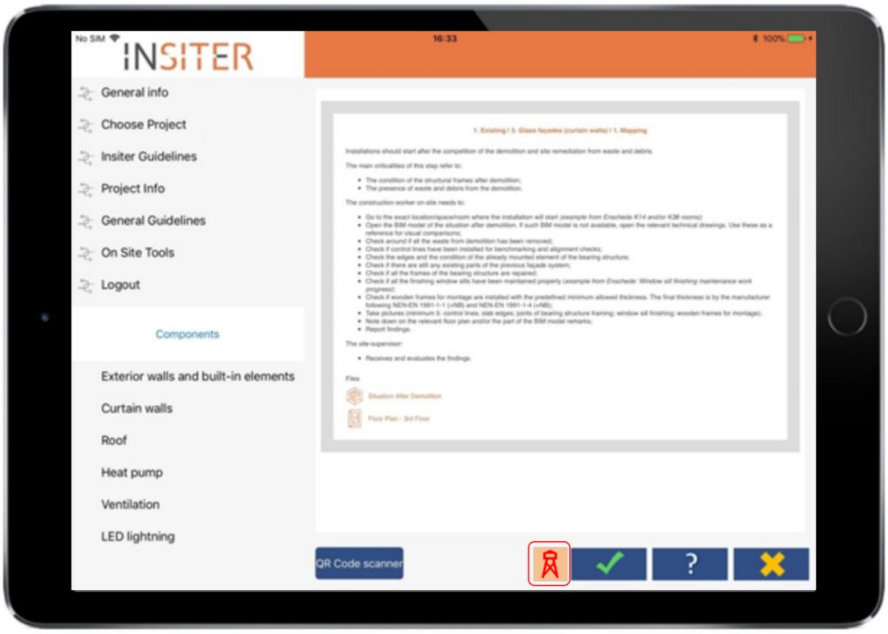
14. Click on the menu option Insiter Guidelines again. This time select Step 6 (‘self-instruction’), click on the Link under “Files” to open a popup window, displaying the 3D self-instruction model (resulting from the RDF BIM self-instruction configurator web tool as described in deliverable D4.4).



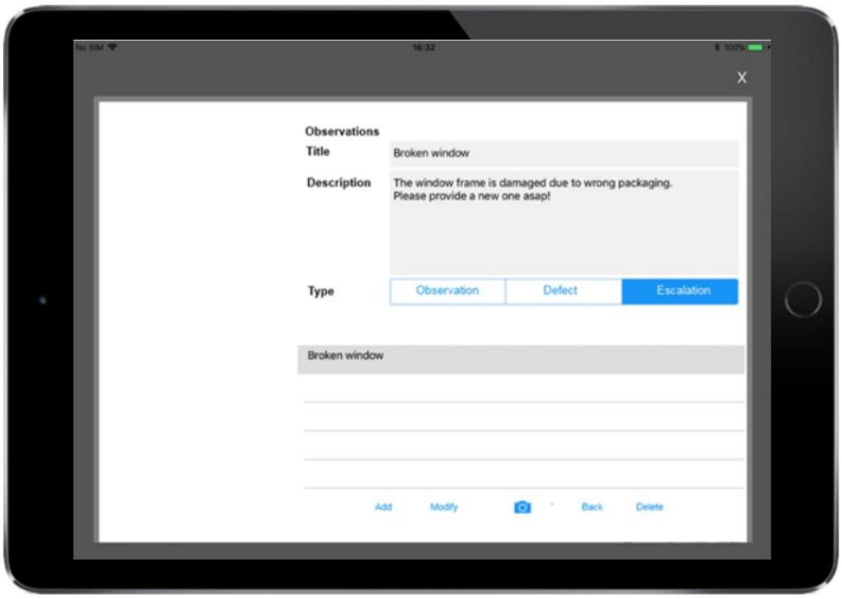
15. Now choose step 7 and click on the button that reads Checklist. A Checklist containing relevant questions for each component will appear. The Checklist creator is included in the Desktop / Client application, the resulting checklist is deployed on the mobile app that you see right now.



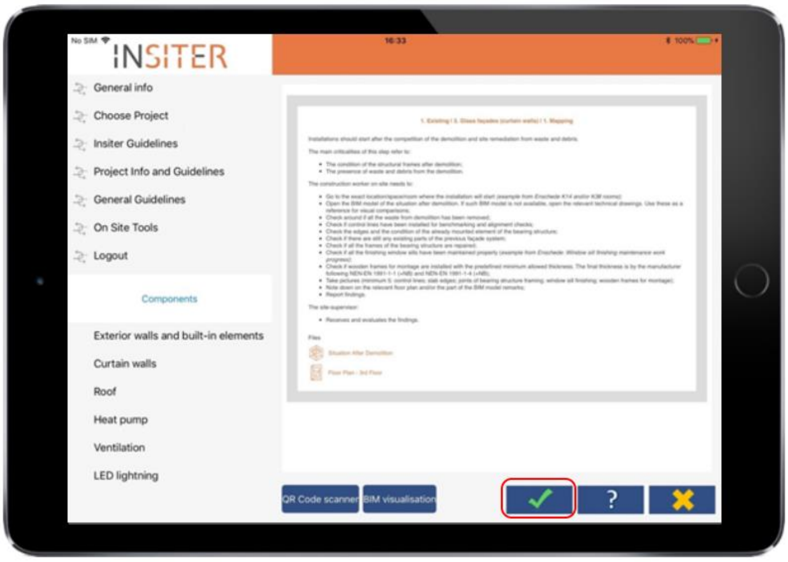
16. In the end of every step (at step 1 through to 8) by clicking on the button Observations, the Observation functionality can be utilized. Observations can be a part of providing progress information.



17. The available observation functionalities are:
    - Create a new observation or modify an existing one
    - Enter a title and description
    - Take a picture and attach it to an observation
    - Create a mark on the picture to highlight a particular area or issue
    - Delete an observation



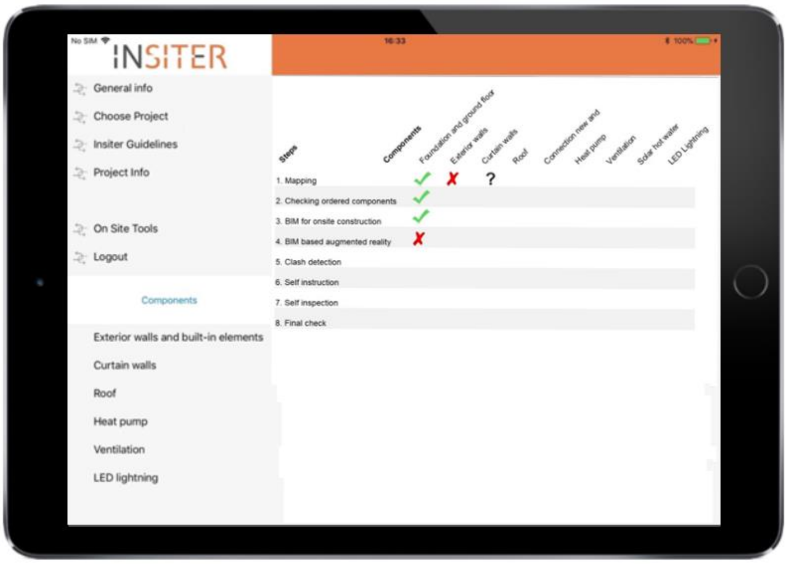
18. To indicate the progress for the selected combination of step and critical component the worker can click on the ‘**OK’** button



A worker can also mark the selected combination of step and critical component as not OK. This will mark the step and component as not OK and it will result in sending a mail to the supervisor, who can act upon it.
The **question mark** button will mark the progress status for the selected combination as something that needs the supervisor’s judgement.

19. The worker can see his own progress for the project by choosing the **Progress Report** option from the menu.

20. In a matrix the progress per step and component for the project is shown, visualized by a checkmark, question mark and a red cross, representing a state of OK, questionable and not OK, respectively.



As a site supervisor, you can see the statuses for a particular project, as provided by one or multiple workers.

After logging in and selecting a project the supervisor can obtain this information by clicking on the **Report** button from the menu, resulting in the same view as shown here but from a different perspective.

Unlike the worker, who just will see the reported progress by himself, the supervisor will see the input from all workers, related to a particular project.

The progress report has different angles. The supervisor can see the overall progress for the project, the progress for each step, the progress for a particular worker and even for a particular combination of a specific critical component and step.

Observations can also be made with regards to the selected project only by clicking on the **Observation** item in the menu. A dialog will be shown, where one can enter one (or multiple) observations.

21. Finally, by clicking on the **Logout** button the user will log out.

Appendix 2 - INSITER MEASUREMENT PROCEDURES

Actual conditions to be measured

2.1. Thermal bridge identification - Thermal bridge check;

2.2. Air-leakage assessment - Air-leakage assessment;

2.3. Acoustic transmission loss measurements.

Procedure for the measurement of thermal bridges

(according to the guidelines described in D5.1, Section 3.2):

- Install thermal camera in front of the glass facade outside the building at a sufficient distance to frame the whole glass panel plus 50 cm of another panel around it.
- Create a thermal gradient (of about 10 °C) between the interior and the exterior surface of the building element where the curtain wall is installed.
- Store the thermal map in a repository folder (e.g. the BIM model of the building project).
- Assess the acceptability of the thermal bridge.

Procedure for the measurement of air leakage of seal of glass panel

(according to the guidelines described in D5.2, Section 2.3):

- Install the ultrasonic source inside one room where the glass panel is installed. Ascertain that all the openings are closed.
- Scan the junctions between the glass and the frame and the frame and the structure by means of the ultrasonic detector.
- Store the air leakage map in a repository folder (e.g. the BIM model of the building project).
- Assess the acceptability of the air leakage.

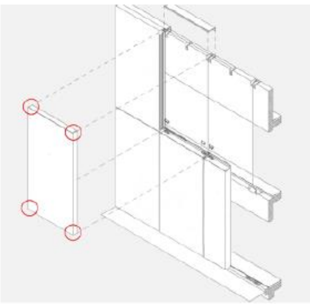
Procedure for the measurement of acoustic transmission loss

(according to the guidelines described in D5.1, Section 4.3):

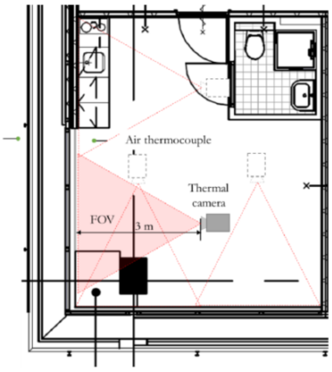
- Install a sound source outside the building in front of the building element where the glass panel is installed. Preferably, an omnidirectional broadband source is to be used. Ascertain that all the openings are closed.
- Scan both the whole interior and exterior surface of the glass panel plus 50 cm of other panel around it with the Sound Brush. The scanned areas at both sides of the glass panel must be identical and facing each other.
- Store the acoustic transmission loss value in a repository folder (e.g. the BIM model of the building project).
- Assess the acceptability of the air leakage.

Appendix 3 - Thermal Bridge Identification and Quantification Procedure

After the installation of prefab solution façade panels, it is very important to verify the connection between these elements to avoid energy loss. Each connection, joint or support could generate thermal bridges and these could have effect on the envelope's thermal performance.



The INSITER procedure for the quantification of the effect of thermal bridges in terms of building envelope thermal transmittance is based on infrared camera measurements. In this set-up only the external walls are monitored using sequential measurements at different positions of the infrared camera as sketched in the following figure, where a provisional experimental set-up is drafted.



Procedure for the identification of thermal bridges

(according to the guidelines described in D5.1, Section 3.2; D5.2, Section 2.1.2; and D2.3, Section 3.2):

- Inspect the condition of the room and environment. There must be no rain during the measurement neither in the 12 hours before the survey.

Identify the wall under test by QR-coding.

- Install thermal camera inside the room in front of the wall. The distance of the camera from the wall is a compromise between the Field of view (FOV) of the thermal camera and the surface of the room. The farther from the wall is positioned the camera the larger area can be framed, but that distance is limited by the size of the room. Four measurement positions are needed to cover the whole surface of the two external walls. In Table 1 the main characteristics of the adopted infrared camera are reported.

Type of detector	microbolometer
Spectral range	7 -14 μm
Temperature resolution	0.03 °K
Spatial resolution	1024x768 pixels
Optics	Wide angle lens 15 mm
Field of View (FOV)	≥ 3.4x2.6 m at 3 m distance

- Verify that a thermal gradient of about 10°C between inside and outside exists. Usually a good insulated facade guarantees this thermal gradient, otherwise the room must be conditioned to detect thermal bridges. Infrared camera or additional thermal sensors can be used to estimate internal and external temperature.
- Estimate the emissivity of each surface framed by the infrared camera.
- Quantify the environmental reflected temperature.
- Acquire and store the thermal maps in a repository folder (e.g. the BIM model of the building).

Procedure for the quantification of the thermal bridges

(according to the guidelines described in D2.3, Section 3.2 and BRE Information Paper IP 1/06, 'Assessing the effects of thermal bridging at junctions and around openings'):

Thermal bridge represents the transmittance of an area where the thermal properties are significantly different from the rest of the element. Consequently, the temperature in this area, when a thermal gradient exists between the two surfaces of the element, differs with respect to the sound area (where no thermal bridges are existent). Quantify the effect of thermal bridges in the whole element transmittance is an important issue.

A parameter for the assessment if a thermal bridge affects the thermal transmittance of a building element is defined in the BRE Information Paper IP 1/06, 'Assessing the effects of thermal bridging at junctions and around openings' which makes also recommendations for the limits of that parameter.

Such parameter is defined as Thermal Index, TI, (also known as Surface Temperature Factor) which is the following ratio:

$$TI = \frac{(Tsi - To)}{(T_{AI} - T_O)} \quad (1)$$

where:

T_{si} = temperature of the anomaly (measured by the infrared camera on the area interested by the thermal bridge)

T_O = external air temperature.

T_{AI} = internal air temperature, i.e. the "ambient temperature".

The limits fixed by the BRE Information Paper IP 1/06 are: 0.75 in dwellings, 0.5 in offices and shops.

If TI is lower than those limits it is likely that condensation will form on the surface at some time in a typical year.

If only a small portion of the structure has a TI below the threshold that thermal bridge cannot compromise the global thermal transmission of the building element. It is important, then, to estimate the influence level of the thermal bridge on the element, by calculating the percentage surface affected by the thermal bridge with respect to the total area of the element. A procedure has been described in D2.3, Section 3.2, where it has been defined the incidence factor of the thermal bridge I_{tb} as the ratio between the heat flowing in real conditions, when a thermal bridge exists in the wall, and the heat flowing in absence of the thermal bridge:

$$I_{tb} \frac{= \sum_{p=1}^{N}(T_{AI} - T_{p\_is})}{N * (T_{AI} - T_{1D\_is})} \quad (2)$$

where:

T_{p_is}= temperature at each pixel of the camera, where p is the current pixel which goes from 1 to N (N number of pixels)

T_{1D_is}= temperature in the sound area (not affected by the thermal bridge)

T_{AI} = internal air temperature

The thermal transmittance of the element in the presence of the thermal bridge is given by the thermal ideal transmittance in the absence of the thermal bridge (U1d or thermal transmittance of the sound area) weighted with the incidence factor I_{tb}.

$$\boldsymbol{U = U_{1d} * I_{tb}} \quad (3)$$