ET4D

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ET4Digital – Empowering Trainers for Digital Innovation in Construction Ecosystem

Deliverable 3.3

Guidelines for the replicability of the demonstrator

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INTRODUCTION

Summary

ET4Digital – Empowering Trainers for Digital Innovation in construction Ecosystem is dedicated to advancing the quality, effectiveness, and innovation in training trainers and teachers within the construction sector for the seamless integration of digital technologies. The initiative involves creating innovative tools and a comprehensive capacity-building programme. Trainers will engage with a specially designed digital technologies demonstrator, fostering hands-on experience. The project aims to overcome barriers hindering SMEs from adopting digital technologies by co-designing, testing, and validating training programmes. The ultimate goal is to empower trainers to lead the digital transition in the construction industry, tapping into its significant but underexplored potential.
Although digital innovation has grown significantly in recent years, companies are finding it difficult to effectively exploit this enormous potential. Instead, digitisation in the construction sector can offer significant opportunities for the entire value chain by not only improving existing practices but also integrating disruptive technologies and tools that can lead to new processes, business models, materials and solutions. It is important to underline that the combination of digital technologies makes it possible to maximise the benefits associated with digital transformation. For example, BIM, IoT, Augmented Reality and Digital Twins are deeply interconnected, as they refer to technologies that leverage each other and can be seen as different phases or elements of the same digital transformation.

As demonstrated by several European and national research studies, the construction sector lags far behind other industrial fields when it comes to digitalisation.
To date, the European construction sector is facing challenges that are hampering its competitiveness. Among these are:

- Labour shortage
- Lack of digital skills in some countries
- Lack of interest among entrepreneurs and workers in the digitalisation of processes
- Lack of motivation on the part of young people to work in the sector
- Need to increase productivity while improving quality, cost efficiency and project delivery
- High costs related to technologies and digital tools

Therefore, the specific objective of the project is to deliver customised programmes to professional trainers, aiming to equip them with new digital strategies, tools and skills. As intermediaries, these trainers play a crucial role in demonstrating to enterprises and workers the benefits of digitalisation and the positive outcomes it can yield. This approach facilitates the upgrading of workers' skills in digitalisation, emphasising that traditional materials and techniques can be innovatively supported by digital technologies, leading to reduced costs and time wastage.

Furthermore, the job market continually evolves, shaping the required profiles and skills that workers need to possess in response to the demands of companies and employers. By updating the professional profiles required in the construction sector and digitalising its processes, we can attract young, educated workers to a field of work still considered 'traditional'.

Purpose of the document

The purpose of this document is to provide trainers with a set of clear and operational guidelines for replicating the Digital Twin demonstrator developed in the ET4Digital project within their own vocational education and training contexts.
The document is designed as a methodological support that accompanies the trainer throughout the entire process of implementing the Digital Twin, from understanding the conceptual framework to building the demonstrator, to its use in teaching and its adaptation to different training and professional contexts.
The proposed guidelines are not intended to provide detailed technological instructions or prescribe unique solutions, but to offer a replicable and flexible model based on real and accessible tools already present in the operational processes of the construction sector. The focus is on understanding the construction process and the educational value of the Digital Twin as an environment for mediating between practical experience and digital representation. The technical configuration of the ET4Digital demonstrator (collaborative platform, information model, sensors, data acquisition and dashboard) is documented separately in Annex I.
The document is aimed in particular at:

- trainers and teachers in the construction sector;
- vocational education and training institutions;
- those involved in the design and management of training courses geared towards digital transition.

These guidelines help trainers to develop teaching programmes that use the Digital Twin as a tool to reinforce experience-based learning, encourage critical analysis of the construction process and develop transferable skills in a professional context.
The guidelines are supplemented by multimedia resources (video recordings of training sessions), developed as part of the Transnational Training for Trainers programme, to support the independent implementation of the demonstrator.

The videos are available at the following links:
Part 1 – Prof. Marco Alvise Bragadin
LINK
Part 2 – Andrea Ballabeni
LINK
Part 3 – Shrinija Poudel
LINK

Target audience

This document is primarily intended for trainers and teachers involved in vocational education and training in the construction sector, with particular reference to those working in technical training, continuing education and professional development. The guidelines are designed to support trainers in introducing and using Digital Twin as a teaching tool, providing a methodological and operational reference that can be adapted to different training contexts.
The document is also aimed at vocational education and training institutions, technical training centres and organisations involved in the design and management of training courses geared towards the digital transition of the construction sector. In this context, the guidelines provided can be used as a basis for structuring training activities that integrate practical experience, digital tools and analysis of the construction process.
Another target group is professionals and technicians from small and medium-sized enterprises in the construction sector who are interested in understanding and experimenting with the use of Digital Twin in relation to their operational processes. Thanks to the use of real, accessible tools that are already present in professional practice, the document can also support business contexts in understanding and gradually adopting digital approaches.
Finally, the document may be of interest to institutional stakeholders, training support bodies and those involved in skills policies who wish to explore training models geared towards the integration of digital technology, the construction process and skills development.
Annex I is addressed in particular to the technical staff (IT, BIM or electronics specialists) who support trainers and institutions in setting up and maintaining the demonstrator.

PART I – CONCEPTUAL AND METHODOLOGICAL FRAMEWORK

1. The Digital Twin in training for the construction sector

The digital transformation of the construction sector is profoundly changing the processes of design, construction and management of works. The introduction of information models, collaborative platforms and data management systems has made it increasingly important to interpret the project as a structured process over time, rather than as a simple result. In this scenario, vocational training plays a strategic role in supporting the development of skills consistent with the evolution of the sector.
The Digital Twin is a paradigm that allows a real system to be described and observed through a dynamic digital representation, capable of integrating geometric, organisational and temporal information. In the construction sector, the Digital Twin is increasingly recognised as a tool for

understanding and managing the life cycle of a building, as it allows the project to be linked to the construction activities and data generated during the construction process (Boje et al., 2020).
Applied to training, the Digital Twin takes on significant methodological value because it allows the processes that characterise work on site to be made explicit. Through the digital representation of the project in the Digital Twin, students and trainers can observe the sequence of work, the relationships between activities, the organisation of work and the evolution of the intervention over time. This approach promotes process-oriented learning, in which practical experience is accompanied by tools for analysis and reflection.
In the context of vocational training, the Digital Twin supports the development of cross-cutting skills that are fundamental to the construction sector, such as the ability to plan activities, interpret work progress, understand the interdependencies between operational phases and read the project as a complex system. In this sense, the Digital Twin becomes a mediator between operational experience and organisational understanding of the construction process, reinforcing experiential learning and professional awareness.

2. The ET4Digital Digital Twin demonstrator

The Digital Twin demonstrator developed in the ET4Digital project fits into this conceptual framework and is designed as a training support tool for the construction sector. The demonstrator translates the concept of Digital Twin into a replicable operational configuration, adapted to vocational education and training contexts.
The demonstrator is based on the integration of three fundamental elements: the real project, understood as a set of construction activities carried out in the laboratory or on the training site; the digital representation of the project, built using information models and project management tools; and the information flow that links activities, times and data generated during the process. This architecture allows the project to be viewed as a dynamic system, in which activities are planned, executed and monitored over time.
In the ET4Digital project, the Digital Twin was developed according to a level of maturity consistent with the training needs and small and medium-sized enterprises in the sector. The digital representation integrates the information model of the work with the planning of activities and data from the real project, allowing the organisation of work and the progress of the work to be analysed without introducing unnecessary technological complexity in the educational field (Sacks et al., 2020).
The ET4Digital demonstrator was designed with a replicability-oriented approach, using collaborative platforms and open formats so that it can be adapted to different training contexts. The focus is not on the tool itself, but on the method: the Digital Twin is used as a learning environment in which the real project becomes the subject of observation, analysis and discussion. Through the demonstrator, trainers have an operational framework to guide students in understanding the construction process, linking practical experience to its digital representation. In this way, the ET4Digital Digital Twin acts as a methodological support for training, capable of

strengthening understanding of processes and preparing students for the transformations taking place in the construction sector.

PART II – CONSTRUCTION OF THE DEMONSTRATOR

3. Launch of the real project (Physical Twin)

The construction of the Digital Twin demonstrator starts with the real project, which is the concrete reference point for the entire system. In the training context, the real project represents the set of construction activities carried out in the laboratory, on the teaching site or in a controlled learning environment and provides the basis on which the digital representation of the process is developed. The selection of the real project is based on the training objectives and the skills to be developed. The project may involve a single process or a limited sequence of activities, if it allows for the observation of a process articulated over time. Defining the operational scope allows for the identification of the relevant phases, the resources involved and the relationships between activities, making the project readable and structurable from a digital point of view.
During the practical activities, the real project is accompanied by a systematic collection of information, including descriptions of the processes, indicative times, materials used and visual documentation. This phase allows for the construction of a first level of knowledge of the process, which feeds into the subsequent development of the Digital Twin.

4. Digital architecture of the demonstrator

Once the real project has been launched, the construction of the demonstrator continues with the definition of the digital architecture, understood as the set of tools and environments that host the representation of the project and support its organisation.
In the ET4Digital demonstrator, the digital architecture is based on an open collaborative platform (OpenProject BIM in the ET4Digital implementation; see Annex I), which allows the project to be managed as a unified information system. The platform acts as a central environment where activities are organised, content is shared and the progress of the process can be observed over time.
From a methodological point of view, the choice of digital architecture responds to the need to ensure accessibility, interoperability and replicability. The adoption of open solutions allows working with standard formats and adapting the demonstrator to different training contexts, while maintaining methodological consistency and operational continuity.

5. Construction of the digital twin: information model

The digital twin is built from an information model of the project, which represents the structured basis on which information relating to activities and processes is grafted. In the ET4Digital demonstrator, the information model serves as a common reference for reading the project, allowing construction elements, operational phases and project data to be linked.
The information level of the model is defined in line with the training objectives, favouring a clear and legible representation of the project. The use of open BIM formats, particularly the IFC format, makes the model interoperable and accessible within the digital platform, facilitating the involvement of trainers and students with different skills.
The relationship between the information model and the actual project allows the parts of the work to be associated with the activities carried out, making the link between digital representation and the construction process explicit.

6. Structuring the digital project

The construction of the demonstrator continues with the structuring of the digital project, using tools for organising and planning activities. In this phase, the project is broken down into a Work Breakdown Structure (WBS) that reflects the sequence of work and the relationships between the operational phases.
The time planning of activities allows the project to be represented over time, associating each phase with an indicative duration and a location within the overall process. The link between activities, times and information model allows the evolution of the project to be observed and the progress of the work to be analysed in a structured manner.
This approach enhances understanding of the organisation of work and supports the analysis of interdependencies between the different phases of the project.

7. Collaborative environment and visualisation

The collaborative environment represents the operational level through which the Digital Twin demonstrator is used in training practice. The platform allows users to visualise the information model, navigate the project through views and sections, and access information associated with activities.
User and role management allows collaborative work to be structured, encouraging the participation of trainers and students within the same digital environment. The visualisation of the project thus becomes a tool to support discussion, analysis and information sharing.
In the training context, the collaborative environment facilitates understanding of the project as a shared system, in which practical activities correspond to the digital representation of the process.

PART III – DATA AND DATA-DRIVEN DIGITAL TWIN

8. Integration of data from the real project

A central feature of the Digital Twin is its ability to integrate data from the real project, making the digital representation informed by the actual performance of the activities. In the training context, data integration allows the construction process to be observed over time and practical activities to be linked to the operating conditions in which they take place.
In the ET4Digital demonstrator, the data-driven approach has been developed in a progressive and controlled manner, with the aim of making the data understandable, readable and usable for educational purposes. The data provides an information base for observing, analysing and discussing the construction process, strengthening the link between the real project and the digital representation.

8.1 Types of data in the demonstrator

In the ET4Digital model, the data integrated into the Digital Twin can be divided into three main categories:

- Descriptive data, related to the activities of the real project, such as work phases, indicative times, materials and resources involved;
- Documentary data, such as photographs, images, annotations, surveys and materials produced during the activities;
- Measured data, coming from detection devices installed in the context of the real project.

This classification allows the trainer to structure the integration of data in a gradual manner, starting with directly available information and progressively introducing more structured data.

8.2 Integration of environmental sensors

In the ET4Digital project, environmental sensors are used to collect data on the operating conditions of the educational construction site. They allow the monitoring of parameters relevant to the reading of the working context, such as:

- air temperature;
- relative humidity;
- atmospheric pressure;
- oxidising, reducing and ammonia gases (indicative of NO_2, CO and NH_3 levels);
- particulate matter (PM1, PM2.5 and PM10);
- light intensity and sound level.

The sensors used are low-cost, easy-to-integrate devices that are compatible with prototyping platforms commonly used in education. Their integration enriches the Digital Twin, allowing activities to be linked to the environmental conditions in which they take place. The gas sensor provides indicative values, suitable for observing trends rather than for regulatory measurements. The sensor configuration used in the ET4Digital implementation is described in Annex I, Section 6.

8.3 Integration of the camera as a source of visual data

In addition to environmental sensors, the ET4Digital demonstrator uses a camera as a source of visual data from the real project. The camera contributes to the collection of documentary data, integrating qualitative information into the Digital Twin.
The images acquired allow you to:

- document the status of the construction site or educational laboratory at specific times;
- observe the progress of activities over time;
- support the interpretation of the organisation of work and the configuration of the construction site;
- provide a visual reference for interpreting the data measured by environmental sensors.

In the demonstrator, the camera is used as a tool for observing the process and documenting the status of the actual project, contributing to the construction of a more complete and consistent digital representation.
The camera is also used to estimate the number of people present on site through an automatic image-recognition routine: at each acquisition only, the resulting count is transmitted to the platform, while photographs are stored only at the start and at the end of the working day. Before replicating this function, the organisation should assess it against the applicable data-protection rules (GDPR), inform the people involved and position the camera to limit the capture of identifiable individuals.

8.4 Data collection and management methods

In the ET4Digital demonstrator, data collection takes place during the phases of the real project, in a manner consistent with the training context. Environmental data is acquired at regular intervals (every five minutes during working hours in the ET4Digital implementation) and associated temporally with the activities in progress, while visual data is collected at significant moments of the working day (at its start and end in the ET4Digital implementation).
From an operational point of view, for the trainer this involves:

- defining the data collection periods;
- associating data with project phases;
- maintaining temporal consistency between activities carried out and information collected.

The data is initially stored as raw data within the digital platform and then organised to facilitate reading and interpretation.

8.5 Integration of data into the digital platform

Data from the actual project is recorded in the demonstrator platform as dedicated measurement Work Packages, within the same project as the construction activities and with the time of acquisition. This approach allows a direct link to be maintained between:

- the data collected;
- the time of its acquisition;
- the activities underway in the real project.

Within the platform, the data is made accessible to trainers and students in a structured form, helping to consolidate the Digital Twin as a single environment for observing the project.

8.6 Dashboards and data visualisation

To make the data usable for training purposes, visualisation dashboards have been developed in the ET4Digital demonstrator, which transform raw data into graphs and time representations.
The dashboards allow you to:

- observe the trend of parameters over time;
- compare different environmental parameters and read them alongside the site photographs;
- link operating conditions to the activities carried out;
- stimulate discussion and interpretation of results.

These tools support the transition from data collection to data analysis, promoting the development of critical information reading skills.

8.7 Educational value of the data-driven approach

The integration of data into the Digital Twin reinforces experience-based learning, offering students the opportunity to observe the real project as a dynamic system, informed by operating conditions and collected data.
Data becomes a tool for:

- understanding the work context;
- analysing the organisation of the construction site;
- reflecting on safety, comfort and environmental quality;
- connecting activities, times and real conditions.

For the trainer, the data-driven approach provides a concrete basis for designing teaching activities that integrate practice, observation and reflection, using the Digital Twin as a learning environment geared towards understanding the construction process.

PART IV – TRAINING USE AND ADAPTATION

9. Use of the Digital Twin in teaching

In the ET4Digital project, the Digital Twin is used as an integrated learning environment, in which the real project and its digital representation are closely linked. This approach allows operational activities to be accompanied by structured moments of observation, analysis and discussion of the construction process, strengthening the link between practical experience and organisational understanding.
In the classroom, the Digital Twin supports the introduction of the project, the presentation of the operational phases and the reading of the sequence of activities. The visualisation of the information model, planning and collected data allows a shared vision of the process to be constructed before the practical activities begin.
In the laboratory or on the teaching site, the Digital Twin accompanies the work, providing a digital reference that makes it possible to observe the relationships between activities, times and operating conditions. At the end of the activities, the Digital Twin becomes an analysis tool, through which trainers and students can reflect on the progress of the project, compare what was planned with what was achieved and discuss the organisational choices made.
This use promotes process-based learning and prepares students to read the project as a dynamic system, in line with professional practices in the sector.

10. Adaptation of the demonstrator to educational and professional contexts

The ET4Digital Digital Twin demonstrator has been designed to be adaptable to different contexts, both in training and professional settings. As highlighted in Deliverable 3.1, the demonstrator is built using real tools that are already present or easily introduced into the operational processes of the construction sector, making it accessible even to small and medium-sized enterprises.
The use of open collaborative platforms, interoperable information models and easily integrated planning and data collection tools allow the Digital Twin model to be applied not only in structured educational contexts, but also in small-scale production environments. This is particularly relevant, as many SMEs operate with limited resources and need solutions that can be progressively integrated into existing processes.
In the educational context, this feature reinforces the value of the demonstrator as a bridge between education and the world of work. Students can engage with tools and operating methods consistent with those used in businesses, developing skills that are directly transferable to the professional context.
The demonstrator can be adapted by modulating:

- the complexity of the real project;
- the information level of the digital model;
- the degree of integration of data and sensors;
- the methods of use of the collaborative platform.

This flexibility allows trainers and companies to calibrate the Digital Twin according to their needs, while maintaining the methodological principles that characterise its approach.

11. Evaluation and improvement of the experience

Assessment of the Digital Twin experience is a key element in the consolidation and evolution of the demonstrator. In line with Deliverable 3.1, the evaluation concerns both the training outcomes and the effectiveness of the Digital Twin as an operational and educational tool.
Trainers can collect evaluation data through:

- observation of the activities carried out;
- comparison between planning and results obtained;
- collective discussion with students or participants;
- reflection on the use of digital tools and data.

This information allows for the identification of possible improvements, both in relation to the organisation of the actual project and to the configuration of the Digital Twin. The demonstrator can thus be progressively refined, maintaining a consistent structure that is adaptable to the needs of different educational and professional contexts.
Evaluation becomes an integral part of the process, helping to make the Digital Twin a dynamic tool, capable of evolving over time and accompanying the digital transformation of the construction sector.

CONCLUSIONS

This document has presented a structured approach to using and replicating a Digital Twin demonstrator in the context of training for the construction sector. The aim is to provide trainers with a clear and operational reference for integrating digital technology as a tool to support understanding of the construction process, combining practical experience with a structured and shared representation of the actual project.
The Digital Twin, as described in these guidelines, allows the project to be observed as a dynamic system in which activities, times, resources and operating conditions are closely connected. Through the organisation of work processes, time planning, visualisation of the information model and integration of data from the educational construction site, the trainer has a tool to make the dynamics that characterise daily work in the construction sector readable and discussable.

A central element of this approach is the focus on replicability. The demonstrator is built using real, accessible tools that are already present in the sector's operational processes, such as collaborative platforms, interoperable information models and low-complexity data collection systems. This approach allows the model to be adapted to different training and professional contexts, including those of small and medium-sized enterprises, promoting continuity between training and work practice.

The integration of data into the Digital Twin reinforces experience-based learning, offering students the opportunity to observe the project in relation to the operational conditions in which it is developed. Descriptive, documentary and measured data become tools for analysing the organisation of the construction site, reflecting on operational choices and developing critical reading skills of the construction process.

The role of the trainer remains central to this process. Through the selection of the real project, the organisation of activities and the conscious use of digital tools, the trainer accompanies and guides students in building an integrated vision of the project. The Digital Twin thus becomes an environment for educational mediation, supporting experiential learning and contributing to the development of transferable skills in the professional context.

The proposed guidelines aim to provide a solid and flexible basis on which each trainer can build their own path, adapting it to the available resources, the profile of the students and the training objectives. In this sense, the Digital Twin represents not a technological achievement, but a methodological support to accompany training in the construction sector towards greater awareness of the processes and transformations taking place.

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ANNEX I

Technical Guide for Replicating the ET4Digital Digital Twin Demonstrator

OpenProject BIM · IFC · REST API · Sensors · Dashboard

Operational guide to the configuration, integration and verification of the ET4Digital demonstrator.

Document status and scope

Purpose. This annex provides a structured technical procedure for replicating the ET4Digital Digital Twin demonstrator. It complements the methodological and educational framework of the main text by translating it into an operational sequence covering platform configuration, IFC model management, project organisation, sensor-based data acquisition, REST API communication, dashboard visualisation and final system verification.
Application criterion. The guide distinguishes between components and procedures defined for the ET4Digital demonstrator and parameters that depend on the local installation. Where a value must be selected by the organisation replicating the system — for example hostname, credentials, network configuration, project ID or custom fields — it is identified as a specific parameter to be defined and recorded during installation.

Technical replication requires both a common procedure and parameters specific to the local installation. This guide therefore distinguishes between operational steps of the demonstrator and configurations that must be defined and recorded by the organisation implementing the replication.

Replication at a glance

Layer	Documented element	Role in replication
Platform	OpenProject BIM	Project management, CDE, BIM/IFC visualisation and integration hub
BIM	IFC + Revit add-on	Exchange of model geometry and data
Project structure	Work Packages / WBS / Gantt	Organisation of activities, responsibilities and schedule
Integration	REST API	Machine-to-machine communication between sensors and OpenProject BIM
Field data	Raspberry Pi + environmental sensors + microphone + AI camera	Periodic acquisition of measured and visual data
Dashboard	OpenProject BIM plugin	Graphical access to sensor trends and measurements
Deployment	Docker / Kubernetes / Linux package installation	Alternative ways to create the platform environment
Release workflow	Development → Test → Production	Controlled validation before production release

Replication logic

How to replicate the demonstrator. Replication should start from a real case that is sufficiently limited in scope to be observed over time. The physical project may be a laboratory activity, a training construction site or a limited sequence of construction operations. For each phase, activities, indicative durations, resources, materials and documentary information should be identified. On this basis, the digital representation is built: IFC model, WBS/Work Packages, schedule and collaborative environment. Descriptive, documentary and measured data are then linked to the activities and made accessible within the same platform. Integration can be progressive: it is possible to start with the model and schedule and subsequently add sensors, images and dashboards while maintaining the same Digital Twin methodological logic.

1. Reference technical architecture

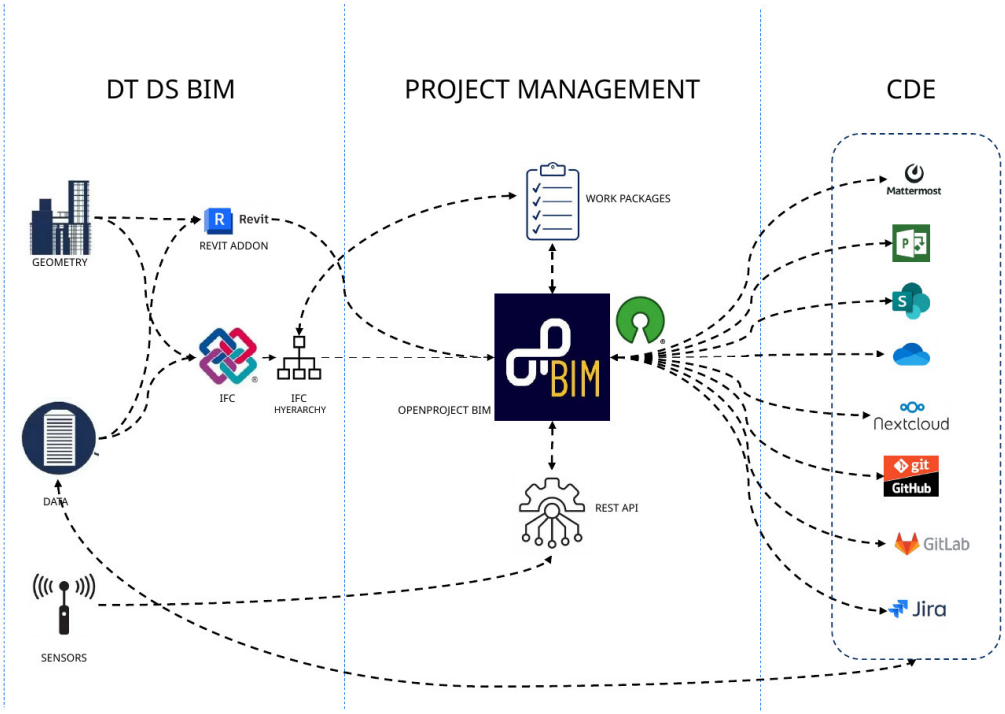


Figure 1 - Demonstrator integration flow: BIM/IFC, project management, CDE, REST API, sensors and Revit add-on.

OpenProject BIM is the central environment of the demonstrator and connects project management, the Common Data Environment (CDE), BIM geometry and data, IFC models, the Revit add-on, REST API integration and sensor data. The architecture should therefore be understood as an integration pattern built around a common project environment rather than as a single software feature. Consistently with Section 2 of the main text, the demonstrator integrates three elements: the real project or Physical Twin, the digital representation based on the information model and planning tools, and the information flow linking activities, time and data collected during the

process. The external services shown on the right of Figure 1 (file sharing, messaging, code and issue tracking) are optional integrations and are not required for replication.

Table 1 - External services

Component	Function	Input / interface	Output / use
OpenProject BIM	Central project and collaboration platform	Web interface, IFC, REST API	CDE, Work Packages, Gantt, BIM views, sensor data
IFC models	Open BIM geometry and data	IFC import	Model visualisation and model-linked project information
Revit add-on	Access to OpenProject BIM functions from Revit	Revit 2017–2022 in the ET4Digital implementation	Issues / BCF and OpenProject BIM access
REST API	Application-to-application communication	Calls from sensors and software	Creation/update of measurement records
Raspberry Pi	Edge acquisition unit	Connected sensors, microphone and camera	API calls over Wi-Fi
Sensor dashboard plugin	Measurement visualisation	OpenProject project ID + custom-field IDs	Charts and comparison views

Design principle: the demonstrator prioritises open solutions, interoperable formats, IFC compatibility and API-based integration. The replication objective is to reconstruct the functional architecture and integration method, adapting the software configuration to the local context without losing consistency between model, activities and data. Revit and the Revit add-on are optional: any BIM authoring tool able to export IFC, including open-source tools, can be used to produce the model.

2. Platform deployment options

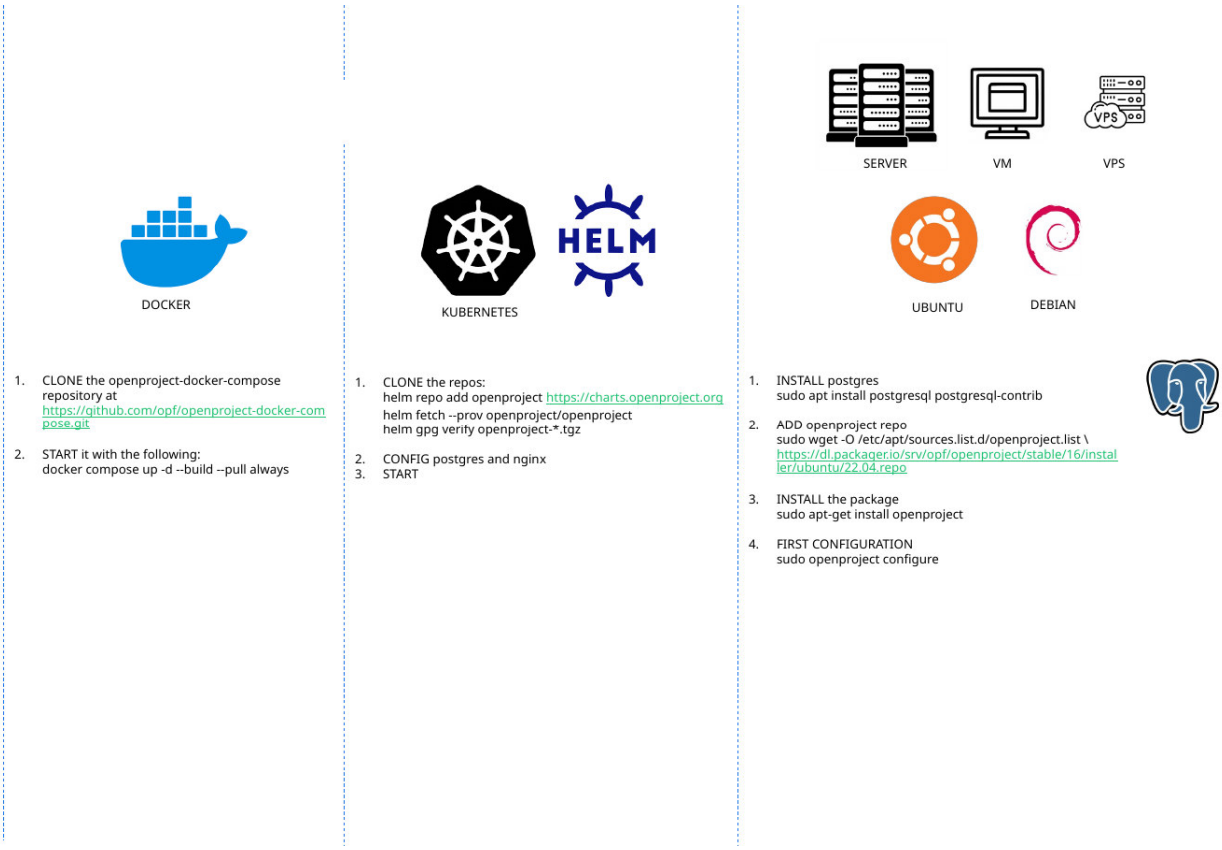


Figure 2 - Alternative OpenProject deployment options: Docker, Kubernetes and server/VM/VPS.

Three alternative deployment methods are provided. The choice should be based on the available infrastructure, system-administration skills and the required level of scalability. No single method is mandatory: the objective is to obtain a stable and accessible OpenProject BIM environment on which to configure the demonstrator project and its integrations.

2.1 Option A — Docker Compose

1. Clone the official OpenProject Docker Compose repository.

```
git clone https://github.com/opf/openproject-docker-compose.git
```

2. Start the environment with the following command:

```
docker compose up -d --build --pull always
```

To be defined locally: host name, persistent volumes, e-mail settings, TLS/HTTPS termination, administrator credentials and backup policy. Record these values in the installation Configuration Record.

2.2 Option B — Kubernetes

1. Add the OpenProject Helm chart repository.

```
helm repo add openproject https://charts.openproject.org
```

2. Fetch and verify the OpenProject chart (verification requires the helm-gpg plugin):

```
helm fetch --prov openproject/openproject
helm gpg verify openproject-*.tgz
```

3. Define the Helm values file (database, ingress, persistent storage, secrets) and install the chart:

```
helm upgrade --create-namespace --namespace openproject --install my-openproject openproject/openproject -f values.yaml
```

To be defined locally: Helm values file, namespace, storage class, ingress configuration, secrets and resource sizing. Record these values in the installation Configuration Record.

2.3 Option C — Server / VM / VPS on Ubuntu or Debian

1. Install PostgreSQL.

```
sudo apt install postgresql postgresql-contrib
```

2. Import the OpenProject signing key, add the package repository for Ubuntu 22.04 / stable 16 and update the package index:

```
sudo curl -fsSL https://packages.openproject.com/srv/deb/opf/openproject/gpg-key.gpg -o /usr/share/keyrings/openproject.gpg
```

```
sudo curl -fsSL https://packages.openproject.com/srv/opf/openproject/stable/16/installer/ubuntu/22.04.list -o /etc/apt/sources.list.d/openproject.list

sudo apt-get update
```

3. Install OpenProject.

```
sudo apt-get install openproject
```

4. Run the initial configuration.

```
sudo openproject configure
```

Version note: the described configuration uses the “stable/16” path for Ubuntu 22.04. Before a new installation, verify the compatibility of the selected version with the required plugins and integrations, and record the version actually installed. The official package repository has moved from dl.packager.io to packages.openproject.com; the commands above follow the current OpenProject documentation.

3. Initial OpenProject BIM configuration

Once the environment is available, create or configure the demonstrator project and reproduce an information structure consistent with the selected construction process. Work Packages are the central organisational element: they make it possible to structure the WBS, associate statuses and responsibilities, add custom fields, define relationships and dependencies, and connect activities to the time schedule. This structure makes the process readable over time and links activities, the information model and the collected data.

- Create the demonstrator project in OpenProject BIM.
- Define project members and roles according to the training scenario.
- Create the Work Breakdown Structure (WBS) through Work Packages.
- For each Work Package, configure status, assignee/responsible user and any required custom fields.
- Where needed, define relationships between Work Packages (predecessor, successor, parent, child).
- Use the Gantt functionality to represent the schedule, start/finish dates and dependencies.
- Use the platform as a common data environment for project documents and coordination information.

4. BIM and model integration

4.1 IFC workflow

IFC is the main open interface for exchanging model geometry and data. The use of an Open BIM format makes the model interoperable and accessible within the collaborative platform. OpenProject BIM can import and visualise IFC models and link model information to project-management functions, making the relationship between the digital representation and operational activities explicit.

- Export or prepare the project model in IFC format.
- Import the IFC model into OpenProject BIM using the IFC importer.
- Verify that the model is displayed correctly in the IFC viewer.
- Use BIM Collaboration Format (BCF) / issue-management functions, where required, to connect model-related issues with project activities.

4.2 Revit add-on

A Revit add-on is available for the versions from 2017 to 2022 considered in the ET4Digital implementation. The add-on makes the OpenProject BIM interface available within Revit and allows Revit to be used as the main interface while retaining access to collaborative functions, including the management of issues linked to BCF elements.

Revit integration: completing the replication requires the add-on installation package, the relevant procedure and the authentication parameters for OpenProject BIM. These items must be obtained from the project technical resources or from the documentation of the solution used and recorded in the Configuration Record.

5. Preparing OpenProject BIM for sensor measurements

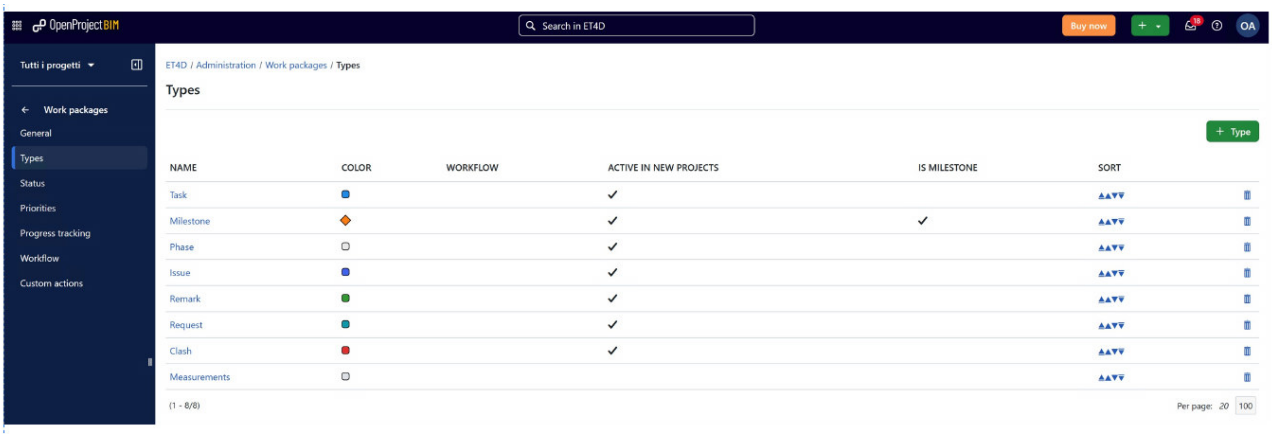


Figure 3 - OpenProject administration console used to create the Work Package type dedicated to sensor measurements.

Before connecting the hardware, a data structure for measurements must be prepared in OpenProject BIM. A dedicated Work Package type is created for this purpose and custom fields are configured for the acquired parameters. The numeric IDs of the fields must be recorded because they are used in REST API calls to correctly associate the received values. Each measurement is stored as a Work Package of this type in the same project as the construction activities, together with its acquisition date, so that measurements can be read alongside the activities scheduled in the same period.

1. **Open the OpenProject administration console.**
2. **Go to Work Packages → Types and select "+ Type" to create a new Work Package type dedicated to measurements.**
3. **Add existing custom fields or create the required new fields and field types.**
4. **Record the numeric ID of each custom field used for sensor measurements.**
5. **Maintain a configuration register containing at least the project ID, the measurement Work Package type and the custom-field IDs.**

Table 2 - Custom type configuration

Configuration item	ET4Digital value	Local value
OpenProject project ID	10	To be recorded
Measurement Work Package type	8 ("Measurements")	To be recorded
Temperature custom-field ID	1	To be recorded
Pressure custom-field ID	14	To be recorded

Configuration item	ET4Digital value	Local value
Humidity custom-field ID	2	To be recorded
Light custom-field ID	9	To be recorded
Reducing gases (CO) custom-field ID	12	To be recorded
NH3 custom-field ID	13	To be recorded
Oxidising gases (NO2) custom-field ID	11	To be recorded
PM1 custom-field ID	6	To be recorded
PM2.5 custom-field ID	5	To be recorded
PM10 custom-field ID	8	To be recorded
People-count custom-field ID	15	To be recorded
Sound-level custom-field ID	10	To be recorded
Measurement-date custom-field ID	16	To be recorded

6. Sensor and edge-device configuration

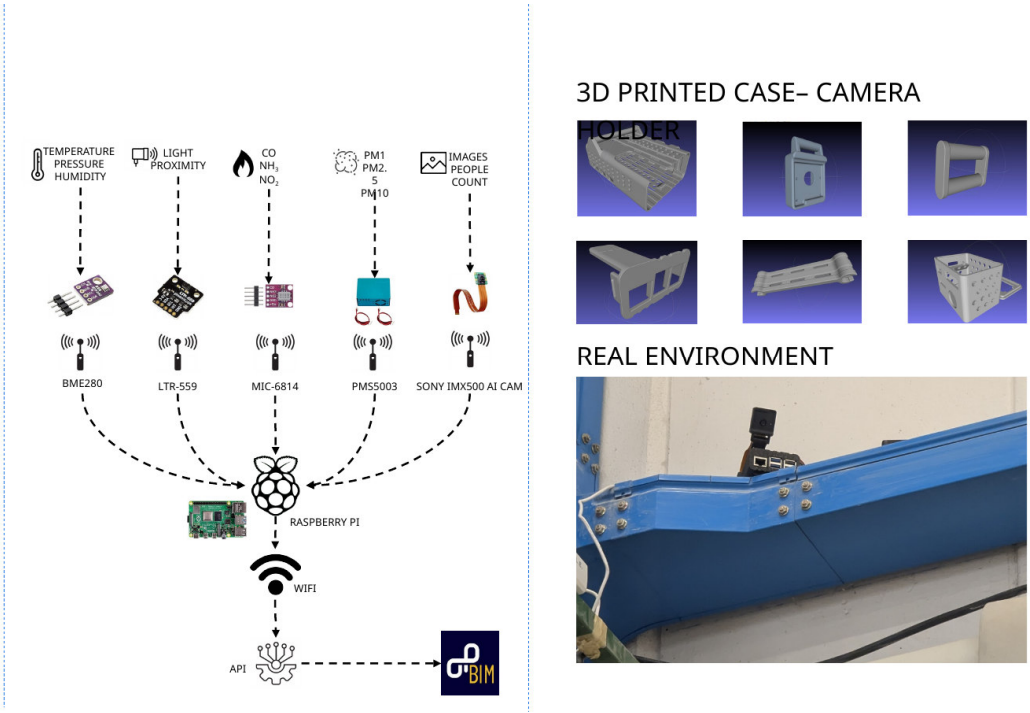


Figure 4 - ET4Digital sensor architecture: environmental sensors and AI camera connected to a Raspberry Pi, with data sent

The ET4Digital implementation uses a Raspberry Pi as the acquisition and communication unit. The device collects data from the connected sensors, runs the acquisition logic and sends measurements via Wi-Fi to the OpenProject BIM REST APIs. This configuration creates the link between the Physical Twin and the digital environment, allowing real conditions to be associated with project activities. The BME280, LTR-559 and MICS-6814 sensors are mounted on a Pimoroni Enviro+ board, managed through its Python libraries, to which the PMS5003 particulate sensor is connected. Sound level is measured with a microphone: the on-board microphone of the Enviro+ board in the first version of the script, and a calibrated miniDSP UMIK-1 USB microphone in the current version.

Table 3 - Setting up types

Device	Parameters / role	Documented model
Environmental sensor	Temperature, pressure, humidity	BME280
Light / proximity sensor	Light (proximity is not transmitted)	LTR-559
Gas sensor	Reducing (CO), NH3 and oxidising (NO2) gases – indicative resistance values (kΩ)	MICS-6814
Particulate sensor	PM1, PM2.5, PM10	PMS5003
Microphone	Sound level (dB)	Enviro+ on-board microphone / miniDSP UMIK-1

Device	Parameters / role	Documented model
AI camera	Images and people count	Sony IMX500 AI CAM
Edge computer	Data acquisition, image processing, API communication	Raspberry Pi

- Connect the sensors and camera to the Raspberry Pi using the electrical interfaces required by each device.
- Connect the Raspberry Pi to the network via Wi-Fi and verify that it can reach the OpenProject BIM instance.
- Protect the electronics for use in a construction-site or training-site environment. In the ET4Digital implementation, 3D-printed cases were used for the Raspberry Pi and camera together with a camera support arm; equivalent solutions may be adopted provided that they ensure protection, stability and correct positioning of the devices.

Calibration limitation: the low-cost sensors used in the demonstrator were not laboratory-calibrated. If the replicated system is used for measurements requiring quantitative accuracy, provide a calibration procedure and document uncertainty, checking frequency and operating conditions. The acquisition script also applies fixed empirical offsets to temperature and humidity readings: these must be checked and adjusted for each installation.

7. Data-acquisition software and API communication

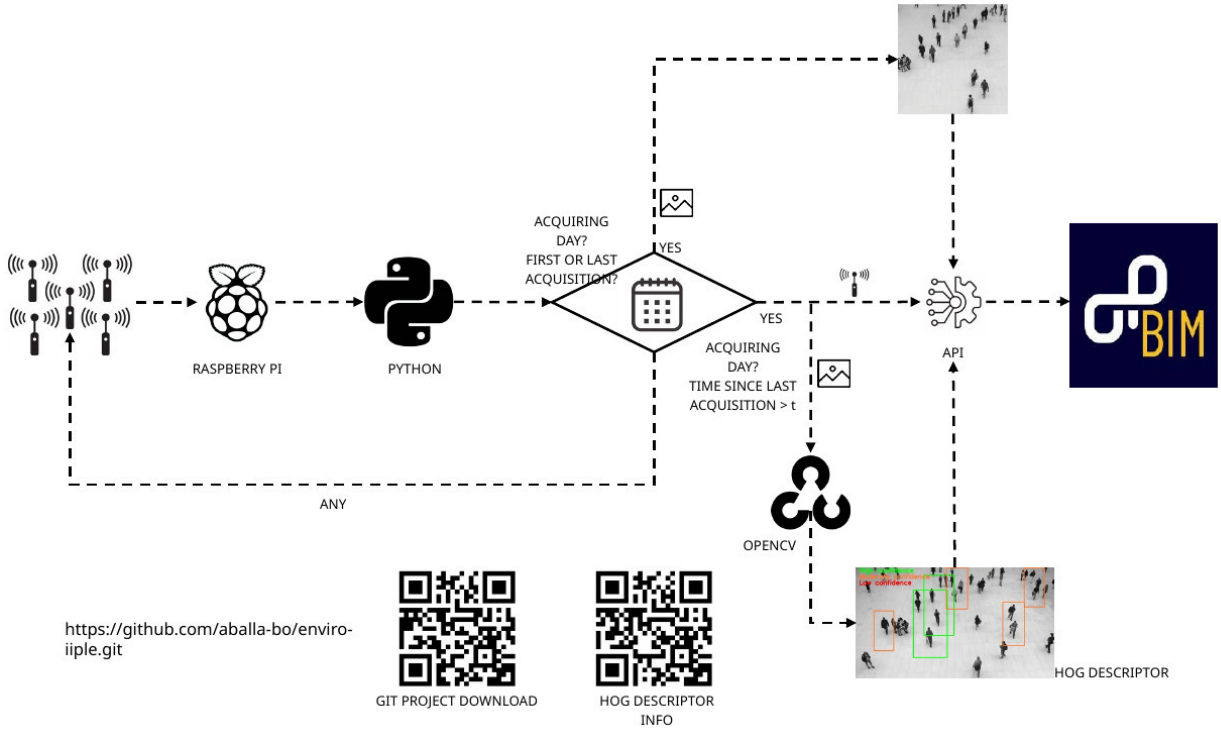


Figure 5 -Data-acquisition logic implemented in Python on the Raspberry Pi, including sensor acquisition, image processing and API communication. The diagram refers to an earlier prototype based on a HOG descriptor; the published script detects people based on YOLOv8 model.

The Raspberry Pi runs a Python script that manages the acquisition cycle. The logic checks the required time conditions, reads sensor values, acquires and processes images, and sends the resulting data to the OpenProject BIM REST APIs. In this way, measurements are integrated into the project and can be consulted together with activities, documents and the information model. The acquisition calendar is defined in the schedule_config.json file, and the script runs as a system service (enviro.service) that restarts automatically in case of error.

Step	Documented behaviour
1	Check whether the current day and time fall within the acquisition calendar (Monday to Friday, 08:00–14:00 in the ET4Digital implementation).
2	Check whether the configured time interval since the last transmission has elapsed (5 minutes).
3	Read the sensor values continuously and calculate the average of the readings collected since the last transmission.
4	Acquire an image and count the people present using a YOLOv8 object-detection model (OpenCV / Ultralytics).
5	Send the averaged values and the people count to the OpenProject BIM REST API, creating a measurement Work Package.
6	If the network is unavailable, store the measurement in a local queue and resend it when the connection is restored.
7	Attach the photographs taken at the start and end of the working day (08:05 and 12:55) to the corresponding measurement Work Package.

Source-code repository for acquisition and API communication: https://github.com/aballa-bo/enviro-iiple.git

Runtime: Python 3.11 in a virtual environment on the Raspberry Pi; the dependencies are listed in the requirements.txt file of the repository.

API configuration: the script uses the OpenProject API v3 (endpoint <host>/api/v3/work_packages) with Basic authentication based on a personal API key (user name “apikey”). The endpoint, project ID, Work Package type ID and the mapping between sensor values and custom-field IDs are set at the beginning of the enviro.py file and must be adapted to the local installation before operational start-up. The API key must never be stored in a public repository: keep it in an environment variable or in a local configuration file excluded from version control.

8. Sensor dashboard plugin

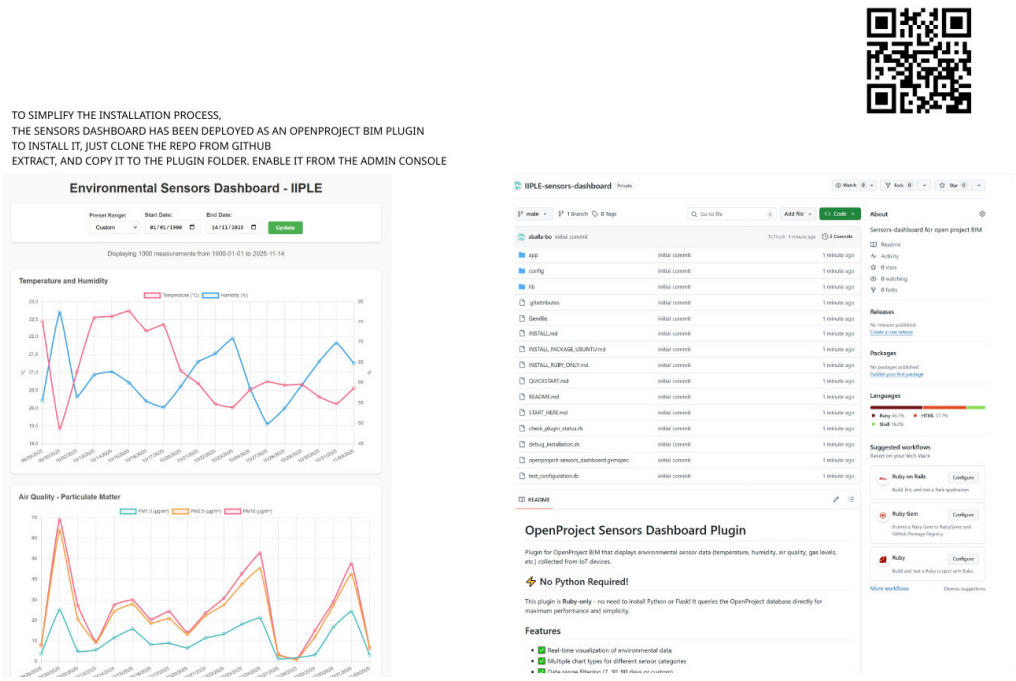


Figure 6 - Sensor dashboard developed for OpenProject BIM, with graphical visualisation of the acquired measurements.

To make data immediately accessible, the sensor dashboard is integrated as an OpenProject BIM plugin. The dashboard transforms raw data into charts and time series, making it easier to compare environmental parameters with project activities. The installation follows the procedure below.

1. Backup current OpenProject db and gemfile. This step is especially recommended if your server already contains production data:

```
sudo cp -a /opt/openproject/modules ~/modules_backup_$(date +%F)

sudo cp /opt/openproject/Gemfile.modules ~/Gemfile.modules.bak
```

2. Clone the Chart plugin from github:

```
git clone --branch v1.0.0 git@github.com:aballa-bo/openProjectMeasurementCharts.git
```

3. browse to the cloned folder and install the plugin through the following command:

```
sudo bash install.sh
```

After the install script has finished running, the server will reload its service. For a few seconds the server will be unreachable. As soon as the server is back, you can enable the newly installed module. This configuration can be project specific.

To enable it:

- Select the project
- Go to project settings
- Modules
- Enable the module “Measurement Charts”

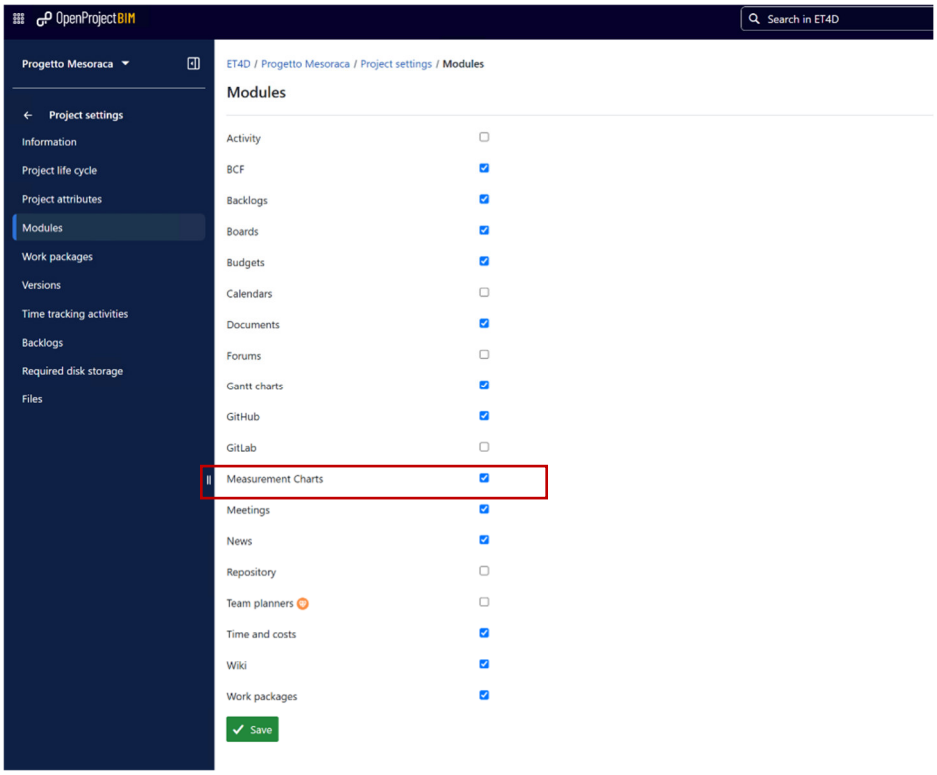


Figure 7 - Once installed, enable the Measurement Charts Module in the project module settings

9. Development, test and production environments

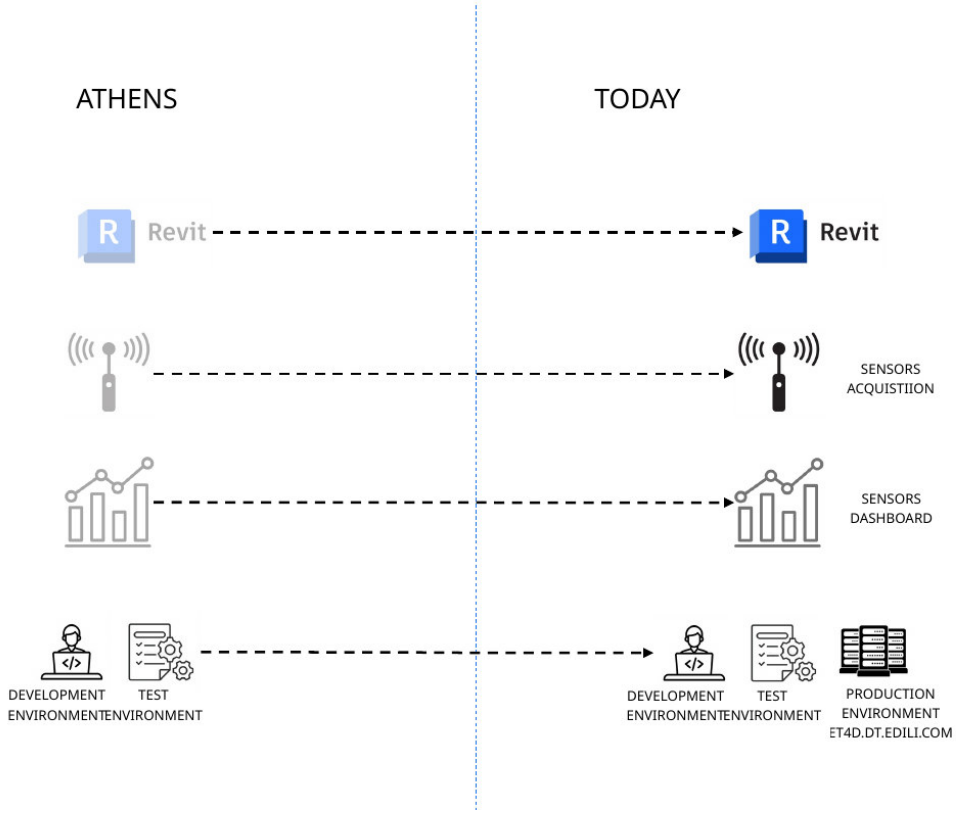


Figure 8 - Evolution of the ET4Digital technical environment from development/test to production, including sensors and dashboard.

A three-stage architecture — development, test and production — is recommended for controlled change management. This separation allows functions to be introduced or modified in the development environment, verified in the test environment and transferred to production only after validation.

- Development environment: used by developers to add or modify features.
- Test environment: used by testers or project managers to evaluate new features before release.
- Production environment: hosts the instance used for operational and training activities. In the ET4Digital implementation, the production instance is available at et4d.dt.edili.com.
- Promote a change to production only after it has passed the agreed tests in the test environment.

Security note: the organisation hosting the system must define and document access-control rules, firewall configuration, TLS/HTTPS certificates, secrets management, backup and restore, updates and administrative responsibilities. These measures must be verified before production deployment.

10. Replication verification checklist

The following acceptance checks form the minimum verification sequence for the replicated system. An installation should be considered technically functional only after the relevant checks have been completed and the corresponding results recorded.

Area	Acceptance check	Result
Platform	The OpenProject BIM environment is reachable and an administrator can access the administration console.	☐ Pass ☐ Fail ☐ N/A
Project	A demonstrator project exists with members, Work Packages and a WBS structure.	☐ Pass ☐ Fail ☐ N/A
BIM	At least one IFC model can be imported and visualised.	☐ Pass ☐ Fail ☐ N/A
Coordination	BCF / issue functionality can be used in relation to the BIM model.	☐ Pass ☐ Fail ☐ N/A
Schedule	Project activities can be viewed in the Gantt chart with dates/dependencies.	☐ Pass ☐ Fail ☐ N/A
Sensor data model	A dedicated measurement Work Package type and the required custom fields exist.	☐ Pass ☐ Fail ☐ N/A
API	The Raspberry Pi / acquisition software can communicate with the OpenProject BIM APIs.	☐ Pass ☐ Fail ☐ N/A
Hardware	The configured sensor stack can produce consistent measurements and transmit them to the system.	☐ Pass ☐ Fail ☐ N/A
Visual data	The camera can acquire images and the processing routine can produce the intended output.	☐ Pass ☐ Fail ☐ N/A
Data protection	Camera positioning, image storage and people counting have been assessed against the applicable data-protection rules (GDPR).	☐ Pass ☐ Fail ☐ N/A
Storage	Measurements are recorded in OpenProject BIM while maintaining the intended relationship with project and time.	☐ Pass ☐ Fail ☐ N/A
Dashboard	Sensor data can be visualised through the dashboard plugin.	☐ Pass ☐ Fail ☐ N/A
Release process	Changes can be tested before being promoted to production.	☐ Pass ☐ Fail ☐ N/A

11. Installation-specific parameters (Configuration Record)

Certain parameters depend on the specific installation and must be defined and recorded by the organisation implementing the system. The following list constitutes the minimum "Configuration Record" to be completed and kept up to date together with this guide; the values used in the ET4Digital implementation are indicated, where relevant, in the previous sections.

- OpenProject BIM version and list of installed plugins.
- Revision/tag of the sensor-dashboard plugin installed.
- Complete OpenProject plugin installation/rebuild commands for the selected deployment method.
- API endpoint, API key and secure storage of credentials for the local installation.
- Mapping between sensor values, Work Package type and custom-field IDs in the local installation (see Section 5).
- Operating-system image/version used on the Raspberry Pi.
- Electrical connection and bus configuration of any sensors not mounted on the Enviro+ board.
- Network architecture and DNS, TLS/HTTPS and reverse-proxy configuration.
- Database backup, restore and upgrade procedure.
- Role and permission matrix for trainers, students, administrators and developers.
- Minimum server/VM hardware sizing and storage requirements.
- End-to-end commissioning test with expected results.

Recommended action: complete the items above in a project-specific "Configuration Record" and keep it under version control together with the local copy of this annex.

12. Relationship with the main text of D3.3

This annex complements the methodological content of the main text with the technical implementation pathway. The main text defines the demonstrator as an adaptable configuration based on the integration of the real project, information model, planning and data flows; this guide specifies how to configure the main digital components and how to verify their operation. Replication can be calibrated according to the complexity of the real project, the information level of the model, the degree of sensor and data integration, and the way the collaborative platform is used.

Table 4- D3.3 comparison

Replication dimension	D3.3 main text	This technical annex
Method and educational use	Primary reference	Technical complement
Physical/digital architecture	Conceptual description (Sections 2–4)	Implementation structure
Collaborative platform	Methodological and educational use (Sections 4, 7 and 9)	Deployment, configuration and verification of OpenProject BIM

Replication dimension	D3.3 main text	This technical annex
IFC/BIM workflow	Role of the information model (Section 5)	Technical integration role
Sensors and data	Educational/data-driven use (Part III)	Hardware + API + acquisition workflow
Dashboard	Educational use of visualisation (Section 8.6)	Plugin installation/configuration
Adaptability	Primary reference (Section 10)	Configuration points and acceptance checks

Reference sources

Repositories and technical references:

1. https://github.com/aballa-bo/enviro-iiple.git;
2. https://github.com/opf/openproject-docker-compose.git
3. https://charts.openproject.org

OpenProject package repository for stable/16 on Ubuntu 22.04.

Usage note: installation-specific parameters must not be replaced with generic values. For each replication, the Configuration Record must be completed and versioned, including software, plugins, endpoints, IDs, network, security, backup and commissioning-test results.

ET4Digital

Empowering Trainers for Digital Innovation in the Construction Ecosystem

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