D3.1 – Technology Demonstrations

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 958450. This document reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains.

Project Title	Improving Building Information Modelling by Realtime Tracing of Construction Processes
Project Acronym	BIMprove
Grant Agreement No	958450
Instrument	Research & Innovation Action
Topic	Industrial Sustainability
Start Date of Project	1st September 2020
Duration of Project	36 Months

Name and Number of the deliverable	3.1 – Technology Demonstrations
Related WP number and name	WP 3 - Integration, testing & piloting
Deliverable dissemination level	Public
Deliverable due date	30 September 2021
Deliverable submission date	30 September 2021
Task leader/Main author	Klodian Gradeci (SINTEF)
Contributing partners	SINTEF, VTT, ZHAW, ROBI, AFG
Reviewer(s)	Gabor Sziebig (SINTEF)

Abstract

This report is the first version of BIMprove's Deliverable *3.1. Technology Demonstration*. The report describes the functional elements developed until M12 of BIMprove project and it will be updated with newer results after the end of each cycle marking M19 and M25. It provides a snapshot of the devloped technologies, and refers to the BIMprove video depository, where the developments are more comprehensively demonstrated through video recordings.

Keywords

Technology demonstrations; demos; functionalities

Revisions

Version	Submission date	Comments	Author
v0.1	01.09.2021	Initial version	Klodian Gradeci (SINTEF)
v0.2	15.09.2021	Corrections	Ruprecht Altenburger (ZHAW)
V1.0	30.09.2021	Approved, final version	Gabor Sziebig (SINTEF)

Disclaimer

Acronyms and definitions

Acronym	Meaning
AR	Augmented Reality
BCF	BIM Collaboration Format
BIM	Building Information Modelling
IFC	Industry Foundation Classes
MUVR	Multi User Virtual Reality
VR	Virtual Reality
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle

BIMprove project

In the past 20 years, productivity in the European construction industry has increased by 1% annually only, which is at the lower end compared to other industrial sectors. Consequently, the sector has to step up its digitization efforts significantly, on the one hand to increase its competitiveness and on the other hand to get rid of its image as dirty, dangerous and physical demanding working environment. Construction industry clearly needs to progress beyond Building Information Modelling when it comes to digitizing their processes in such a way that all stakeholders involved in the construction process can be involved.

The true potential of comprehensive digitization in construction can only be exploited if the current status of the construction work is digitally integrated in a common workflow. A Digital Twin provides construction companies with real-time data on the development of their assets, devices and products during creation and also enables predictions on workforce, material and costs.

BIMprove facilitates such a comprehensive end-to-end digital thread using autonomous tracking systems to continuously identify deviations and update the Digital Twin accordingly. In addition, locations of construction site personnel are tracked anonymously, so that **BIMprove** system services are able to optimize the allocation of resources, the flow of people and the safety of the employees. Information will be easily accessible for all user groups by providing personalized interfaces, such as wearable devices for alerts or VR visualizations for site managers. **BIMprove** is a cloud-based service-oriented system that has a multi-layered structure and enables extensions to be added at any time.

The main goals of **BIMprove** are a significant reduction in costs, better use of resources and fewer accidents on construction sites. By providing a complete digital workflow, BIMprove will help to sustainably improve the productivity and image of the European construction industry.

Contents

Index of Figures

Context

Scope: This report is the first version of BIMprove's Deliverable *3.1. Technology Demonstration*. The report describes the functional elements developed until M12 of BIMprove project and it will be updated with newer results after the end of each cycle marking M19 and M25. The report demonstrates a wide range of BIMprove developments covering stationary, ground- and UAV-based data acquisition systems; augmented reality (AR) visualisation of BIM model; application of multi-user virtual reality (VR); computer vision model for detection of safety structures in the construction site; mapping of point clouds to IFC elements; and BIMprove web front end. This document provides a snapshot and a short description of each development, and refers to the BIMprove video depository, where the development are more comprehensively demonstrated through video recordings. The subsequent updates of this deliverable will illustrate the presented functionalities in a more advanced level and will include newly developed ones.

BIMprove: The BIMprove project (Improving Building Information Modelling by Realtime Tracing of Construction Processes) is intended to demonstrate how key processes can be automated and how the digital twin concept, representing a dynamic and expanding image of a real building asset, can benefit the management of a building throughout its life cycle. The overall objective of the BIMprove project is to go beyond the static BIM approach and create a digital thread that acts as a dynamic metrical building model, a digital twin. This will promote the easy monitoring of construction site status, effective resource scheduling and improved work planning. The new technology will offer greater levels of flexibility and safety, and enhanced productivity.

Audience: This report targets all active organisations along the construction value chain including contractors; suppliers of building materials, chemical and construction equipment; architecture and engineering firms; building owners and developers. Government authorities, which may impact the future of the industry via regulations and standardisation, or act as the main procurer of the construction projects, are also a targeted audience. Furthermore, this reports targes also members of academia and research institutes as a resource to foster effective collaboration and build upon BIMprove project in the future.

Foreword

BIMprove project will invest in the development of a system that promotes fast-track productivity by cutting costs and improving working conditions by employing 3D model-based BIM systems in combination with a digital twin technology to the construction sector, constituting a dynamic and multi-functional system based on real-time data. The technology will enable a real-time status overview of all construction sites, facilitating the early identification of errors and their remediation at the lowest possible cost. It will also be possible to control resource scheduling and transactions in real time, hence, ensuring high levels of construction site security and efficient adherence to, and adaptation of, work schedules, according to need. The technology is actualised using ground-based robots and unmanned aerials vehicles (UAVs) to monitor site status and detect deviations that can be used to update the digital twin and the underlying BIM model. It will facilitate the anonymous tracking of site personnel, thus enabling both the system and personnel supervisors to optimize resource allocation, personnel flow, and worker safety. The BIMprove system will be easily accessible to all stakeholders in the form of various user interfaces, including the provision of notifications to site workers via wearable devices, and to supervisors via virtual reality (VR) visualisations. The system will be a cloud-based service with a layered structure, enabling the addition of future extensions, as required.

The BIMprove system will be developed in a series of six-monthly iterative cycles, which will ensure adequate time for the fine-tuning of system functionalities to meet the requirements of the consortium's industry partners. This aim of this report is to demonstrate developed functional elements of the BIMprove system after the first 12 months of the project. This report firstly introduces the overall BIMprove data architecture, which provides an outlook of the anticipated technology developed throughout the project. Afterwards, it provides a snapshot and a short description of each of the developed functionalities and demonstrates them through video recordings, which will be stored in the BIMprove video depository and can be accessed by the targeted audience and the public through the provided link.

The BIMprove Data Architecture

The BIMprove system is constructed from some loosely coupled data interfaces that each provide sporadic information updates, while the core element, referred to as a 'backend', provides highly integrated and near real time information exchange for use in data analytics and visualization services, as described in the BIMprove requirements list.

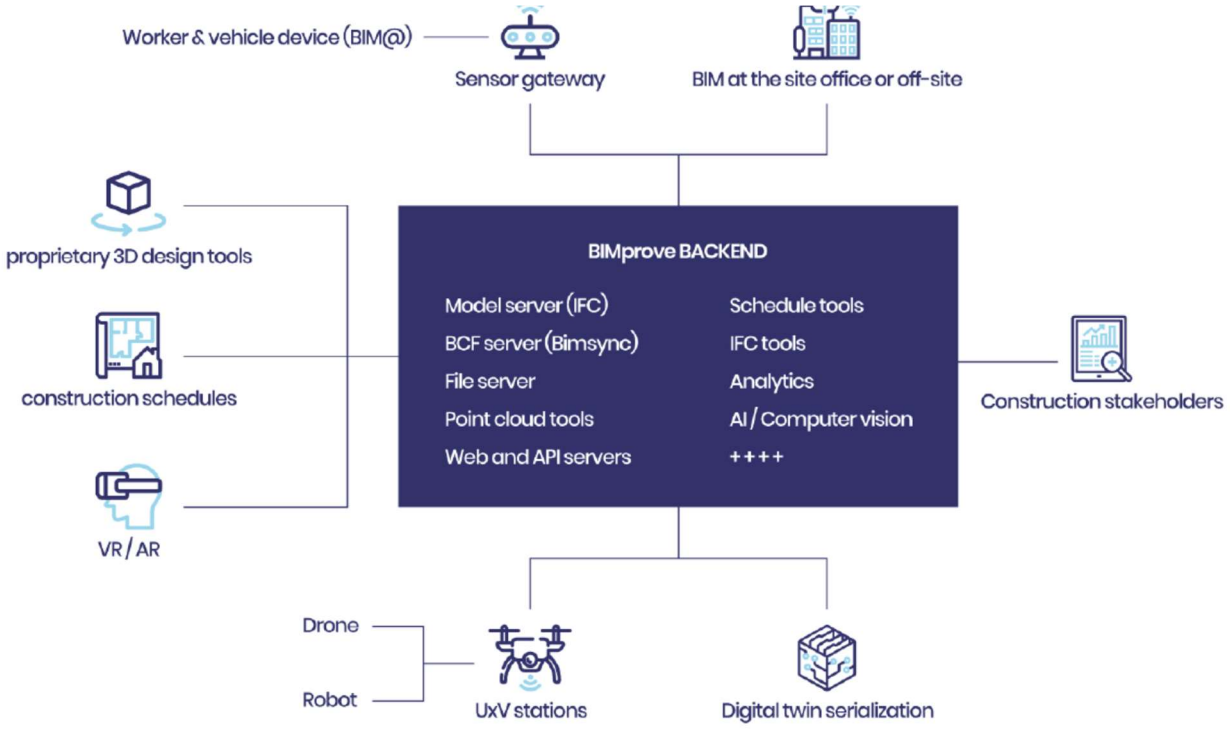

Figure 1. The main components of BIMprove data architecture

The main components of the BIMprove data architecture are visualized in the figure above. and described in the following:

Proprietary 3D design tools. Building asset designers (architects and engineers) will work using their own applications, such as Revit, ArchiCAD, Tekla, MagiCAD, DDS and Allplan, in the same way as they do today. In a BIMprove context, such tools will output in open BIM (IFC) models that illustrate the 'as-designed' appearance of the building asset that includes not only its 3D-geometry but also rich information on physical elements such as slabs, walls and windows, as well as non-physical elements such as rooms, building storeys, zones, systems and design layers. If any design changes are initiated from BIMprove, these will be issued by BCF.

Construction schedules. Provided they exist, highly detailed (daily) construction schedules will be stored in a variety of highly heterogeneous ways, and may be exchanged using IFC (e.g., IfcTask). However, such exchanges will only be carried out very rarely. BIMprove will enable data entry either manually or by another standardized approach, such as by using a predefined scheme.

VR/AR. Data visualization is one of the main benefits of digital twins. Geometry derived from IFC (with intact identifiers) can be presented on demand in VR and AR applications, and users can return tasks/issues to the backend using BCF.

UxV stations. Drones and mobile ground exploration robots are not directly connected to the backend, but communicate indirectly via intermediate stations, which obtain their data from the backend to plan their UxV reality capture paths. These paths are based on data from the future construction and its location, taken from the schedule and BIM models. The stations send back point clouds, aligned with the coordinate system of the BIM models, together with geometry derived from the point clouds and thermal photos.

Digital twin serialization. In contrast to a BIM file, a BIMprove digital twin cannot simply be exported from or transferred between construction sites. This raises the question of how a digital twin, representing the sum of all information, can be accessed after the project end date. We propose to develop a strategy for the serialisation of key data, including revisions and time stamps so that the content of the main data entities can be restored outside the system. Our aim is to achieve this as far as is practically possible using open standards such as IFC for BIM, open point cloud formats, open image formats, BCF for issue history, etc.

Construction stakeholders. The various stakeholders will be presented with the information that they have to consider and decide on. For example, a scanning function may be introduced to see if security protection is present when it should be. This will enable decision-makers to inspect the point cloud (perhaps accompanied by a system-generated suggestion), determine whether a deviation has occurred and, if so, decide what the next step should be.

BIM at the site office or off-site. It will be possible to visualise and analyse a wide range of information both at the site office and off-site. Information from scans, as-designed BIM, schedules, etc., will be made available from the backend and viewed on a big screen or in virtual reality. Questions and decisions that require human intervention can be sent to the backend using BCF.

Sensor gateway. Sensor data such as worker or truck positions are sent to the backend via the gateways. Urgent warning notifications, such as a truck reversing towards a worker, are sent directly to the worker or truck, and not via the backend.

Technology Demonstrations

Demo 1: Augmented Reality (AR) visualisation of BIM Model

Description: The demo shows BIM@Construction AR tool demonstrated with Android table and Microsoft HoloLens 2 devices.

Outcome: The following functionalities have been demonstrated: BIM Model visualisation in AR in 1st and 3rd person point of view.

Snapshot of the demo:

Figure 2. Augmented Reality (AR) visualisation of BIM Model

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 2: Multi-User Virtual Reality

Description: The demo shows the different functionalities already implemented in the MUVR-Viewer.

Outcome: The following functionalities have been implemented and tested successfully for both PC- and VR-users: a) automatically loading 3D-geometry (including point cloud-data) and deriving a user-menu from it; b) connecting to a virtual room and joining a multi-user-session; c) (de-)selecting 3D-models to show/hide them; d) 1st rudimentary version of issue management; and e) means of remote communication.

Snapshot of the demo:

Figure 3. Multi-User Virtual Reality

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 3: Ground Robot BIMprove system integration and operation

Description: The demo shows how the localization and navigation on ground robots works, by illustrating the integration between Bimsync and Robotnik's Backend, in which one the robot automatically gets both 2D and 3D model and use them to locate and navigate on site.

Outcome: The use of 2D-3D BIM models for ground robot navigation and localization.

Snapshot of the demo:

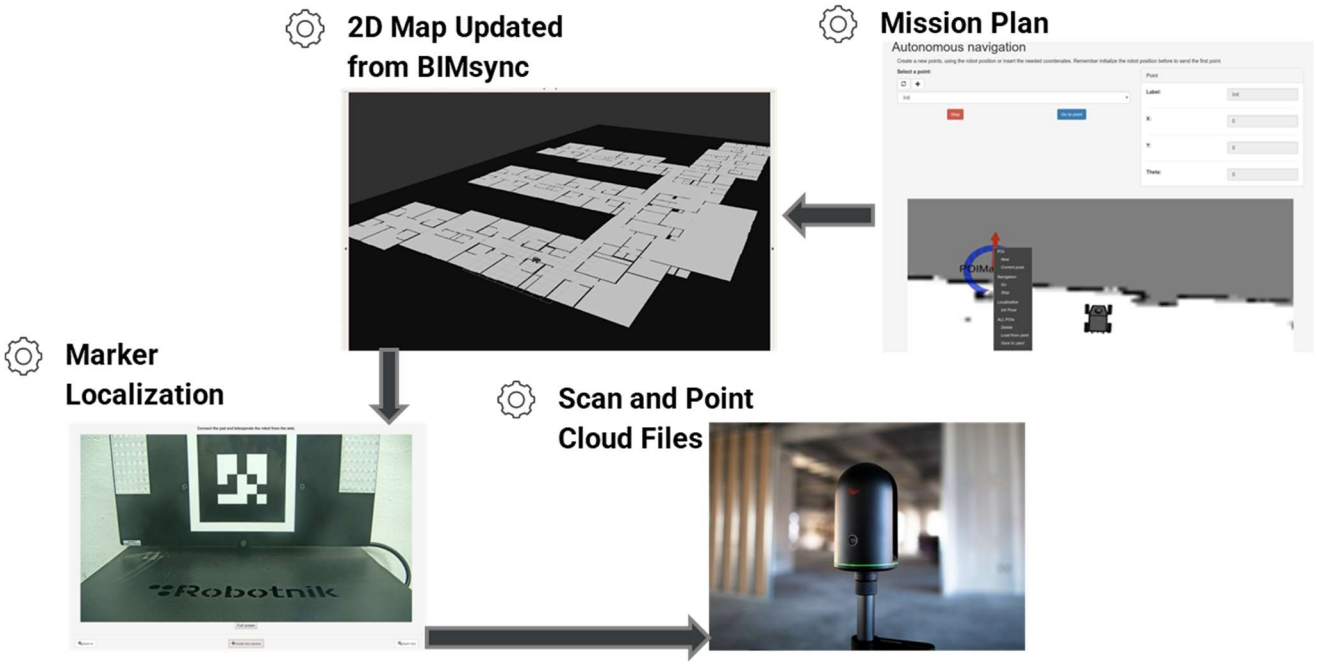

Figure 4. Ground robot BIMprove system integration and operation

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 4: Leica BLK 360 Point-clouds scans

Description: The demo shows the Leica BLK360 laser scanning the scene by obtaining the point cloud, heat map and high resolution images.

Outcome: Through the SW Cyclone the laser scanning information is obtained and allows to export it to e57 for its interpretation.

Snapshot of the demo:

Figure 5. Ground robot BIMprove system integration and operation

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 5: Data-capturing drones

Description: The demos shows the inndoor helicopter flight with on-board sensors, gimbal camera for data capture, and the process of scanning at fixed distance and angle to wall.

Outcome: A stable flight, flexible system, and extendable with other sensors/needs.

Snapshot of the demo:

Figure 6. Data capture drones

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 6: Detection of safety structures and untidy places in images

Description: The demo shows the computer vision based analyser finds safety barriers, safety nets and untidy places from the construction site images. These are pointed out with rectangles in the images. Health and safety inspections are required at construction sites to prevent accidents including falling from heights and fire hazards. In BIMprove, safety inspections will be supported by computer vision.

Outcome: Computer vision model for detecting safety barriers, safety nets, and untidy places in received images. Web UI for viewing the results.

Snapshot of the demo:

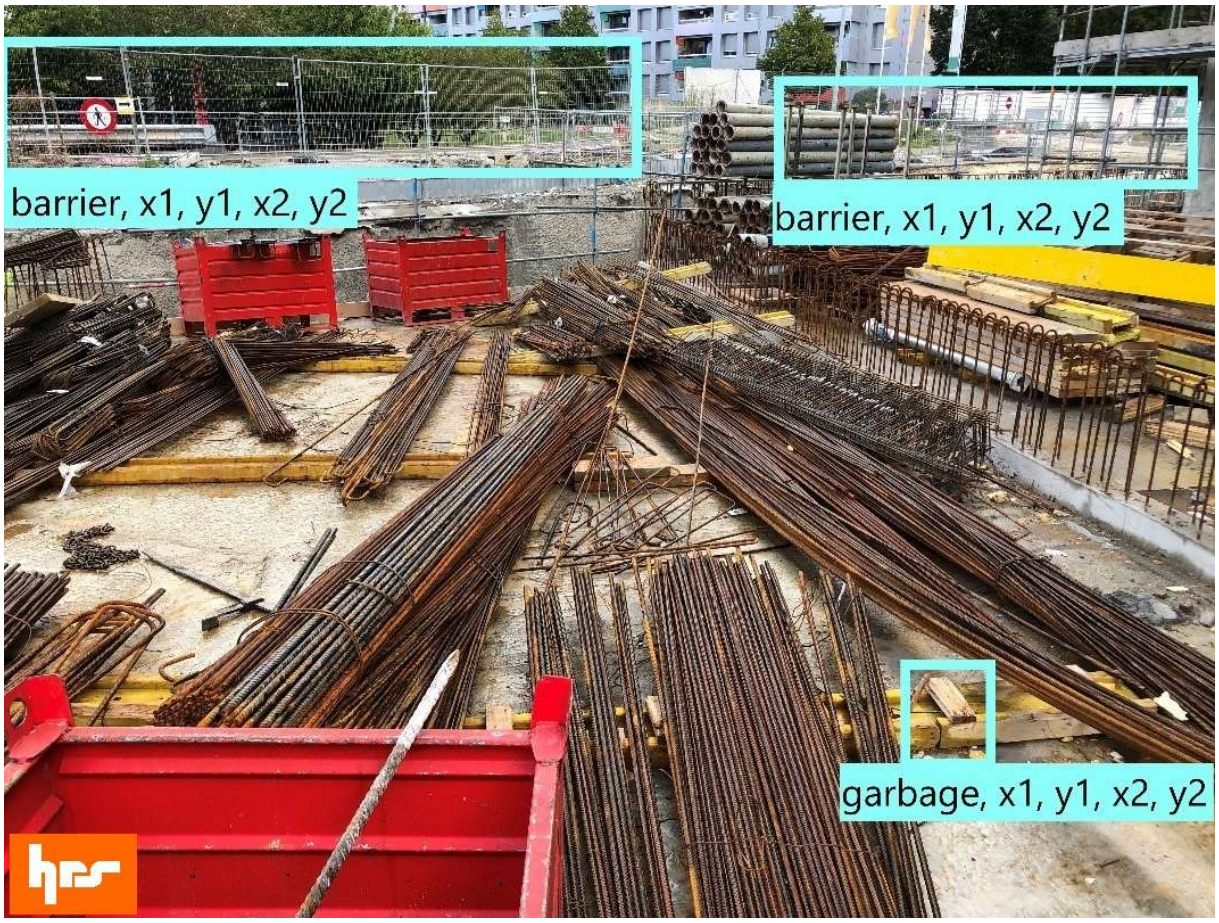

Figure 7. Detection of safety structures and untidy places in images (© HRS)

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 7: Mapping point clouds to IFC-elements

Description: The demos shows the classification of which points in a cloud that belongs to a certain IFC-element.

Outcome: Two point clouds, one consisting of all points mapped to an ifc-element and the second is all points to mapped to an ifc-element.

Snapshot of the demo:

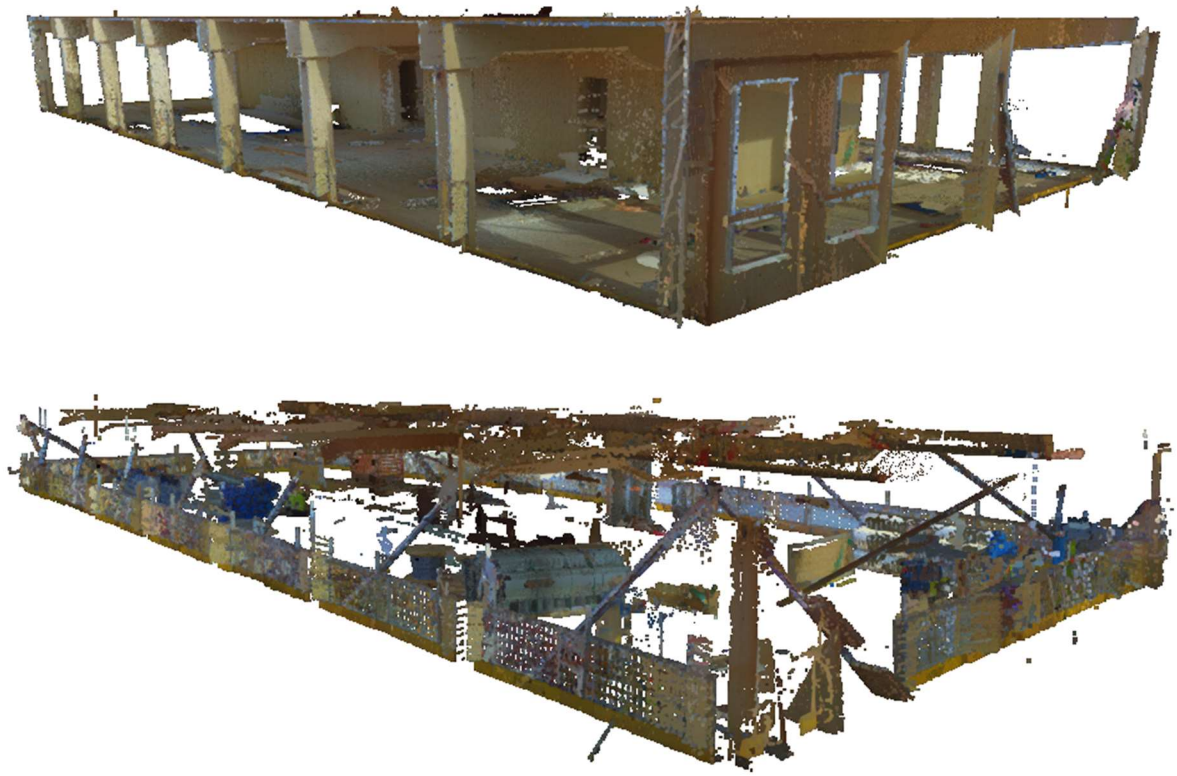

Figure 8. Mapping point clouds to ifc-elements

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 8: Revision change visualisation

Description: The demo shows BIMSync Backend register revisions update of IFC-file, which produces a difference file between original and new revision.

Outcome: Colored IFC-file illustrating the difference and a BCF issue list.

Snapshot of the demo:

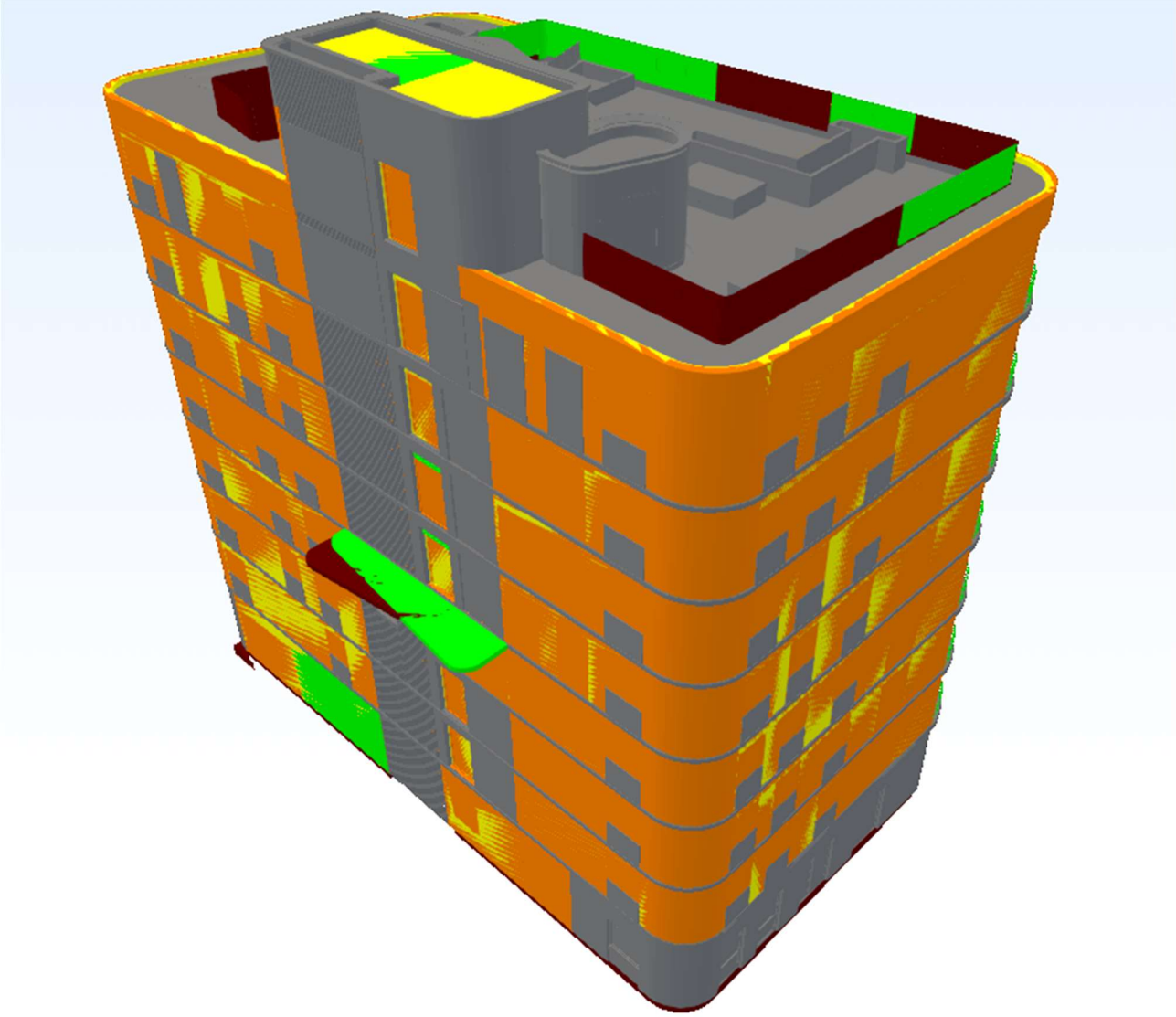

Figure 9. Revision change visualisation

Link to video: https://www.bimprove-h2020.eu/demos/

Demo 9: Schedule import and view

Description: The demo shows the import schedule from Microsoft Project native format into a database, and this data in a Gantt diagram on a web page.

Outcome: Import and viewing of schedule works with MPP files.

Snapshot of the demo:

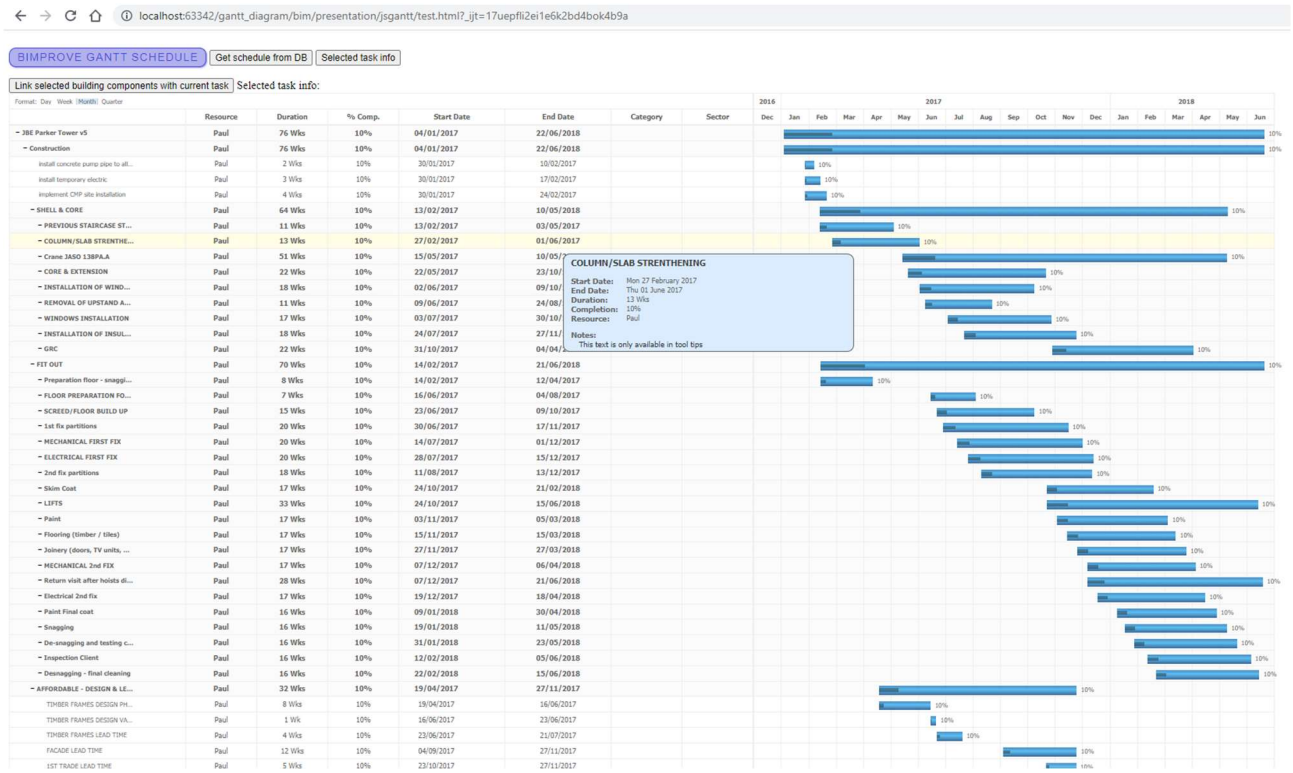

Figure 10. Schedule import and view

Link to video: https://www.bimprove-h2020.eu/demos/