INSITER INTUITIVE SELF-INSPECTION TECHNIQUES

INSITER Guidelines for refurbishment

Deliverable report D1.3

Deliverable Report: Final version, issue date on 15 May 2018

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

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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

Numerous studies have revealed that problems related to performance gap between the calculated annual energy consumption and the actual measured annual energy consumption is due to the fact that, quality is not assured in construction. While quality control has to do with the product, quality assurance is all about processes to be followed correctly. Quality assurance practices in construction should help to ensure that the end result of the projects is consistent with the design and implementation planning. This includes also ensuring that the methods followed to complete projects are safe and that workers on-site are protected from any failures or accidents, while poor workmanship is prevented. The scope of Task 1.1 of INSITER - *with D1.2 and D1.3 reports as results* - is to treat comprehensively the lessons learned from past performance studies and put together practical guidelines under a common methodological framework (the INSITER 8-step Methodology) that seeks to the maintenance of construction quality process-wise.

The main purpose of the research study within this deliverable is to develop a quality assurance tool applicable to the construction phase that guides the construction worker through his daily on-site activities, while giving him indications and hints of mistakes to be avoided that could potentially lead to energy efficiency related shortcomings. This aim is to be achieved by 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 developed knowledge within INSITER.

In this Deliverable, the INSITER Guidelines for refurbishment projects are described. The context differentiates to Guidelines for self-inspection in new buildings (D1.2.), while the retrofitting approach is described in Guidelines for self-inspection in refurbishment (D1.3), anticipating the different needs of new and existing buildings respectively.

The adaptation in the construction reality of such quality assurance framework and tool, envisions construction workers that receive regular training and education on best practices and the introduced new technologies within INSITER. Therefore, it is critical to create a professional culture that encourages such framework.

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:
  1. Lab testing case: performed at the laboratory or artificially created test sites at the factory
  2. Factory testing case: performed at the factory related to real projects and its components
  3. 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:** 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) in D1.3

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 link.

Fulfilment of WP, Task and Deliverable scope and objectives

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 D1.3, as an integration of D1.2, the focus is on refurbishment. – 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 D1.2 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. D1.3 collects and describes only the specificities of existing buildings and is considered an integration of D1.2. – 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.

Deliverable D1.3 scope and objectives:	**Achievement:**	**%**
– 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.	– 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: 1) 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. 2) 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).	100%
	– 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 re	100%

Project's progress relevant to the deliverable within the corresponding timeframe:	
– 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 present 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 analyzed; the intervention description; the technical data and information upload on the SharePoint.
– Stakeholders, process and actors 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 Pisa (Italy) and Cologne (Germany).

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NOTE:

Some parts of the INSITER Guidelines for refurbishment projects are similar to those for new construction projects. In order to avoid repetition / duplication, this deliverable (D1.3) should be read in conjunction with the sister deliverable (D1.2). Parts which are overlapping between these deliverables are only presented once in Deliverable D1.2. A cross-referencing is indicated for these parts.

1. Introduction

1.1 Understanding the "INSITER Guidelines"

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 developed within INSITER self-instruction and self-inspection methods, measurement procedures and tools in order to meet INSITER's goal. 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;

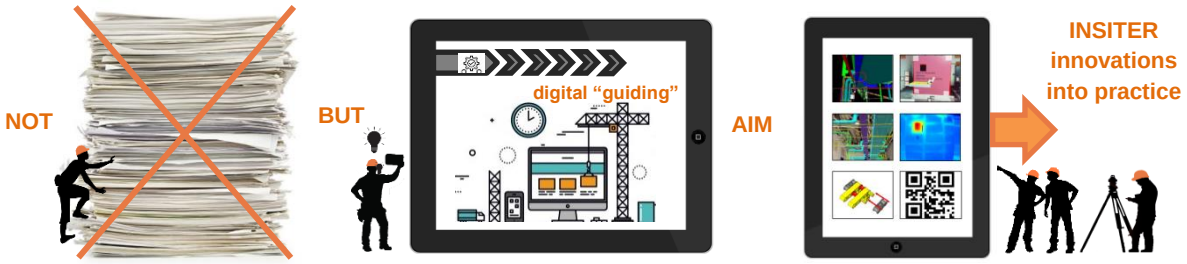


Figure 1: The storyline of the aim of the "INSITER Guidelines"

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 gabs. In this context, Critical EeB Components have been selected and explained in the preceding deliverables 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 deliverable 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 2: The scope of the "INSITER Guidelines"

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 2 main IT solutions of WP3:

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

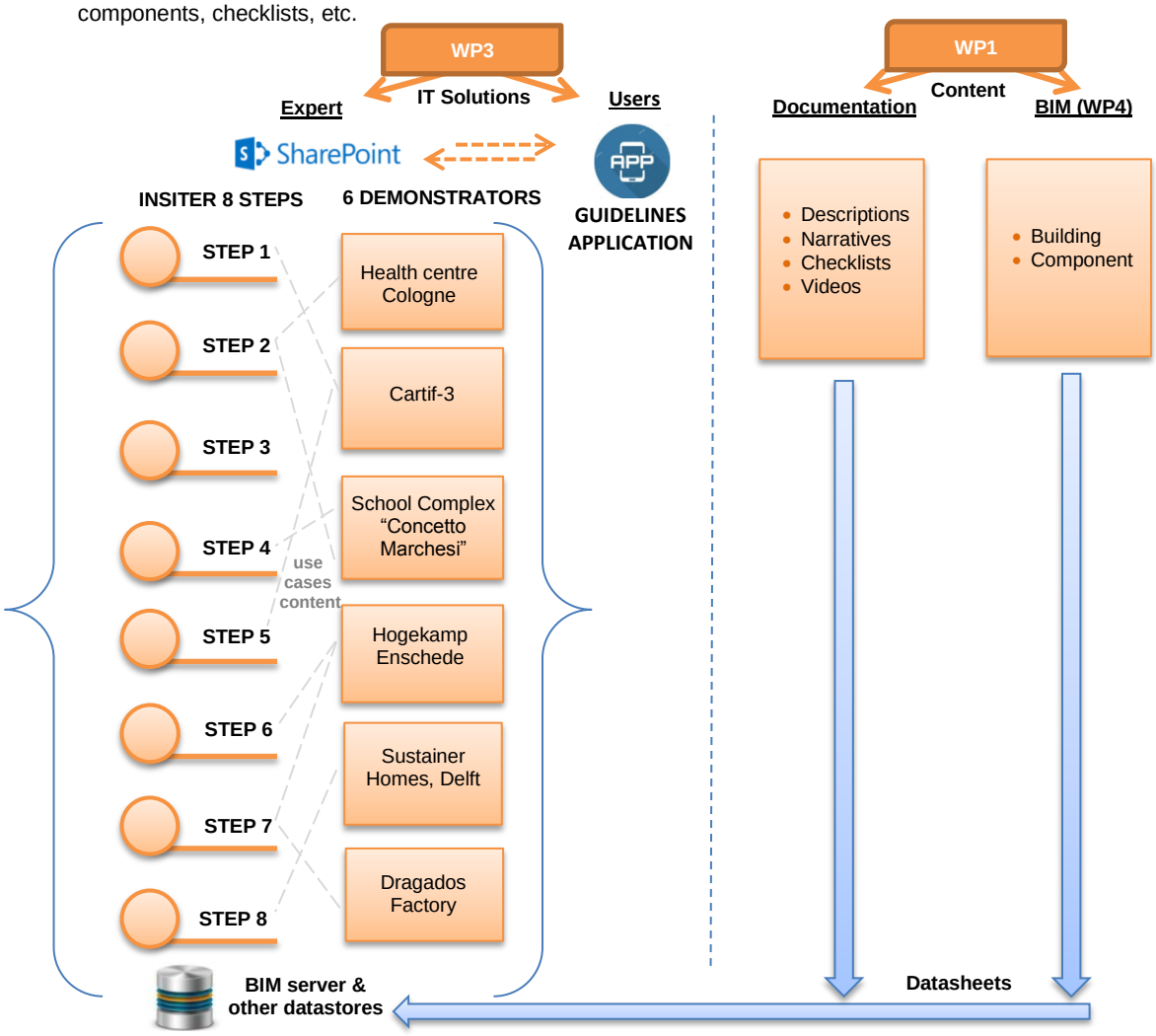


Figure 3: The "INSITER guidelines" relationship framework between content (WP1) and IT (WP3)

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. Each datasheet describes a specific step of the "INSITER 8-step methodology" for a specific critical component at a specific demo case. These data sheets will be made available online and will also be used for training purposes involving real practitioners, which will be organised in Work Package 6 in synergy with the Horizon 2020 project BuildUpSkills and CSA project PROF_TRAC.

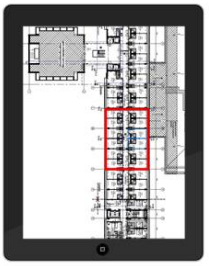
1.2 Example of practical use of INSITER Guidelines according to the 8-Step methodology

The "INSITER Guidelines" timeline for the construction worker:

STEP 0 - Log-in & work schedule

The construction worker log-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

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.

STEP 5 - Clash detection during construction

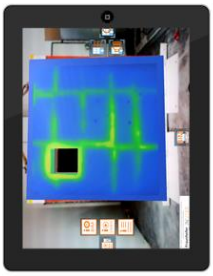
During this step, the worker on site can project the designed situation (correct situation) of the critical EeB components on real situation within the building, while focusing on the criticalities (clashes). He facilitates AR to check if the critical EeB component to be assembled really fit within the 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 etc.) 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.

1.3 Preliminary user manual of the mobile app (same as D1.2)

The description of the preliminary user manual for the INSITER Mobile App is already addressed in D1.2.

1.4 Demonstration of the mobile app in operation

The demonstration for the INSITER Mobile App is already addressed in D1.2.

1.5 What comes next in this report

1.5.1 Positioning *with*in *WP1 deliverables*

D1.3 is a follow-up of already produced deliverables in WP1 that analyse the construction errors 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 ongoing 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 and diagnosis solutions for inspecting building components and *MEP/HVAC* respectively.

1.5.2 Structure and scope of D1.3

D1.3 Guidelines for self-inspection in refurbishment explains 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 existing 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.

Within the scope of D1.3, the retrofitting of buildings shows different characteristics of processes and assigned

performing activities as the new building sector and represents other needs, often related more to the treatment of existing structure and the joints between the existing building and the new prefab components. Therefore the retrofitting approach is separately treated in *D1.3 Guidelines for self-inspection in refurbishment.* Following the same approach as the one of D1.2, in D1.3 the relevant critical components in INSITER demonstrators for existing buildings are presented.

1.5.3 How to read the following chapters

As D1.2, D1.3 is composed by 4 main chapters. As for the deliverable regarding new construction (D1.2), Chapter 1 defines and describes the INSITER Guidelines and the 8 steps methodology used on site by the worker. 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. The steps that are the same for new buildings and for refurbishment are not repeated in this deliverable, in order to avoid repetitions and overlapping.

Outside the table, additional useful information for the same step is presented.

The table is organized in two main parts: the “intervention description” and the “technical data and information”.

The “Intervention description” presents

- which are, in overall, the “***Main critical points***” of the step itself;
- which are the “***Key activities***” that the worker has to do within the step, and
- which are the situations or points on which the worker has to put “***Special attention***”.

“Technical data and information” contains all the useful documentation available for the worker.

Chapter 4, that describes the main features of the INSITER App and the main IT architecture developed to accommodate the functional and technical requirements of the App.

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.

2. Implementation guidelines of INSITER 8-step methodology addressing critical architectural/ structural components in existing buildings

2.1 Connection foundation - ground floor (not applicable for existing buildings; See for further details D1.2)

Not applicable for existing buildings. The INSITER guideline addressing this component in new buildings is presented in D1.2.

2.2 Exterior wall and opening

2.2.1 Explanation of EeB component (for the general part refer to D1.2)

In addition, specifically for refurbishment, it should be underlined that the proper installation of facade elements made of multifunctional panels and prefabricated window modules are primarily suited for retrofitting existing and old buildings to improve the energy efficiency. The applied materials and integrated technology can be combined based on the customer's needs. Supply lines for electricity, data, heat and sanitation can be integrated as technical components into the facade. One big advantage of the multifunctional facade elements is that they can be applied from the outside onto the original facade; the inhabitants are less disturbed by the renovation work as a result. The craftsmen also need less time to complete their work. The window modules are first mounted onto the facade, and then a first layer of insulation containing integrated ducts is mounted. The pipes for the building technology and sanitation systems are installed using a simple click system. A second insulation layer is mounted afterwards and then plaster is applied. Finally, the old windows are removed from the inside. The process enables fast, cost-effective and high-quality renovation. Another possible scenario is the replacement of some limited modules of the exterior facade: normally this situation occurs for the replacement of windows or openings, which usually represents weaknesses in the building envelope during its service life.

2.2.2 Explanation of Pisa case as example of window replacement

The reference demonstration case is the school complex Concetto Marchesi in Pisa. The facility, built in the 1970s, is made of prefab concrete elements. The building has a load-bearing structure of precast concrete elements, and the exterior walls consist of prefab module (opaque/transparent envelope). The most significant problems and refurbishment scenarios are related to durability of such building components such as the replacement of doors, windows and openings in general. In addition, other critical points are related to the passageways of systems, due to modifications occurring during the service life of the building.

As further described in WP5, field demonstration activities will focus on three use cases:

- Checking of geometric consistency
- Checking of thermal performance on 2D components
- Checking of the connection between existing building and additions using Augmented Reality

In accordance with these inputs, the analysis of 8-step methodology for the "refurbishment" is similar to the "new construction": the indications are compliant with D1.2 and the focus in the present deliverable will be limited only to

significant differences. It should also be stressed that renovation projects often cannot provide standard solutions and therefore the installer / worker must follow the technical specifications, construction details and work procedures established for the specific project.

Category Intervention	Existing building
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 presence of any local damages on the horizontal/vertical structure on which the modules will be mounted* • Air leakages (gaskets, sealings); • Presence of mold/moisture on the perimeter; • Water penetration; • Condensation; • Non-functioning opening / closing mechanisms (hinges); • Breakage of some components (glass pane, leaf); • Noise penetration. ***Key activities:*** • Take measure of the geometric accuracy to replace the module; • Check the condition of the opening; • *Check for any local damages on the horizontal / vertical structure on which the modules will be mounted;* • *Check the proper set-up of the benchmarking (GPS) for the mounting of the façade elements;* • *Take pictures (minimum 3);* • *Note down your remarks on the observation panel.* ***Special attention:*** • *Check with the site supervisor to perform a quick laser-scanning of the existing conditions.*
Technical data and information	• Example_site visit report • Example_IR_0609 • Example_IR_0610 • Example_IR_0611 • Example_IR_0612 • Example_IR_0613 • Example_IR_0614 • Example_IR_0615 • Example_IR_0616 • Example_IR_0617 • Example_IR_0618

In italic are the common descriptions as in D1.2 for the same component.

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 measurement procedures required for laser scanning.*
- Checks the presence of thermal bridges at the joints;
- Checks the presence of water infiltration and condensation;
- Checks the presence of acoustic transmission losses;
- Checks the geometrical accuracy;
- Checks for air leakages (moisture penetration);
- Decides to replace the entire windows OR the replacement of the glass pane.

Category Intervention	Existing building
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.*
Technical data and information	• Pisa_site plan logistics

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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 exterior wall elements are modelled;* • *Use the component BIM model (if available) of the exterior wall and opening component to check the technical details;* • Observe the window component in-situ. • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• Pisa_BIM model • Example_BIM window model • Pisa_Schreenshot1 • Pisa_Schreenshot1 • Pisa_Schreenshot1 • Example_Windows-Replacement_R2-BIM

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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 of the exterior walls elements to be installed, so that you can check visually the correct location and construction position;* • You can project on the exterior walls components to be installed the window elements, 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 movie • Pisa_BIM Model for AR01 • Pisa_BIM Model for AR02 • Example_Critical details

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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	• Pisa_Deviation Analysis01 • Pisa_Deviation Analysis02 • Pisa_Deviation Analysis03 • Pisa_Deviation Analysis04 • Pisa_Deviation Analysis Report

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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.*
Technical data and information	• Example_Window replacement instructions • Example_Window replacement manual • Example_Detailing sill • Example_Detailing frame01 • Example_Detailing frame02 • Example_Detailing frame03 • BIM-based Self-Instruction model for mobile devices_Green Village • https://www.youtube.com/watch?v=KtQHd1DPNtM • https://www.youtube.com/watch?v=z1zR_k4GGBs • https://www.youtube.com/watch?v=6ayu5Pa3GEs • https://www.youtube.com/watch?v=Flink2HrhVY

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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;* • Acoustic transmission losses; • Geometric accuracy; • Inspection of the façade to verify the congruence of the construction details with the approved shop drawings and the tested samples; • Verification of the finishes and quality of the installation, based on assembly requirements; • Verification of the flatness of the façade elements and the assembly tolerances; • verify that the test results correspond to the performances required by the specific facade construction system; • Inspection of the façade to verify the execution of the repairs required during the intermediate delivery; • The different acceptance tests are usually established during the drafting of the technical specifications and in the supply and installation contract. ***Key activities:*** • *Fill-in the* **checklist***;* • *Take at least one picture for each question of the* ***checklist****;* • *Check with your site supervisor the possibility to perform a quick laser-scanning of the existing condition;* • *Add notes when needed and report your findings.* ***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_Thermal bridges01 • Example_Thermal bridges02 • Example_Thermal bridges03

In italic are the common descriptions as in D1.2 for the same component.

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 an acoustic test;
- 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	Existing building
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:* 7. *To what extent have the tools contributed to properly performing the dedicated activity?* 8. *To what extent have the tools contributed to avoiding mistakes?* 9. *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 in D1.2 for the same component.

2.3 Curtain wall / glazed façade

2.3.1 Explanation of EeB component

These kinds of components present similar issues to solid facades in terms of air tightness and general performance (from acoustic, thermal points of view). In addition, they present specific problems related to the presence of glass panes and sealing. In the case of curtain walls, large transparent surfaces constitute a potential weak point of the envelope and have an impact on energy performance, acoustics, functionality, indoor air quality.

Main energy-efficient and quality construction errors to be checked (typical performance failure):

- 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.)

2.3.2 Explanation of Enschede case

Within the Enschede demonstrator, a deep renovation solution for the façade takes place, utilizing prefab panels. The panels construction typology is based on a glazed symmetric “3-chamber system”, having aluminium extrusion profiles that enclose glazing, with different symmetries. Such systems constitute a common prefabricated façade solution within the construction industry and can fall within the category of glass façades in terms of function, due to the enclosed glazed surfaces that ensure maximum daylight.

Figure 4: Outside and inside view of the façade system and its construction process

At the same time, such systems are relatively light, minimizing the required installation time. In addition, are not that expensive compared to more advanced glass façade systems such as the stick-built curtain walls that are described in D1.2. As a result, this typology was selected to be described here within the guidelines for glass facades for refurbishment, in order to provide for D1.2 and D1.3 a different spectrum of glass façades typologies, while facilitating real demonstration material from WP5 as a proof of concept.

The technical properties of the panels and its performance descriptions in terms of specifications of components are described in D5.4 (refer to Chapter 5, page 48 & 49). Starting from the 9th (last) floor and proceeding downwards: 40 façade panels are being installed per day. The construction process that was followed on-site has been used as a basis for the development of the following datasheets, enriched with the INSITER knowledge for improvement potential based on best practices.

Category Intervention	Existing building
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 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 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:*** • Use as a reference the floor plans to be sure that you are on the correct floor/room/space where each glass façade panel needs to be installed; • Make sure that all the waste from demolition around you is removed; • Check if there are still any remaining 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.
Technical data and information	• BIM after demolition_Enschede • Floor Plan_Enschede • Front Facade_Enschede • K14 and K38 rooms_Enschede • Site Plan_Enschede • Open frames_Enschede • Window sill finishing_Enschede

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	Existing building
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	• Glass Facade_specs_Enschede • RT 62_specs • Storage of glass on-site • Lifting operations • Logistics on-site_Enschede1 • Logistics on-site_Enschede2 • Storing and handling glass sheets

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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 facade system is modelled; • Use the component BIM model (if available) of the façade system to check the technical details; • *Note down any remarks, questions or doubts on the observation panel.*
Technical data and information	• BIM model_Enscede • Glass Façade_BIM model_Enschede • Glass Façade_Screenshot_Enschede

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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 the open frames the façade panels 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 movie • AR_Facade_Enschede • AR_Facade thermal image_Enschede • AR_Facade video_Enschede • Image_Facade_AR_Enshede • Planning_Enschede • Detailing_Enschede • Concept_Facade_Enscede

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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 façade 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 glass facades brackets; • *Improper or ineffective gasket engagement between modules;* • *Bottoming out of individual module frames;* • *Change in the required glass size;* • *Reduction in the glass bite.*
Technical data and information	• AR_Clash01_Enschede

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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:*** • Ensure that all frames are mounted properly; • Accurately follow the manufacturer's assembly/installation manual; • Focus on joints, sealing and glazing. ***Key activities:*** • Check the available video for "BIM-based Self-Instruction model" showing the installation process for the facade panels *(INSITER Associated tool)*; • Use control lines as a reference for measuring; • Check the layout, determining the exact position of the façade according to the technical drawings; • Check the Assembly/Installation manual from the manufacturer; • Drill/install fixing points as required by drawings, manuals, tech specs, videos; • Utilize facade frames and mount them; • Fast the brackets of the frames (screw); • Mount the glass panes that are positioned close to the columns of each floor; • Seal the panels. ***Special attention:*** • Start installations on the top floor and proceed downwards; • If the weather is not good, place plastic sheets supported by temporal wooden frames to protect the frames; • Pay special attention to the corners; • Check for potential misalignments from terrace roofs or the building interior at inside corners.
Technical data and information	• BIM-based Self-Instruction model for mobile devices_Enschede • Front façade_Enschede • Glass façade_manual_Enschede • Intallations sequence_Enschde • Example_Mullion transom • Example_Curtain wall installation

Category Intervention	Existing building
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	• Loss of insulation_K38 • Thermal bridge_K14

In italic are the common descriptions as in D1.2 for the same component.

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 an acoustic test;*
- *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	Existing building
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 in D1.2 for the same component.

2.4 Roof

2.4.1 Explanation of EeB component

The explanation of the this component and reason why is critical for EeB is described in D1.2

2.4.2 Explanation of Pisa case

The Italian demonstration case analysed regarding the roof component is a school complex built in Pisa in mid-1970s. The complex is realized with prefabricated concrete systems (pillars, beams and panels) and it is characterized by strongly articulated volumes developed on two, three and four floors above ground. The flat roof is a broad, slightly sloping surface realized without thermal insulation and with waterproofing polymer membranes in state of degrade.

The refurbishment program will propose the following interventions in order to improve the roof performance:

- Installation of a new waterproofing membranes;
- Installation of a thermal insulation using a roof prefab sandwich panel. The sandwich panel is a self-supporting simple skin metal faced panel, insulated with polyurethane foam with internal face made of roofing felt. The panel is composed by 5 ribs that allow a good static resistance.

Category Intervention	Existing building
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:*** • Condition of the existing roof before starting with the installation of the new elements proposed by the project team. • Compare the existing condition with the information defined during the project plan. ***Key activities:*** • Note down on the observation panel remarks; • Take at least one picture for each check for ***special attention*** below; • Check roof surface and geometry; • Check the construction technology of the roof in comparison to the information uploaded on the mobile devices (e.g. same finishes material, existing thermal insulation, etc.); • Report the state of degrade of the roof and rooms located in last floor; • Propose data acquisition of the geometric building (point of cloud) using terrestrial laser scanner (Leica Scan Station) along with total station measurements. ***Special attention:*** • Indoor rooms temperature including the surface external walls/floors temperature, eventually using thermal infrared camera; • Humidity level inside the rooms, using thermal infrared camera and hygrometer; • Acoustic insulation, eventually using sound brush; • Existing thermal bridges, eventually use thermal infrared camera; • Air and water leakages, eventually using visual inspection and thermal infrared camera.
Technical data and information	• Pisa_Roof plan • Pisa_Second floor plan • Pisa_scanning • Vista area_Pisa • Pisa_Existing01 • Pisa_Existing02

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 total station measurements to capture the actual condition of the roof system.

Category Intervention	Existing building
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 and quality of components and building materials delivered on-site (waterproof membrane and roof isolated prefab metal sandwich panels);* • *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 on the observation panel.* ***Special attention:*** • *Check if any materials or components have been damaged from transport.*
Technical data and information	• Panel_QR code_Pisa • Isopan_specs_Pisa • Isocop_manual

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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_Insulation_Roof vertical_Pisa • BIM_Insulation_Roof horizontal_Pisa • Isocop_screenshot • Pisa_BIM screenshot01 • Pisa_BIM screenshot02

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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 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 in D1.2 for the same component.

Category Intervention	Existing building
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:*** • *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 on the observation panel;* ***Special attention:*** • Attention at the arrangement of the waterproof membrane; • Attention at the arrangement of the sandwich panels.
Technical data and information	• Pisa_Clash screenshot

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	Existing building
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:*** • Ensure that all elements are mounted properly; • Accurately follow the manufacturer's assembly/installation manual; • Focus on joints and sealing. ***Key activities:*** • Check step-by step waterproofing assembly manual; • Check step-by step ISOPAN assembly manual • Use control lines as a reference for measuring; • Check the layout, determining the exact position of the roof elements according to the technical drawings; • Install the waterproof membrane as required by drawings, manuals, tech specs; • Install the sandwich panels as required by drawings, manuals, tech specs. ***Special attention:*** • Pay special attention to the corners; • Check for potential misalignments.
Technical data and information	• Isocop_manual • Isopan_image mounting • Isopan_video • Example_instructions descriptions • Example_Installation manual • BIM-based Self-Instruction model for mobile devices_Green Village

Category Intervention	Existing building
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:*** • Correctness of the joints (KPI: Geometrical accuracy) • Continuity of the water sealing membranes and insulation in all part of the roof; • Indoor rooms temperature including the surface external walls/slab temperature; • Humidity level inside the rooms; • Acoustic insulation; • Thermal bridges; • Air leakages and water infiltration / condensations. ***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	• Pisa_Thermal image

In italic are the common descriptions as in D1.2 for the same component.

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 an acoustic test;
- 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	Existing building
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 in D1.2 for the same component.

2.5 Connection between new and existing building

2.5.1 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:
    1. geo-location
    2. size
    3. angular alignment
    4. flatness alignment

2.5.2 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 - refurbishment
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 - refurbishment
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 - refurbishment
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

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	New construction - refurbishment
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

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	New construction - refurbishment
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

In italic are the common descriptions as in D1.2 for the same component.

Category Intervention	New construction - refurbishment
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=MFEvE6Ol5T4 • BIM-based Self-Instruction model for mobile devices_Green Village

Category Intervention	New construction - refurbishment
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

In italic are the common descriptions as in D1.2 for the same component.

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 - refurbishment
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.

In italic are the common descriptions as in D1.2 for the same component.

3. Implementation guidelines of INSITER 8-step methodology addressing critical MEP/HVAC components in existing buildings

3.1 Heat pump

3.1.1 Explanation of EeB component

The explanation of the this component and reason why is critical for EEB is already described in D1.2

3.1.2 Explanation of Enschede case

Within the Enschede demonstrator, a deep renovation solution for the HVAC/MEP systems takes place, utilizing new heat pump. The existing building elements may apply limitation for the design of the heat pump system and the choice of the right units/systems (due to size matters and ventilation or exhaust ducts). These issues will be considered in Step 1. All other steps and processes related to the self-instruction and self-inspection are same for D1.2 New Construction.

Category Intervention	Existing building
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 condition of the floor of the mounting place; • The structural condition of the wall and ceiling to hung/mount the piping system (related to the heat pump system); • The possibility to transport, lift and storage the heat pump system within the structural limitations of the building (if the case). ***Key activities:*** • Check the building conditions including structural conditions and accessibility of the building with the help of AR which is available on the mobile device. • Map actual conditions in relation to: • structural conditions in relation to mounting the heat pump; • structural and mechanical conditions for ventilation requirements for the technical room (where the heat pump will be placed); • structural and technical conditions for eventually mounting of exhaust ducts.
Technical data and information	• Example_Heat pump layout

The INSITER guideline addressing steps 2 to 8 for this component in the case of refurbishment is the same as for new building. Hence it is presented in D1.2.

The site-supervisor:

- Receives the findings and decides on plans, among others:
  1. Damage prevention
  2. Recovery / repair
  3. Replacement / reconstruction
  4. Modification / redesign / transformation.

3.2 Mechanical ventilation

3.2.1 Explanation of EeB component

The explanation of the this component and reason why is critical for EeB is already described in D1.2

3.2.2 Explanation of Enschede case

Hogekamp is a good example for a renovation project covering ventilation systems. In the project student hotel rooms and studios are being realized and sufficient ventilation in the rooms is critical to the Indoor Air Quality. Therefore all ventilation components, i.a. ducts and diffusers, need to be installed as airtight as possible. The components working together are critical to the energy performance of the ventilation system.

In practice, what needs to be checked to avoid energy efficiency loss and poor Indoor Air Quality is mainly the mutual connection and correct installation of components.

Figure 5: Photo from the Hogekamp facility showing the central duct system in the hallway. Critical are the right connection between duct parts and right installation of the suspension brackets.

Category Intervention	Existing building
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:*** • Energy losses; • Effectiveness of the ventilation; • Technical performance of the ventilation system; • Operational performance in the relevant room; • Norms and user's preferences (required and desired level of comfort; health and energy norms and building regulations). ***Key activities:*** • Find a reference spot on site, to exactly position the elements in x,y and z coordinates; • Note down remarks on the observation panel. ***Special attention:*** • Check the technical performance of the ventilation system by measuring: • Air tightness of the duct system; • Heat recovery system efficiency; • Energy use of fans and drives; • Sound intensity of HVAC equipment; • Check the operational performance in the relevant room by verifying: • Draught rate in the room; • Air velocity in the room; • Vertical air temperature in the room; • Relative Humidity in the room; • Sound pressure level in the room; • Air supply rates in the room.
Technical data and information	• Ventilation layout_Enschede

The INSITER guideline addressing steps 2 to 8 for this component in the case of refurbishment is the same as for new building. Hence it is presented in D1.2.

The site-supervisor:

- Receives the findings and decides on plans, among others:
  1. Damage prevention
  2. Recovery / repair
  3. Replacement / reconstruction
  4. Modification / redesign / transformation.

3.3 Solar hot water system

3.3.1 Explanation of EeB component

The explanation of the this component and reason why is critical for EeB is already described in D1.2

Category Intervention	Existing building
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:*** • Shadings; • Adequate structural conditions of the floor of the mounting place, as well as other building; elements to support piping and auxiliary components; • Available space for the solar collectors and other equipment; • Adequate accessibility conditions; • Possibility to safely transport, lift and storage the system components. ***Key activities:*** • Check any visible damage on the mounting surface and relevant building elements; • Open BIM model with site information and as-designed solar system layout, positions, dimensions; • Check the presence of skylights, vents and possible obstructions that limit the available space for installation and proper accessibility • Check roof pitch; • Conduct a shade analysis. Identify unexpected obstructions (chimneys, nearby buildings, trees, etc.) and determine the amount of shading affecting the installation site; • Check the adequacy of structural conditions in relation to transport, lift and storage requirements; • Report findings and deviations and inform the site supervisor to take corrective measures (if needed).
Technical data and information	• BIM model_Cartif3 • SolarSystemLayout_02_CARTIF3

The INSITER guideline addressing steps 2 to 8 for this component in the case of refurbishment is the same as for new building. Hence it is presented in D1.2.

3.4 LED lighting

3.4.1 Explanation of EeB component

The explanation of the this component and reason why is critical for EeB is already described in D1.2

Category Intervention	Existing building
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:*** • The amount of energy losses; • The effectiveness of the lighting system. ***Key activities:*** • Mapping the actual conditions of the site and building; • Map the actual conditions in relation to the operational performance in the relevant room. ***Key activities:*** • Check performance in relevant rooms, in particular: 1. Illuminance; 2. Colour temperature; 3. UGR value. • Norms and user's preferences; • The required and desired level of visual comfort; • Health/safety and energy norms and building regulation.
Technical data and information	• Lighting layout_Enschede

The INSITER guideline addressing steps 2 to 8 for this component in the case of refurbishment is the same as for new building. Hence it is presented in D1.2.

The site supervisor:

Receives the findings and decides on plans, among others:

- Damage prevention;
- Recovery / repair;
- Replacement / reconstruction;
- Modification / redesign / transformation.

4. ICT solutions facilitating the Guideline Mobile App

The INSITER guideline Mobile App addressing the main features of the App, and its IT architecture is presented in D1.2.

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