



BIM based fast toolkit for
Efficient rEnovation in Buildings

D4.9 Tested version of the platform



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D4.9 Tested version of the platform

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EXECUTIVE SUMMARY

One of the most critical task in the renovation activities is to collect and gather the information of the existing buildings to develop better solutions to support the early design phases and the construction activities. A good infomation management between stakeholders during renovation operations allows to improve timing, costs, labor, materials, and energy management, to provide finally the best construction developments to the communities. The development of a BIM management system (BIMMS) platform aims to optimize the management of information (collection, share, update, and exchange) during the different stages of a BIM-based renovation process to improve the efficiency compared to traditional processes.

The BIMMS platform is built around a Common Data Environment (CDE) that store, share and visualise BIM models, manage documents, sensors' data-streaming and will link the building data with the richness of semantic web in a common environment. The BIMMS platform is natively open for the integration of digital tools (BIM4EEB toolkit) to support BIM-based building renovation, to exchange data through REST APIs and SPARQL Endpoint services to allow different stakeholders to share information and efficiently manage the renovation processes.

This deliverable document the work carried out in the Working Package (WP) 4 - Task 4.6 about testing and validation, to release the tested version of the BIMMS platform with the complete functionalities ready to be tested and validated with the whole BIM4EEB toolkit on demonstration sites. The document provides the status of the BIMMS functionalities updated and implemented in the final version released in M30 (June 2021). The first section of the deliverable introduces the testing activities with the description of the testing environment, the tests performed, and the results obtained. The second section documents functionalities updated, and the last developments included in the final version of the BIMMS.

PUBLISHING SUMMARY

This deliverable describes the testing activities done in the final version of the BIM Management System (BIMMS) platform. The BIMMS is a collaborative platform with a Common Data Environment (CDE) that allows to store, share and visualise BIM models, manages documents, sensors' data-streaming, and can link the building data with the richness of semantic web in a common environment.

The document describes the enviroment arranged to test the platform, the use cases applied, and the results achieved. Moreover is provided the updated documentation of the BIMMS with the complete functionalities implemented (Web platform, REST API, and SPARQL Endpoint) in the final version released in M30 (June 2021). The deliverable documents the readiness of the final version of the platform to be tested and validated with the whole BIM4EEB toolkit on demonstration sites.

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1 Introduction

1.1 Scope of the document

This document describes the work carried out to release the tested version of the BIM Management System platform (BIMMS). The BIM Management System (BIMMS) platform incorporates a Common Data Environment (CDE) that act as a single source of truth (SSOT) storing all the data and information gathered along the whole building life-cycle, through different sources. The BIMMS can manage documents, data streaming from sensor devices, BIM Models and Linked Data resources in a single environment managing the user access control, versioning and data exchange through the REST APIs and SPARQL Endpoint services.

The testing activities are part of the work defined in the Work Package (WP) 4 - Task 4.6 about testing and validation of the whole BIM4EEB toolkit on demonstration sites.

This deliverable focuses on the testing of the BIMMS platform with all the functionalities updated and implemented in the final version released in M30 (June 2021). The scope is to document and demonstrate the functionalities and the features of the BIMMS available for the different roles and stakeholders involved in the renovation work activities. The testing phase documented in this deliverable demonstrates how the functionalities developed allow the integration between the BIMMS and the toolkit (the BIM4EEB developed tools), and how other tools (i.e. the existing authoring softwares) can be integrated in the platform to further improve the collaboration among the stakeholders.

1.2 Relevance with the other deliverables

The testing phase rely on the activities done in the WP4 and documented in the deliverables listed below.

- PUBLIC DELIVERABLES:
 - Deliverable D4.7 “API, Master end-user front end”, specifying and documenting the APIs and providing an End User manual of the BIM Management System.
 - Deliverable D4.8 “Guidelines for the integration of new tools in the BIM management system”. This is a developers and reference documentation to integrate new tools in the BIM management system.
- CONFIDENTIAL ONLY FOR CONSORTIUM OR ADVISORY BOARD MEMBERS
 - Deliverable D4.1 “Technical specifications for the design of a BIM management system” deliver the technical specifications of the BIM management system.
 - Deliverable D4.2 “Users’ profiles for accessing the BIM management system”, describe the use cases, defining the users’ profiles for accessing the BIM management system and the functions allowed for each group of users.
 - Deliverable D4.3 “CDE Database, Core DB functionalities, Ontological representation, BIM data translation engine to ontology” describes the CDE DB, enriched with the core DB functionalities such as ontological representations of items and their relationships, a translation engine from BIM models to ontology, etc.
 - Deliverable D4.4 “CDE Services, Interoperability Services, Exchange Layer Services, I/O Protocols and Data specification” deals with the CDE Services Interoperability Services, Exchange Layer Services, I/O Protocols and Data specification.
 - Deliverable D4.5 “Technical configuration of the platform”, as the name suggests, gives indications about hardware and software configuration, OS, and DB setup.

- Deliverable D4.6 “Guidelines for the implementation of the BIM management system” provides the documentation such as user’s manual and guidelines to define objects, relationships, and data.

These deliverables take information from other Work Packages where has been defined the stakeholder needs (WP2), the ontologies framework (WP3), the tools’ data exchange requirements (WP5, 6, and 7), and the specific demonstration pilot sites’ requiremnets (WP8).

1.3 References to other activities and to the state of the art

Parts of the contents of this deliverable were published in conference proceedings (Sustainable Places 2020 - (Alessandro Valra, 2021)) as dissemination activities related to the project and in the official BIM4EEB project website (<https://www.bim4eeb-project.eu/> (BIM4EEB, 2020)).

1.4 Innovative results and progresses

The tested version of the BIMMS offers a set of functionalities that meet the stakeholders’ needs during the renovation work. The tested workflows demonstrate that the BIMMS can integrate tools and enable the data interoperability through data exchange services. The proposed implementation can prevent some bottleneck tasks (i.e. the export, upload, download, and import cycle) used in the traditional file exchange to improve the time and cost reduction. Moreover, the BIMMS’ CDE includes some functionalities to support the Linked Data that allow users to define and retrieve resources exploiting the richness of the Semantic Web.

1.5 Structure of the document

The document is structured in two main sections: the first one introduces the testing activities with the description of the testing environment, the tests performed, and the results obtained. The second one documents the updated functionalities, and the last developments included in the final version of the BIMMS.

2 Testing activities

2.1 Introduction

The main scope of the testing activities is to evaluate the functionalities and the feature of BIMMS platform, and to release the tested version in M30 (June 2021). The development phase of the BIMMS platform lasts from M7 (July 2019) to M30 (June 2021), with the first deployment in the production server done in M14 (February 2020). Since the first deployment, the BIMMS has been periodically updated to progressively implement the functionalities planned in the development roadmap. Issues and request for changes have been resolved in a feedback loop with the other project partners to support the parallel developments of the toolkit. In this context the BIMMS platform has been available through Internet with almost 98% of uptime and availability. The host server has been secured and protected, and the users can register and authenticate to start to work with the BIMMS functionalities. Almost all the partner’s team members have been registered and successfully authenticated to the platform and have been accessed to the default testing and the three demonstration site projects.

The official testing phase documented in this deliverable has been performed by One Team as lead developer of the BIMMS, but it should be taken into consideration that some use test cases have been also performed by other project partners during their development activities. The interaction with the project partners’ users has been a first test that demonstrates the capability of the platform to manage the user and project management features including the requirements for the invitation, registration, authentication, and the GDPR notifications. Moreover, the developers use the data exchange services as the REST APIs and SPARQL Endpoints to connect and integrate their tools.

2.1.1 General settings

To test the BIMMS’ functionalities and features several test cases have been defined using the template table shown in Table 1. The test cases are grouped in general test cases and specific test cases:

- General test case: a test case that describes a typical collaboration between two or more users and roles, to complete more than one task related to a specific renovation work phase. A typical general case is the collaboration between the inhabitant and the owner or two design teams. In these test cases, more than one functionality can be used, and the main goal of the test is to demonstrate the successful interaction between the roles and the completion of the entire workflow.
- Specific test case: a test case that evaluates the single functionalities available in the BIMMS’ End user front end (Web portal).
- Interaction between BIMMS and BIM authoring tools: these test cases evaluate the capabilities of the BIMMS to support the integration of external tools. In particular the integrations with the BIM authoring tools are tested.

Table 1 - Test case template

TEST CASE NAME	The name of the test case
BRIEF DESCRIPTION	A brief description of the functionalities that are involved in the test case.
GOAL	The goal of the specific test case
SUCCESS MEASUREMENT	The expected results of the test case
PRE-CONDITION	The required pre-condition to perform the test
TRIGGER	The trigger event to the test case
TYPICAL FLOW OF EVENTS	A brief description of the passages required to complete the test case.

2.1.2 Testing environment and dataset

To simulate a typical renovation project using the BIMMS functionalities, a demo project has been created as testing environment.

The testing environment includes:

- the creation of the different users involved in the project, and the assignment of the BIMMS roles to enable the functionalities and the default permissions.
- the creation of the dataset to define resources in the BIMMS' CDE to store and share documents.
- the use of external tools like BIM authoring tools, BIM viewer and document authoring tools.

Demo Testing project:

- One Team Demo

2.1.2.1 Users and roles

The testing environment is set on the One Team Demo project, creating a set of users with assigned roles. In the BIMMS a role “define a set of permissions that allow users to access to specific functionalities and a user can have more than one role” (One Team, 2021). All the roles available by default in the BIMMS were tested and assigned to the users, following the list in the Table 2.

In the tested version of the BIMMS, seven different roles are available:

- “The BIMMS Administrator: this role is assigned to the user who implements the BIMMS in the Organization. This role can setup the BIMMS and create Projects and assign the Project Administrator role to a user.
- The Project Administrator: this role is assigned to the responsible person of individual projects in the Organization. This role manages the Projects and the users assigned to a project, also defining the role for every single user.
- The Guest: this role is assigned by default to any user registered to the BIMMS before being assigned to a specific role by the BIMMS Administrator or the Project Administrator.
- The End-User: this role is assigned to the inhabitants of the apartments in a Building. The End-User may also have a Owner role if he or she owns the apartment;
- The Owner: this role is assigned to the owner of one or more apartments, buildings, or any other ancillary asset in the Project.
- The Professional: this role is assigned to the people appointed to give consultancy and lead Architectural, Engineering and Construction activities on the apartment, building, other ancillary asset in the project.
- The Developer: this role is assigned to the users that develop the tools to access the BIMMS data” (One Team, 2021).

Table 2 – BIMMS Users and roles mapping

User type	BIMMS Role
BIMMS Administrator	BIMMS Administrator
BIMMS Project Administrator	BIMMS Project Administrator
Guest	Guest
Application	Developer
End-user/Inhabitant	End-user
Client/Owner	Owner
Client adviser	Professional
Technical adviser	Professional
Project leader	Professional
Site surveyor	Professional
Lead designer	Professional
Architectural designer	Professional
Structural designer	Professional
Building services designer	Professional
Fire safety designer	Professional
Landscape designer	Professional
Cost consultant/quantity surveyor	Professional
Health and safety adviser	Professional
Access consultant	Professional
Acoustic consultant	Professional
BREEAM assessor	Professional
Cladding specialist	Professional
Facilities management (FM) adviser	Professional
Information manager	Professional
Interior designer	Professional
Landscape architect	Professional
Lighting designer	Professional
Masterplanner	Professional
Planning consultants	Professional
Security adviser	Professional
Sustainability adviser	Professional
Contractor	Professional
Sub-contractor	Professional
Supplier	Professional
Maintenance planner	Professional
Construction lead	Professional
Contract administrator	Professional
Operational lead	Professional
Party wall surveyor	Professional
Local authority	Professional
Trier	Professional
Tenderer	Professional

Bank or third party financier	Professional
Work supervisor	Professional
Tester	Professional
HVAC Engineer	Professional
Electrical Engineer	Professional
Water and Waste Engineer	Professional

2.1.2.2 Tools

The testing environment uses some other tools to create, modify and manage the BIM Models, documents, and point clouds that were stored in the BIMMS' CDE. These tools are also used to check and validate the results of the testing activities (i.e. to check the changes applied in the IFC files using the BIMMS functionalities). Moreover, the BIM Authoring tools listed in Table 3 are used to evaluate the BIMMS data exchange services (APIs and SPARQL Endpoint) as an example to test the integration of the external tools, in particular with BIM environments.

Table 3 – Tools used in testing environment

External tool	Description
Autodesk Revit	BIM Authoring tool
Dynamo	Visual programming interface to support BIM Authoring tools
McNeel Rhinoceros	CAD and BIM Authoring tool
Grashopper	Visual programming interface to support BIM Authoring tools
Microsoft Office Suite (Word, Excel, Power Point)	Document authoring tools
Adobe Acrobat Reader	PDF Document reader
CloudCompare	Point cloud processing software

2.1.2.3 Dataset

The dataset that has been used to test the BIMMS is a collection of BIM Models, point clouds, and document resources with example data that simulate the kind of information created and shared during the typical renovation works. The Table 4 lists the documents used in the dataset, grouped by resource type.

Table 4 – Dataset used in testing environment

Resource Type	Category	Description	File format	Document/File
Document		Issue report	BCF	Issues and activities.bcf
		Datasheet – Cost data	CSV	Heat cost_selected apartments.csv
		Datasheet – Sensors List	CSV	Sensors.csv
		Datasheet – Measurements List	CSV	Temperatures.csv
		Building energy simulation file	gbXML	gbXMLStandard.xml
		As built floor drawings (scan)	JPG	CA00380007A.jpg
		Image – Leaflet	PNG	The BIM4EEB Postcard - back.png
		Instructional video	MP4	BIMMS_wikidata.mp4
		Project GANTT Chart	XLSX	Gantt Chart IT_v4_BP.xlsx
		Project report	DOCX	Activities.docx

	Project presentation	PPTX	20190327_BIM4EEB_presentation.pptx
	Design guideline	PDF	Design guidelines.pdf
	Installation guideline	PDF	Window Installation Guideline.pdf
	Installation Checklist	PDF	Installation Checklist.pdf
	Window installation drawing	PDF	Survey Window Detail.pdf
	Building floors drawing	PDF	WP8_IT__selected apartments rev 2021.pdf
	Sensor datasheet	PDF	Aeotec Z-Wave Plus Multisensor 6.pdf
	Transport datamodel	OWL	Transport.owl
	Ontology file	RDF\Turtle	MyResidentialBuilding_r02_bot.ttl
	Ontology file	RDF/XML	My Residential Building.rdf
	Classification specification	XML	Uniclass2015_Apr2021.xml
	Building's IfcZones list	JSON	IFC_ZONES.json
	Test ICDD dataset	ICDD	Test.icdd
Model	Native BIM Model	RVT	MyResidentialBuilding_r02.rvt
	IFC BIM Model	IFC	MyResidentialBuilding_r02.ifc
	Native BIM Model	RVT	CDB_SITE.rvt
	IFC BIM Model	IFC	CDB_SITE.ifc
Point Cloud	Room test survey	LAS	Survey_01.las
	Room test survey	E57	Survey_01.e57

2.2 General use test case

The general use test cases are defined taking reference the use case workflows examples described in the deliverable D4.6 “Guidelines for the implementation of the BIM Management System” (One Team, 2021) that explains the functionalities available in the BIMMS. The workflows show how the users (and roles) collaborate together interacting with the BIMMS platform and give a general picture of the data flows between users over time. Moreover the same functionality can be used for different purposes considering the purpose of the role and phase of the renovation work.

2.2.1 Use case 1: Client/Owner and Inhabitant/End-users share information through the BIMMS.

The BIMMS’ CDE can be used as document sharing platform to help owners and inhabitants to communicate, send and store documents regarding the building and the apartment. The versioning and permission features of the resources stored in the BIMMS allows to control the document changes and to manage the information securely. The users can make changes to the resources, creating new updated versions with changes. This workflow can be used to send and share documents like the building management cost report and planning, meeting reports with inhabitants, energy consumption reports, etc..

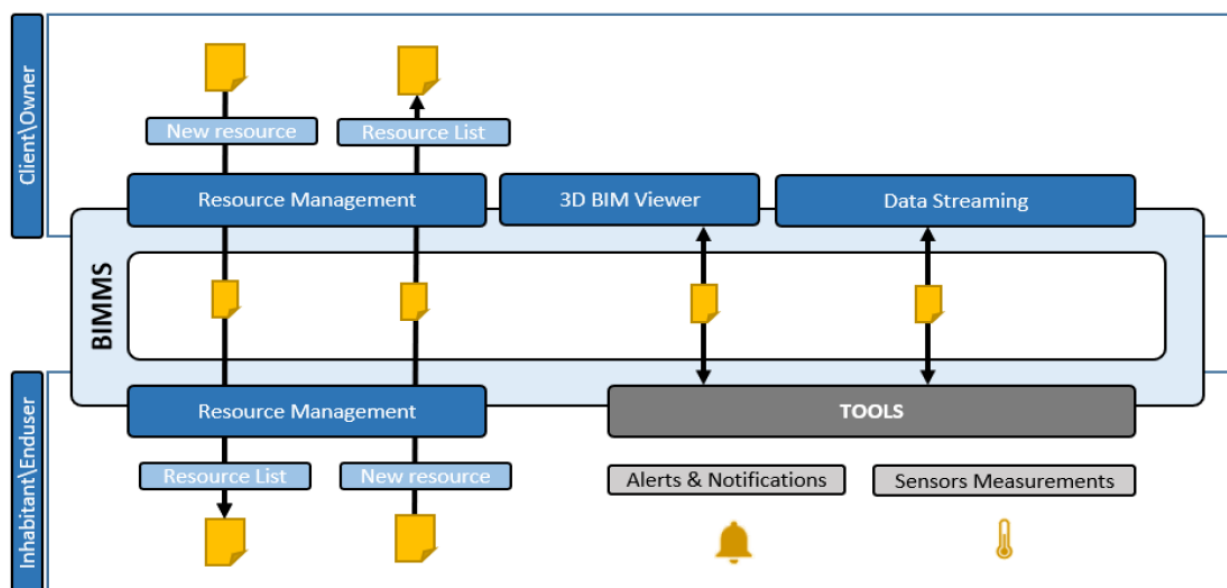


Figure 1 – The general Client/Owner and Inhabitant/End-user test case (source ref. D4.6 - (One Team, 2021))

Table 5 - Use case 1: Client/Owner and Inhabitant/End-users share information through the BIMMS

TEST CASE NAME	Client\Owner and Inhabitant\End-users share information through the BIMMS
BRIEF DESCRIPTION	The Client\Owner and the Inhabitant\End-User upload and share data regarding the building and the apartments (Documents, Contracts, Drawings, etc).
GOAL	Share documents and feedbacks between the Client\Owner and the Inhabitant\End-User.
SUCCESS MEASUREMENT	The users can create, view, and manage the resources in the BIMMS

PRE-CONDITION
TRIGGER
TYPICAL FLOW OF EVENTS

- Users must be registered in the BIMMS.
 Resource management functionalities
1. The user logs in to the BIMMS,
 2. The user creates a new resource
 3. The user uploads a file for resource,
 4. The user sets permissions on the resource,
 5. The user shares the resource with other users,
 6. The user checks the resource file and/or make changes,
 7. The user edits the resource, upload a new document, and make new revision,
 8. The user sets comments on the new revision,
 9. The user shares a new revision.

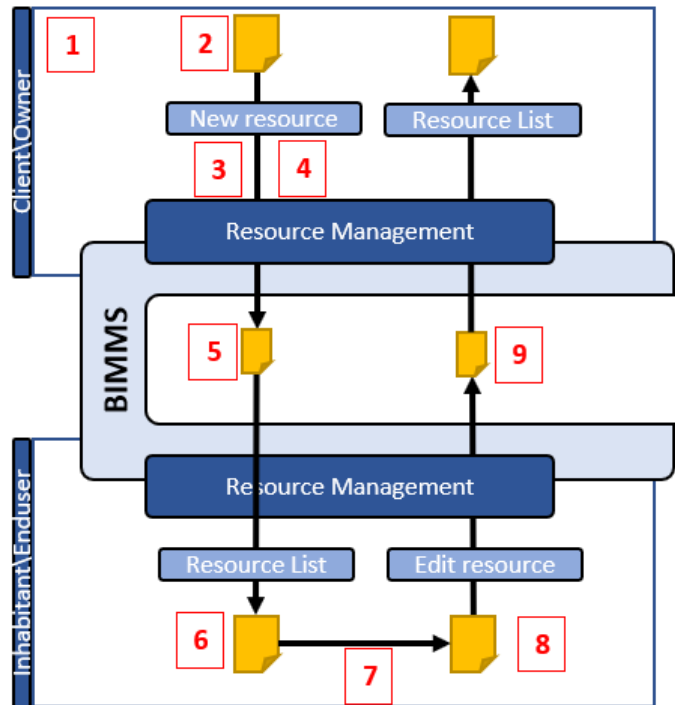


Figure 2 – General Use case 1: Client/Owner and Inhabitant/End-User interaction

Table 6 - Inhabitant\End-user receives Alerts, Notifications, Sensor measurements and give feedbacks through BIMMS

TEST CASE NAME	Inhabitant\End-user receives Alerts, Notifications, Sensor measurements and give feedbacks through BIMMS, using the BIM4EEB’s tools
BRIEF DESCRIPTION	Inhabitant\End-user receives Alerts, Notifications, Sensors measurements and provides feedbacks through BIMMS, using the BIM4EEB’s tools
GOAL	Share feedbacks, alerts, notifications, and sensor measurements to the inhabitant\Enduser.
SUCCESS MEASUREMENT	The inhabitant\end-user views, and manages alerts and notification in the BIMMS using the BIM4EEB’s tools
PRE-CONDITION	Users must be registered in the BIMMS. The user must activate the data exchange between the tool and the BIMMS using the application token provided in his\her BIMMS’ profile. The Project Administrator must defines the lfcZones for the inhabitant\end-user
TRIGGER TYPICAL FLOW OF EVENTS	<p>Resource management functionalities</p> <p>Scenario A – the Inhabitant\End-User creates and shares documents using the BIMMS</p> <ol style="list-style-type: none"> 1. The user logs in to the BIMMS, 2. The user creates a new resource 3. The user uploads a file for resource, 4. The user sets permissions on the resource, 5. The user shares the resource with other users, 6. (optional) The user checks the resource file and\or makes changes, 7. (optional) The user edits the resource, uploads a new document, and makes new revision, 8. (optional) The user sets comments on the new revision, 9. (optional) The user shares a new revision. <p>Scenario B – the Inhabitant\End-User receives Alerts, Notifications, Sensors measurements and feedbacks</p> <ol style="list-style-type: none"> 1. The user logs in to the tool (BIM4EEB Toolkit), 2. The user receives alerts and notifications in the tool 3. The user views his\her sensors and the measurements, 4. The user gives feedbacks on indoor air quality and comfort, 5. The user gives feedbacks on activity planning, 6. The user receives notifications.

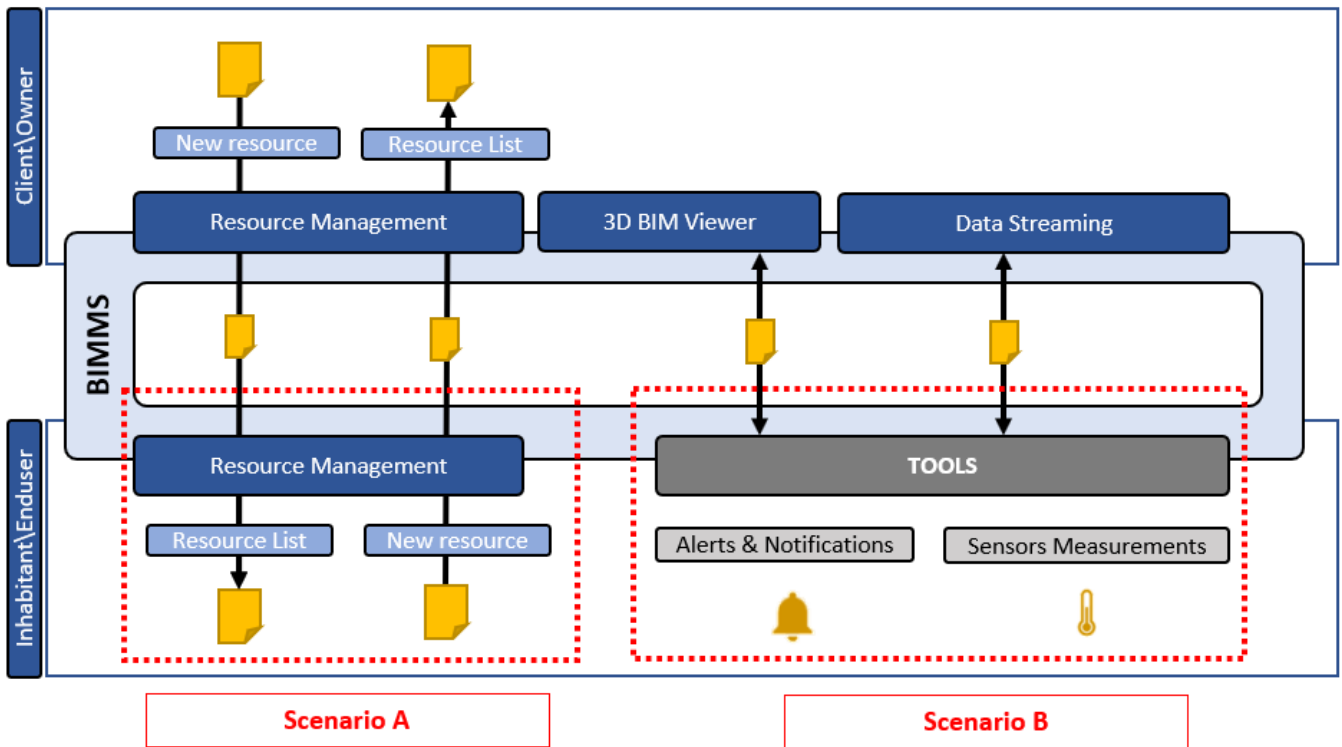


Figure 3 – General Use case 1: Inhabitant\End-user receives Alerts, Notifications, Sensor measurements and give feedbacks

2.2.2 Use case 2: Client/Owner and Professional users share information through the BIMMS.

The BIMMS' CDE can be used to share data between the Client\Owner and the Professionals appointed to provide their professional services about the building or the apartment. The Inhabitant\End-user is also benefited from the use of the BIMMS as document sharing platform to receive and give feedbacks about the activities done by the Professionals.

The Client\Owner can upload and share the data regarding the building and the apartment (documents, contracts, drawings, etc) to the Professionals to give information regarding the works to be done. "After a first upload from the Client\Owner, the resources are shared with a Professional who can start their activities. As a result, we expect a feedback loop where the roles exchange data and therefore update the necessary documents using the New Resource functionality and the New Revision feature. Professionals are also able to upload and view the 3D models using the 3D Viewer or download locally on their devices the IFC and the RDFs source files" (One Team, 2021).

Table 7 - Client/Owner and Professional users share information through the BIMMS

TEST CASE NAME	Client/Owner and Professional users share information through the BIMMS
BRIEF DESCRIPTION	The Client/Owner and Professionals share documentation (documents, contracts, drawings, BIM Models) about the renovation works. The documentation can be revised, edited, and reviewed multiple times. The design team develops the concept, preliminary, developed, and detailed designs, preparing BIM Models, design drawings, reports and specifications. Files are produced, shared, collated, and assembled between specialist consultant (such as acoustic, thermal, structural, fire, safety, environmental, etc). Lead designers checks and integrates the overall design documentation. Project Leaders oversee the execution of the building contract, monitoring, inspecting, and evaluating the documentation provided.
GOAL	The Client\Owner and Professionals are able to upload file resources (BIM models, documents, reports), set permissions to his/her team to collaborate, use the BIMMS' BIM viewer to view and check the models, upload and download changes to the BIMMS using the IFC model as reference or directly using the native model in the authoring tool of choice.
SUCCESS MEASUREMENT	A list of project resources available in the BIMMS with permissions set, revisions, approval workflows set and completed, resource status changed.
PRE-CONDITION	Users must be registered in the BIMMS.
TRIGGER	Resource management and BIM Models functionalities
TYPICAL FLOW OF EVENTS	<p>These events can be done by one or more users, that can create, edit, and manage the resources according to their permissions (as single author with exclusive permission on the resource or multiple authors with a team permission on resource). A single event can be done multiple times in a single designing task by one or more users.</p> <ol style="list-style-type: none"> 1. The design team user logs in to the BIMMS, 2. Creates resource, 3. Uploads file for resource, 4. Sets permissions on resource, 5. Visualizes resources in the resource list, 6. Visualizes BIM Models in the BIMMS' IFC BIM Viewer, 7. Downloads resource file, 8. Checks resource file and/or makes changes, 9. Uploads new revision,

10. Sets comments on new revision,
11. Starts approval workflows,
12. Approves or rejects resource changes,
13. Changes resource status,
14. Publishes and shares new revision.

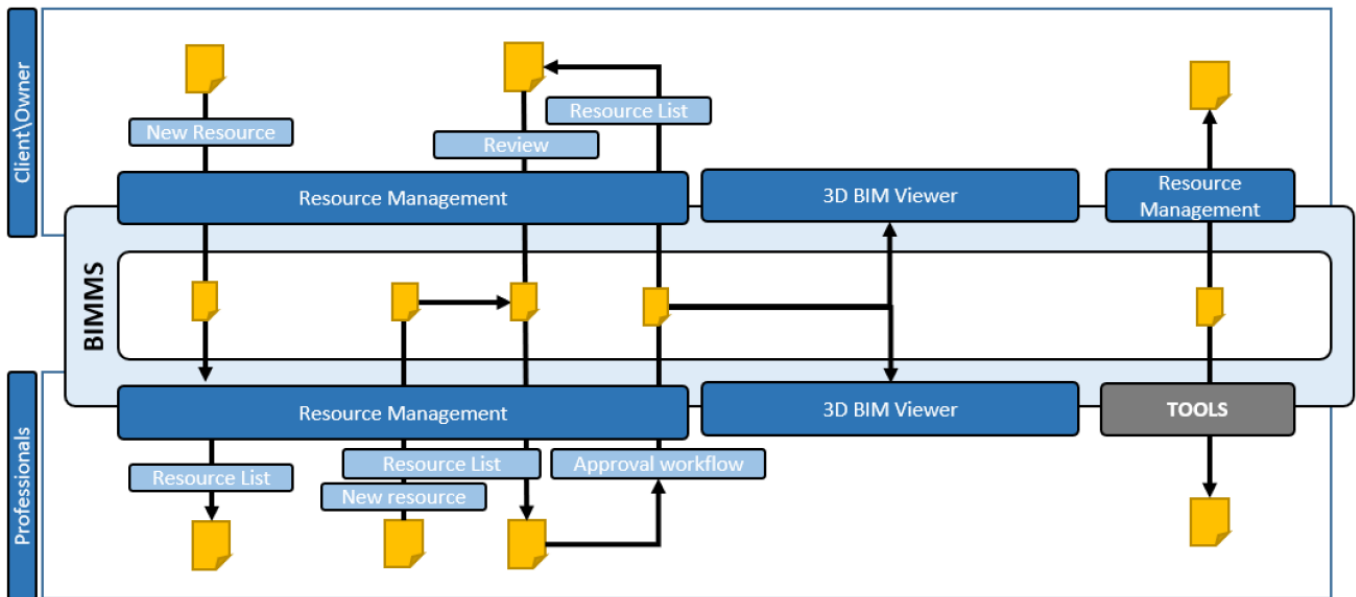


Figure 4 – General Use case 2: Client/Owner and Professional users share information

2.2.3 Use case 3: Professionals. The design team develops the concept, preliminary, developed, and detailed design.

The design team develops the concept, preliminary, developed, and detailed designs, preparing BIM Models, design drawings, reports and specifications. Files are produced, shared, collated, and assembled between specialist consultant (such as acoustic, thermal, structural, fire, safety, environmental, etc). Lead designers checks and integrates the overall design documentation. Project Leaders oversee the execution of the building contract, monitoring, inspecting, and evaluating the documentation provided.

Table 8 – Professionals share design documents in the BIMMS

TEST CASE NAME	Professionals share design documents in the BIMMS
BRIEF DESCRIPTION	Users share design documents with the design team, and other stakeholders to collect feedbacks and makes design changes. The resource can contain design documents as drawings, reports, spreadsheets, BIM models and other file documents supported by the BIMMS’ CDE.
GOAL	Collaboration between users to improve the information exchange sharing resources, collecting feedbacks. The check-in\out features avoid the concurrent editing of the resources and the versioning system allows to control the history of changes of the resources. The approval workflow allows to check and validate the resource before the submission, to share and publish approved information to other stakeholders (internal or external to the design team).
SUCCESS MEASUREMENT PRE-CONDITION	The users will be able to create and share resources, maintaining the control of the version history, permissions and record the approval status. Users must be registered in the BIMMS.
TRIGGER	Resource management and BIM Models functionalities
TYPICAL FLOW OF EVENTS	<p>These events can be done by one or more users, that can create, edit and manage the resources according to their permissions (as single author with exclusive permission on the resource or multiple authors with a team permission on resource). A single event can be done multiple times in a single designing task by one or more users.</p> <ol style="list-style-type: none"> 1. The user uses his\her authoring tool to create a design document (spreadsheet, drawing, report, etc.) 2. The user logs in to the BIMMS 3. The user uses the BIMMS’ “New Resource” functionality to create a new resource in the BIMMS uploading the design document file 4. The user uses the “Info” feature in the BIMMS’ “Resource List” functionality to define permissions on the resource and share the resource with other users 5. The user “checks-in” the resource in the BIMMS 6. The users (not limited to the resource author) authenticated in the BIMMS can view the resource in the BIMMS’ “Resource List” and download the resource to use as reference in their authoring tools (i.e.: a CAD drawing can be downloaded and used as external reference to complete a design task in a CAD drawing software) 7. The users (not limited to the resource author) authenticated in the BIMMS can view the resource in the BIMMS’ “Resource List” and check-out the resource to download and edit the design document. Checking-out the resource will lock the resource to avoid concurrent editing from other users.

8. The user who checks-out the resource can edit the design document in his/her authoring tool and share a new version in the BIMMS using "Edit resource" feature in the BIMMS' "Resource List"
9. The user, until completed the changes, can check-in the resource and let other users to further edit the design document as necessary
10. The user can change resource status using the BIMMS' "Change status" functionality. The user can also request an approval on the resource starting a BIMMS' "Approval workflow", notifying other users to approve or reject the resource contents.
11. The user is notified by the Approval Workflow and can view the resource in the BIMMS' "Resource List" and checks the approval status property. The user can approve or reject the resource. The approval status property will change accordingly to the user response.

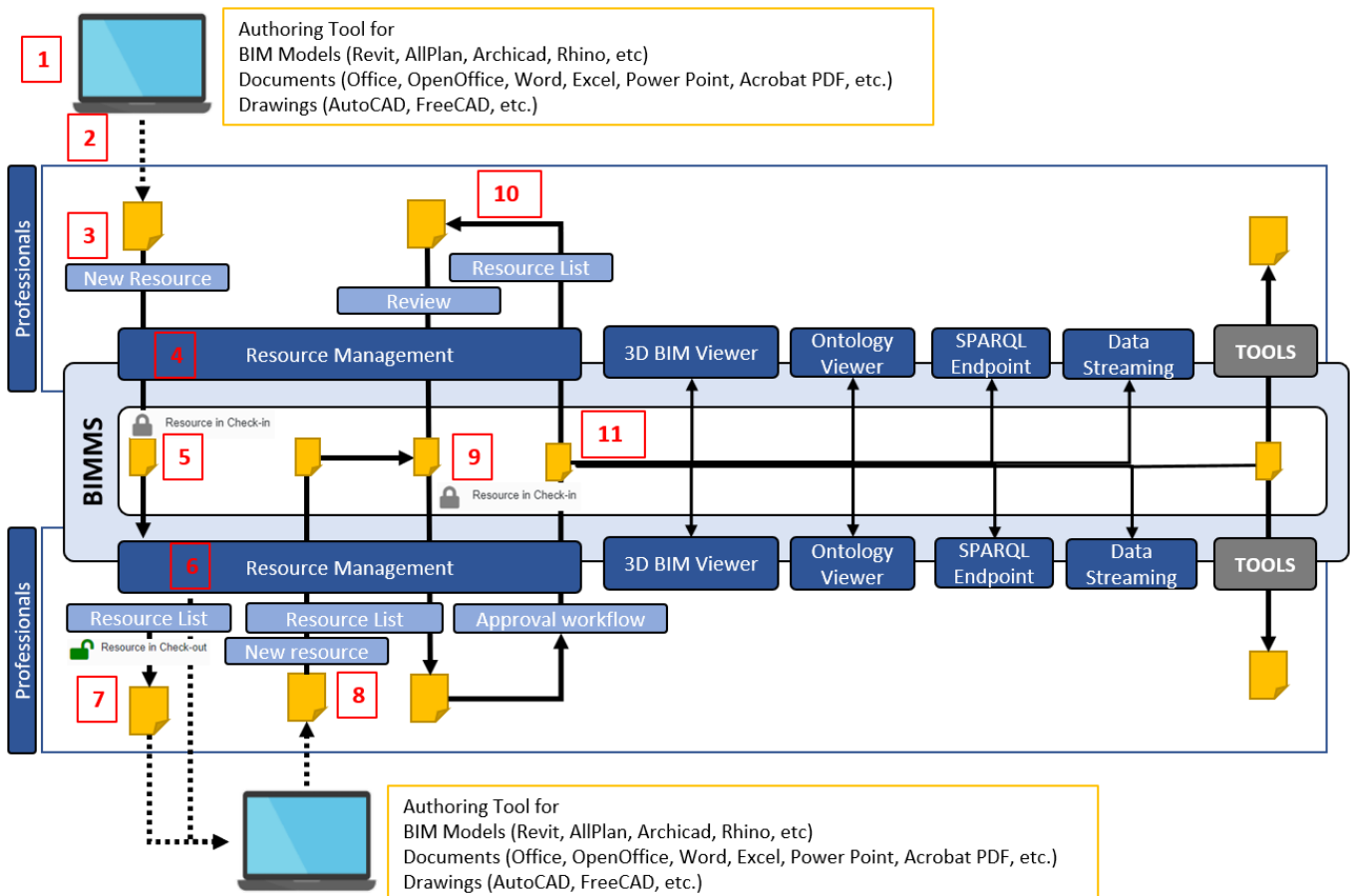


Figure 5 – Use case 3: Professionals share design documents in the BIMMS

2.3 Testing the BIMMS with BIM authoring tools

The following use test cases evaluate the interaction between BIMMS and BIM authoring tools. The test cases evaluate the capabilities of the BIMMS to support the integration of external tools through the use of the data exchange services as REST APIs and SPARQL Endpoint. In particular were tested the integration with some of the CAD and BIM authoring tools available in the market and used by professionals users like designers, engineers, specialists consultant, etc. The testing of the integration of the BIM authoring tool allows to evaluate some of the workflows that includes resources like BIM Models, point clouds, drawings, datasheets, etc. The same workflows can be also applied to other authoring tools like word processors, and general office productivity (i.e. Microsoft Office suite, Apache OpenOffice, etc.). The CAD and BIM authoring tool used for testing are Autodesk Revit (version 2021) and McNeel Rhinoceros (version 7) with the related visual programming interfaces Dynamo for Revit and Grasshopper. Autodesk Revit is one of the most popular commercial BIM authoring tool, as the NBS report says that is used by 50% respondents users in UK in the 2020 (NBS, 2020). McNeel Rhinoceros is another popular commercial 3D CAD modeller with the VisualARQ extensions for BIM authoring (Asuni, 2009). Each software includes additional tools as visual programming interface that allow to extend the functionalities of the host application through the creation of programs and scripts to manipulate elements graphically (visual scripting). This new generation of programming interfaces allows to use most of the methods and libraries available in the traditional development environment to create new applications that can run on the host application.

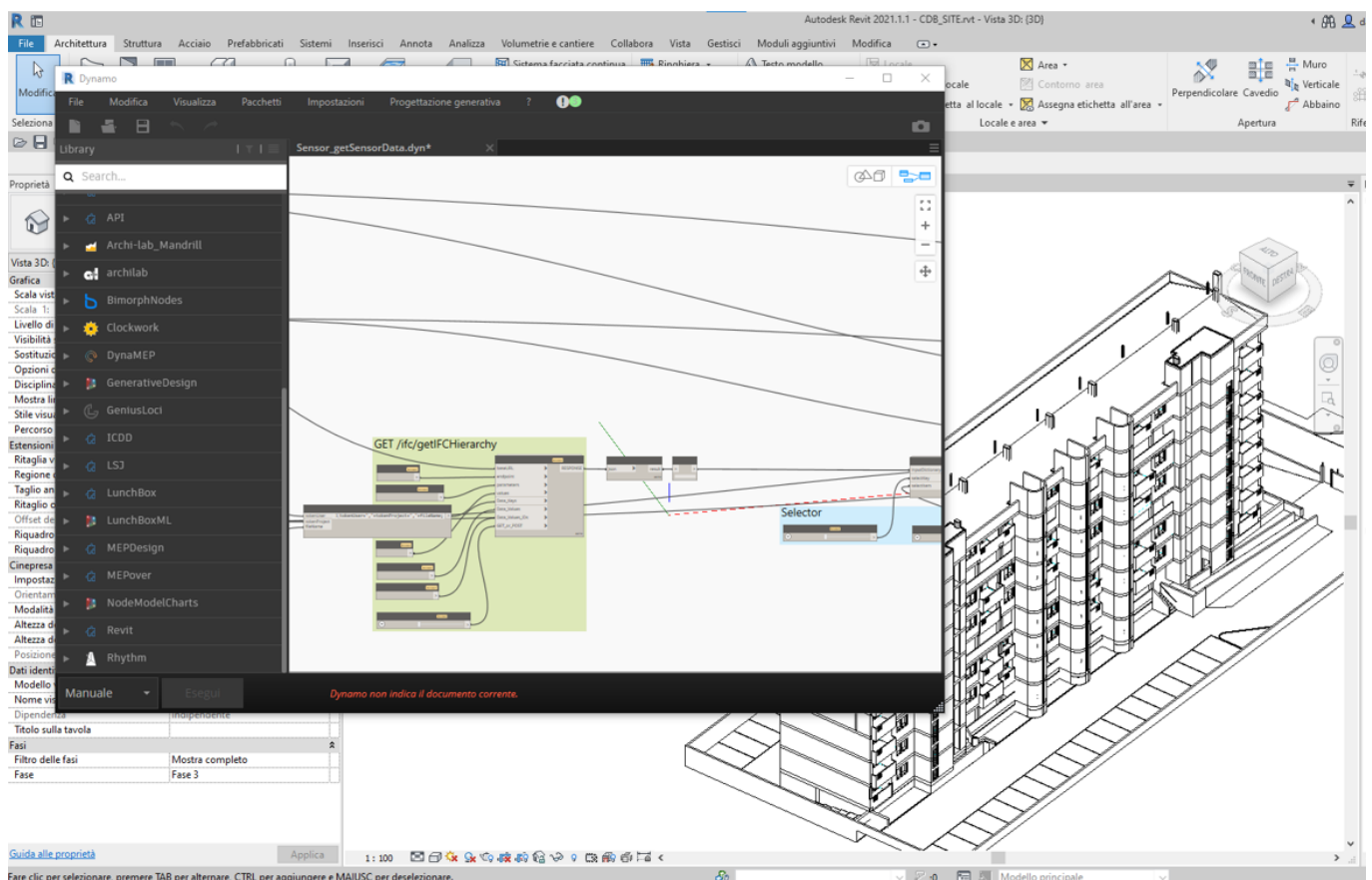


Figure 6 – The Dynamo for Revit interface running on Revit with the testing dataset

Dynamo for Revit and Grasshopper for Rhinoceros are the two visual programming interfaces used to test the BIMMS' API and to develop small prototype interfaces to integrate the BIM authoring tools with the BIMMS platform. A series of scripts have been created to exploit the BIMMS' APIs functionalities and to connect the BIM authoring tools with the BIMMS. The scripts created in Dynamo and Grasshopper will be available for the users and will be part of the delivered work.

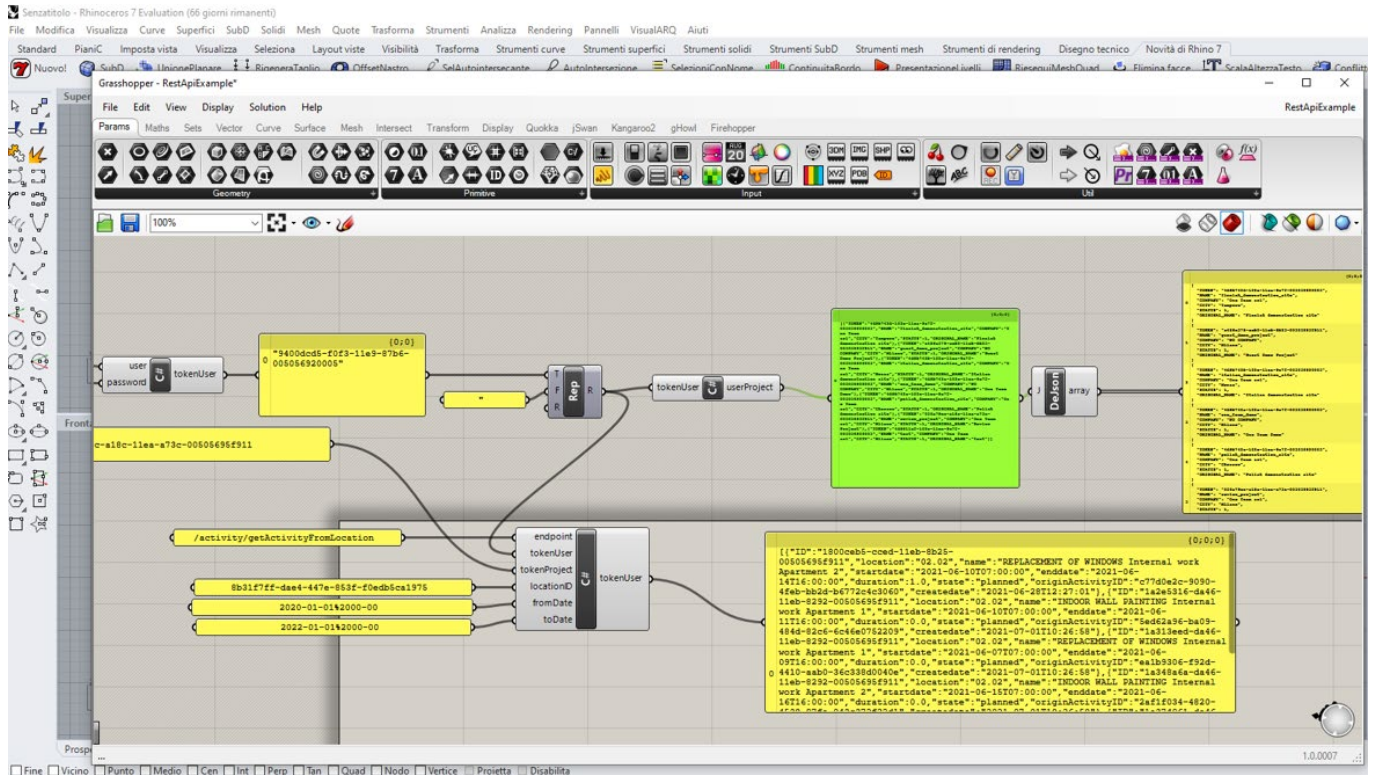


Figure 7 – The Grasshopper interface running on Rhinoceros

The following Table 9 shows the list of endpoints and functionalities used in Dynamo and Grasshopper

Table 9 – API Endpoints and functionalities tested

BIMMS API endpoint	Dynamo (for Revit)	Grasshopper (for Rhino)
GET /user/getUserToken	1Setup_login	Setup
GET /user/getUserProjects	2Setup_selectProject	Setup
GET /project/getProjectIFC	3Setup_selectFile	Setup
GET /ifc/getIFCZones	Activity_getActivity_fromRevitSelection	Get Activities
GET /activity/getActivityFromLocation	Activity_setActivity_fromRevitSelection	-
POST /activity/setActivity	Alert_getAlert_fromRevitSelection	Get Alerts
GET /alert/getAlertFromLocation	Alert_setAlert_fromRevitSelection	-
POST /alert/setAlert	IFC_createRevitRooms_fromIFCLink	-
GET /ifc/getIFCZones	IFC_createRevitZonesFromBIMMS	-
GET /ifc/getIFCZones	IFC_createWorkLocation	-
-	IFC_getIFCFile	-
GET /ifc/getIFCFile		

GET /ifc/getIFCZones	IFC_getIFCZones	Get IFC Zones
POST /ifc/setIFCZone	IFC_setIFCZone_fromIFC_Link_RevitSelection	-
POST /ifc/setIFCZone	IFC_setIFCZone_fromRevitSelection	-
GET/occupancy/getOccupancyFromLocation	Occupancy_getOccupancy	Get Occupancy
GET/occupancy/getOccupancyFromLocation	Occupancy_SaveOccupancyInRevit	-
POST /occupancy/setOccupancy	Occupancy_setOccupancy	-
POST/occupancy/setOccupancySchedule	Occupancy_setOccupancySchedule	-
POST/occupancy/setOccupancyScheduleData	Occupancy_setOccupancyScheduleData	-
GET/occupancy/getOccupancyFromLocation	Occupancy_ShowOccupancyInRevit	-
GET /ifc/getIFCZones GET /sensor/getSensorsFromLocation GET /sensor/getSensorData	Sensor_getSensorData	Get Sensor Data
POST /sparql/getSPARQLData POST /api/OTVirtuoso	SPARQL_SPARQL	SPARQL

2.3.1 Typical scenarios and workflows

A common practice among users is to work with the authoring tool of choice, save the output in the most common file format and share the file in a filesharing application or in a Common Data Environment (CDE). This scenario is valid for all documents used in a typical sharing environment, as the one enabled by the renovation works with different stakeholder participating in the decision and feedback loops.

The professional users, in particular the ones directly involved in the design and construction activities, often work with BIM authoring tools, saves data in the native file format and export in interoperable file formats to share the information with the other working teams. As widely documented (Mirarchi, et al., 2017), the export functionality available in the BIM authoring tool is prone to errors and data loss, and the data exchanged shall be checked to ensure consistency and correctness. The export and data quality check is one of the most time consuming task in a regular design feedback loop. The BIM management best practices recommend to use the same authoring tool in the same discipline design team, and to schedule the data exchanges and limit the export to share the design output only between the design team and the client, or between different disciplines teams (Rafael Sacks, 2018). These recommendations and practices limit the collaboration between design teams, parties and the stakeholders involved in the renovation works.

The workflow proposed in the implementation of the BIMMS is to work using the authoring tools of choice and use the BIMMS functionalities to perform the data exchange between the local version of the file (in native file format) and the shared file (in interoperable file format), managing changes and updates between the two systems. The Figure 8 shows a brief summary of the workflow implemented taking as example a designer that works with his\her BIM authoring tool in a local environment.

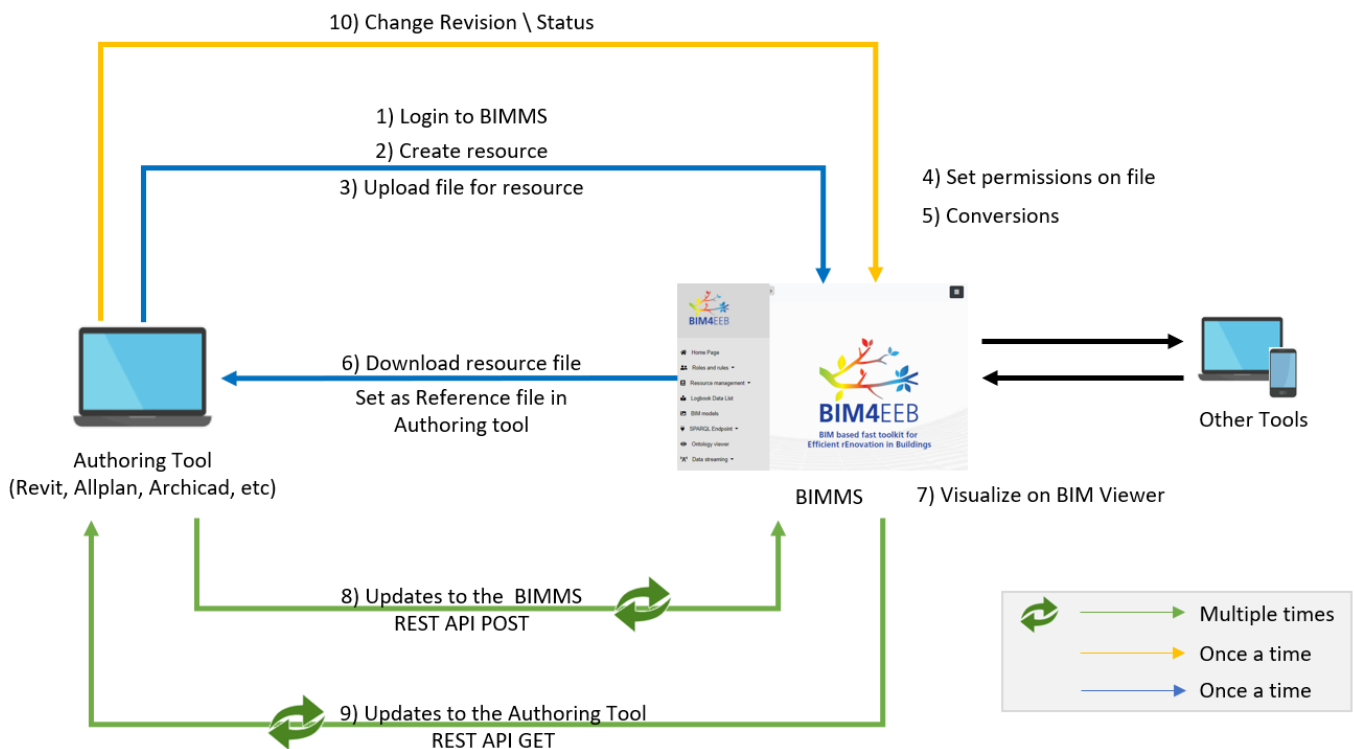


Figure 8 – The implemented BIMMS workflow to work with authoring tools

The designer exports a first version of the design (IFC model) and shares it in the BIMMS: logs in in the BIMMS, creates a resource, uploads the IFC file, sets the permissions on the resource and shares it with other team members. In a collaboration workflow between design disciplines, since the resource is shared in the BIMMS, the other team members can use it as reference (i.e. link an external reference file) to work on their design models. The designers can edit the shared file using the REST APIs endpoints available to retrieve updates and make changes. The APIs can be used to directly exchange data between the application (client) and the BIMMS (host server).

The BIMMS Platform make available some API endpoints that can be used to get and update the IFC model spatial elements hierarchy with the management of the IFCZones and IFCGroups, the management of Activities, Alerts, Occupancy, Sensors, and many others. The BIMMS platform allows to use the APIs to fast update the shared files, avoiding complex and time consuming export workflows.

The following use test cases evaluates some of the typical workflows that can be implemented using the BIMMS and the BIM authoring tools.

Table 10 – Use test cases evaluated

Use Test case	Result	Time to complete (seconds)	Time affected mostly by
Setup the connection with the BIMMS	success	15	user
Create IfcZones	success	30	user
Retrieve existing IfcZones, IfcSpaces, and Ifc Hierarchy	success	10	user
Create IfcGroups	success	30	user
Create work locations	success	60	user
Create Activities	success	30	user
Retrieve Activities	success	20	user
Create Alerts	success	30	user
Retrieve Alerts	success	20	user
Retrieve sensor data and measurements	success	20	user
Set the occupancy data	success	30	user
Get and save the occupancy	success	10	user
Retrieve data from the SPARQL Endpoint	success	60	user, server

The time to complete the use case was calculated as media of three executions. The time is measured in seconds. The tests were done using a laptop with an Intel Core i7-6700HQ CPU, 16 GB of RAM, on Windows 10 64bit, and a FTTN internet connection (30 Mbps). Almost all use cases are affected by the user response time spent in item selection, and compiling the required parameters values.

2.3.2 Setup the connection with the BIMMS in BIM authoring tool

To use the BIMMS functionalities in the BIM authoring tool, the user must be logged in the BIMMS, select the reference project and the IFC file where he/she is currently working. The scripts save the user preferences to allow to run these scripts only at the first connection with the BIMMS and reuse the responses in the next calls.

Table 11 - Setup the connection with the BIMMS

TEST CASE NAME	Setup the connection with the BIMMS in BIM authoring tool
BRIEF DESCRIPTION	The user setups the script to connect his/her authoring tool to the BIMMS using the REST APIs. The following steps are done using Autodesk Revit and Dynamo player.
GOAL	Login to the BIMMS, select the working project and the reference working file stored in the BIMMS. Save the setup in the BIM authoring tool.
SUCCESS MEASUREMENT	The user is able to logs in, gets projects and files from BIMMS.
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	GET /user/getUserToken, GET /user/getUserProject, GET /project/getProjectIFC
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in to the BIMMS in the authoring tool with his/her username and password. The script saves the userToken that will be used in the next API calls. The script downloads, from the BIMMS, a Revit generic workLocation model family used to define and represent as 3D geometry the work location in the Revit environment. 2. The user selects the BIMMS' project. The script saves the projectToken that will be used in the next API calls. 3. The user selects the IFC file used as reference stored in the BIMMS. The script saves the originalFilename of the IFC file that will be used in the next API calls.

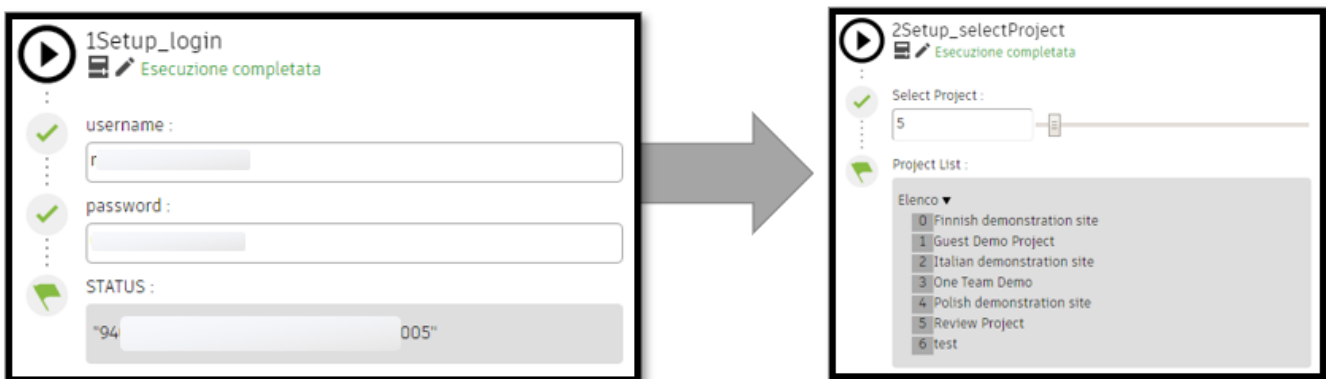


Figure 9 – The connection setup with the BIMMS in BIM authoring tool: the login (left) and project selection (right)

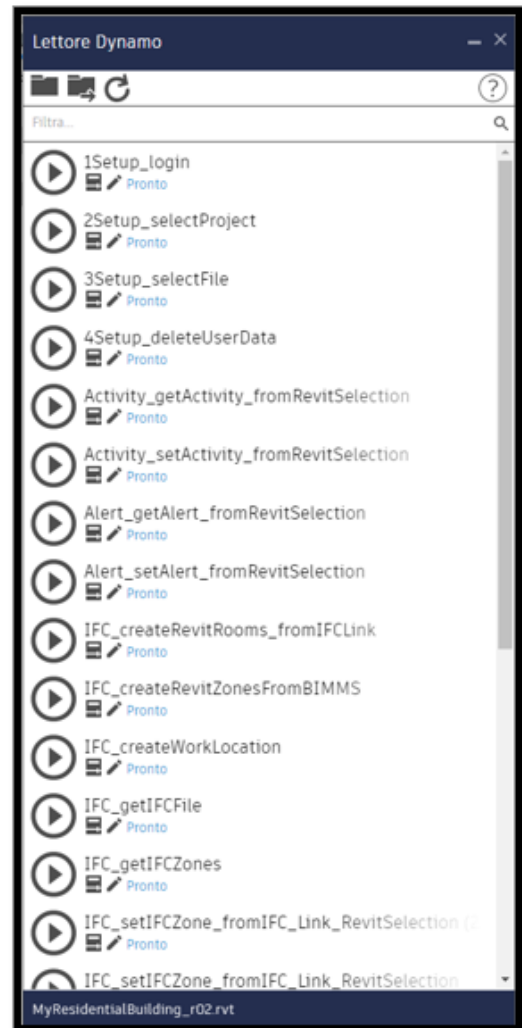
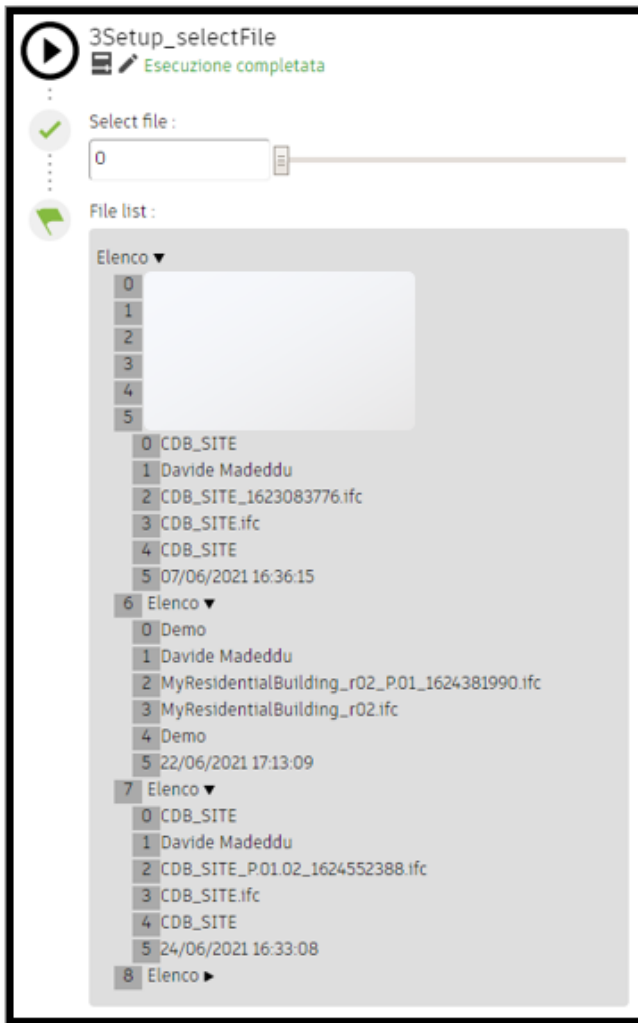


Figure 10 – The connection setup with the BIMMS in BIM authoring tool: the file selection (left), and the list of the scripts available in the Dynamo Player (right)

2.3.3 Create and manage the IfcZones in the BIM authoring tool with the BIMMS

“IfcSpace and IfcZone are entities that can be used to define rooms, spaces, and zones of the building. Together are used to set the data necessary to recognize the use of certain spaces or volumes in the building, set fire safety, lighting, occupancy and thermal requirements. These requirements are then used in energy analysis, fire safety analysis, space planning and cost management. These entities can be placed, defined, or modelled since the early design phases and can be used right through the construction management and facility management stage” (One Team, 2021). More detailed workflows and best practices to manage the IFC spatial hierarchy are described in the last version of the deliverable D4.6 “Guidelines for the implementation of the BIM Management System” published in M26 (February 2021). The BIMMS allows to create, update and delete the IfcZones that can be used to manage work locations, activities, alerts, occupancy and sensors. The following use test cases describe how to manage the IfcZones in the BIM authoring tool.

Table 12 - Create IfcZones in BIM authoring tool

TEST CASE NAME	Create IfcZones in BIM authoring tool
BRIEF DESCRIPTION	The user can create IfcZones in the BIM authoring tool selecting one or more room/space/zone in the existing native model, or in the IFC model linked as external reference
GOAL	Create new IfcZones in the IFC model shared in the BIMMS, using the native model or the IFC model set as external reference
SUCCESS MEASUREMENT	The IfcZone is defined in the BIM authoring tool and recorded in the shared IFC model to be also retrieved by other tools from the BIMMS
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /ifc/setIfcZone
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user creates a new IfcZone selecting the existing room\space\zone in the native BIM Model or in the IFC file set as external resource. 3. The user defines the IfcZone name and description. 4. The BIMMS will create a new IfcZone for the selected room\space\zone.

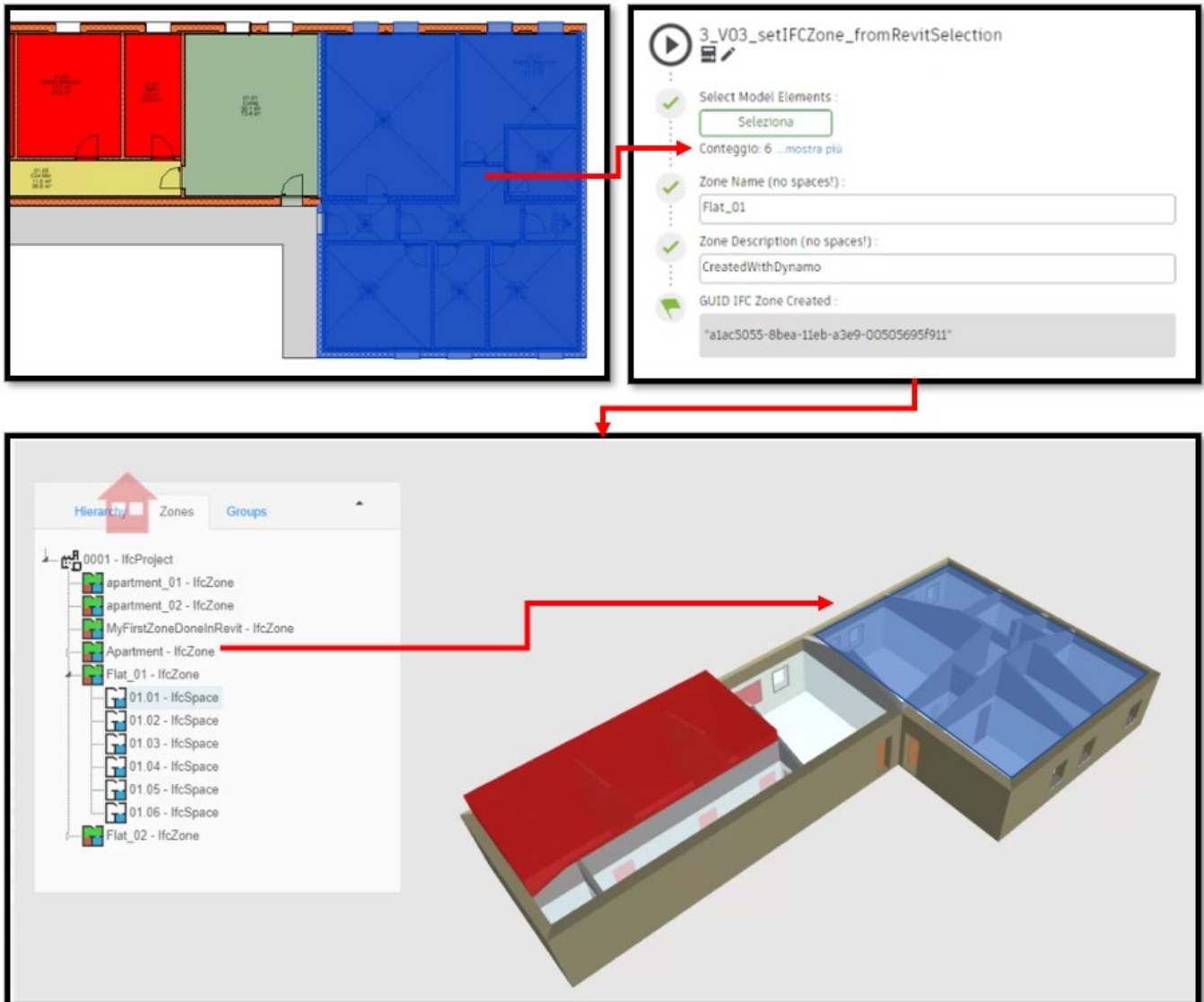


Figure 11 – Create IfcZones in BIM authoring tool

Table 13 - Retrieve existing IfcZones, IfcSpaces, and IFC Hierarchy in BIM authoring tool

TEST CASE NAME	Retrieve existing IfcZones, IfcSpaces, and IFC Hierarchy in BIM authoring tool
BRIEF DESCRIPTION GOAL	The user can retrieve in his/her BIM authoring tool the IfcZones, the IfcSpaces and the IFC model hierarchy of the IFC file shared in the BIMMS.
SUCCESS MEASUREMENT PRE-CONDITION	Retrieve IFC Spatial Element Hierarchy in the BIM authoring tool using the native model or the IFC model set as external reference The IFC model hierarchy is retrieved in the BIM authoring tool
TRIGGER API ENDPOINT SPARQL ENDPOINT TYPICAL FLOW OF EVENTS	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs. The reference IFC model shared in the BIMMS must have the IfcZones or IfcSpaces Resource management and BIM Models functionalities GET /ifc/getIFCZones, GET /ifc/getIFCHierarchy, <ol style="list-style-type: none"> 1. The user connects his/her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user runs the script to get the IfcZone and IFC hierarchy related to the file referenced in the BIM authoring tool

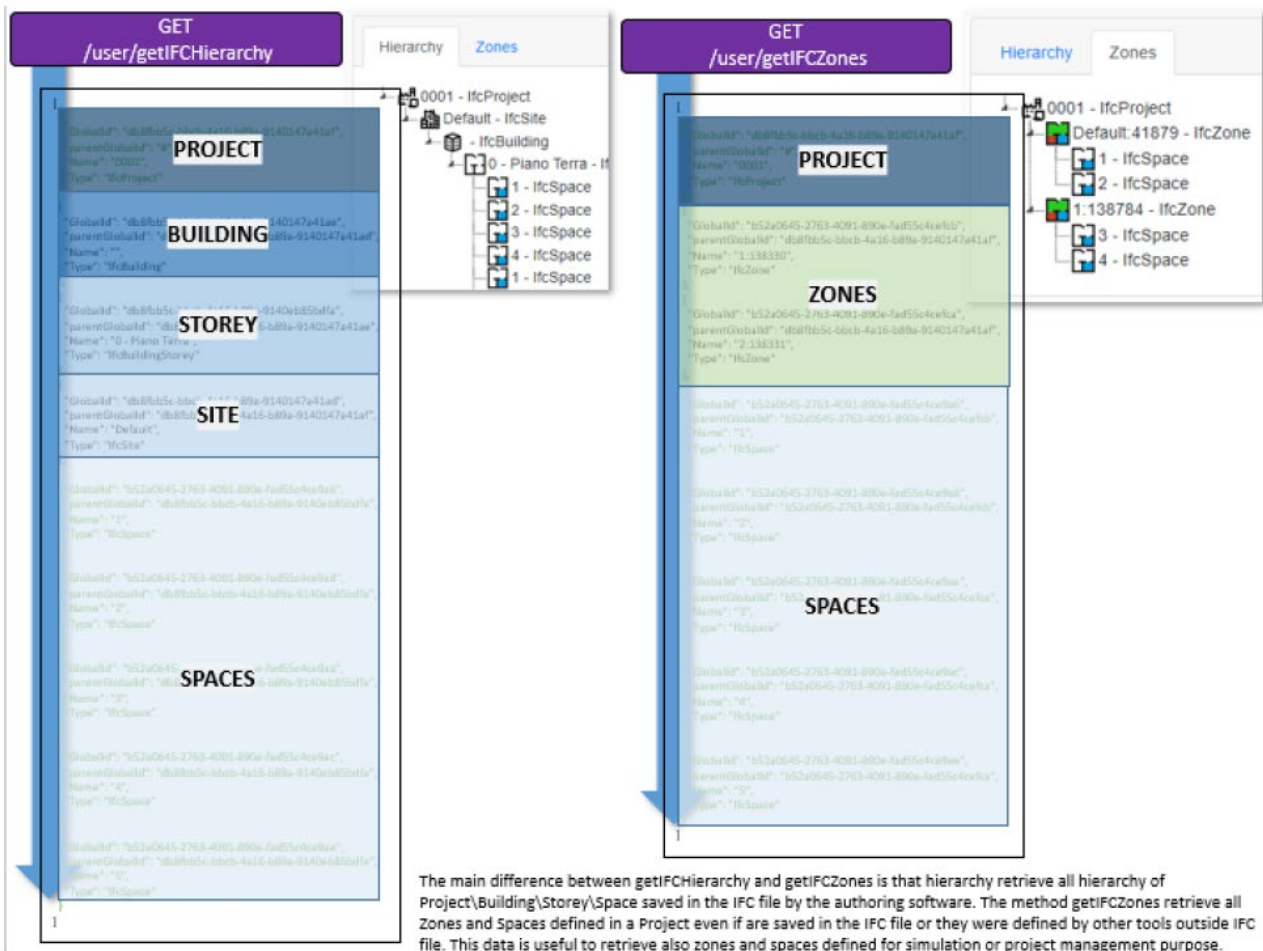


Figure 12 – Differences between getIFCHierarchy and getIFCZones methods (One Team, 2020)

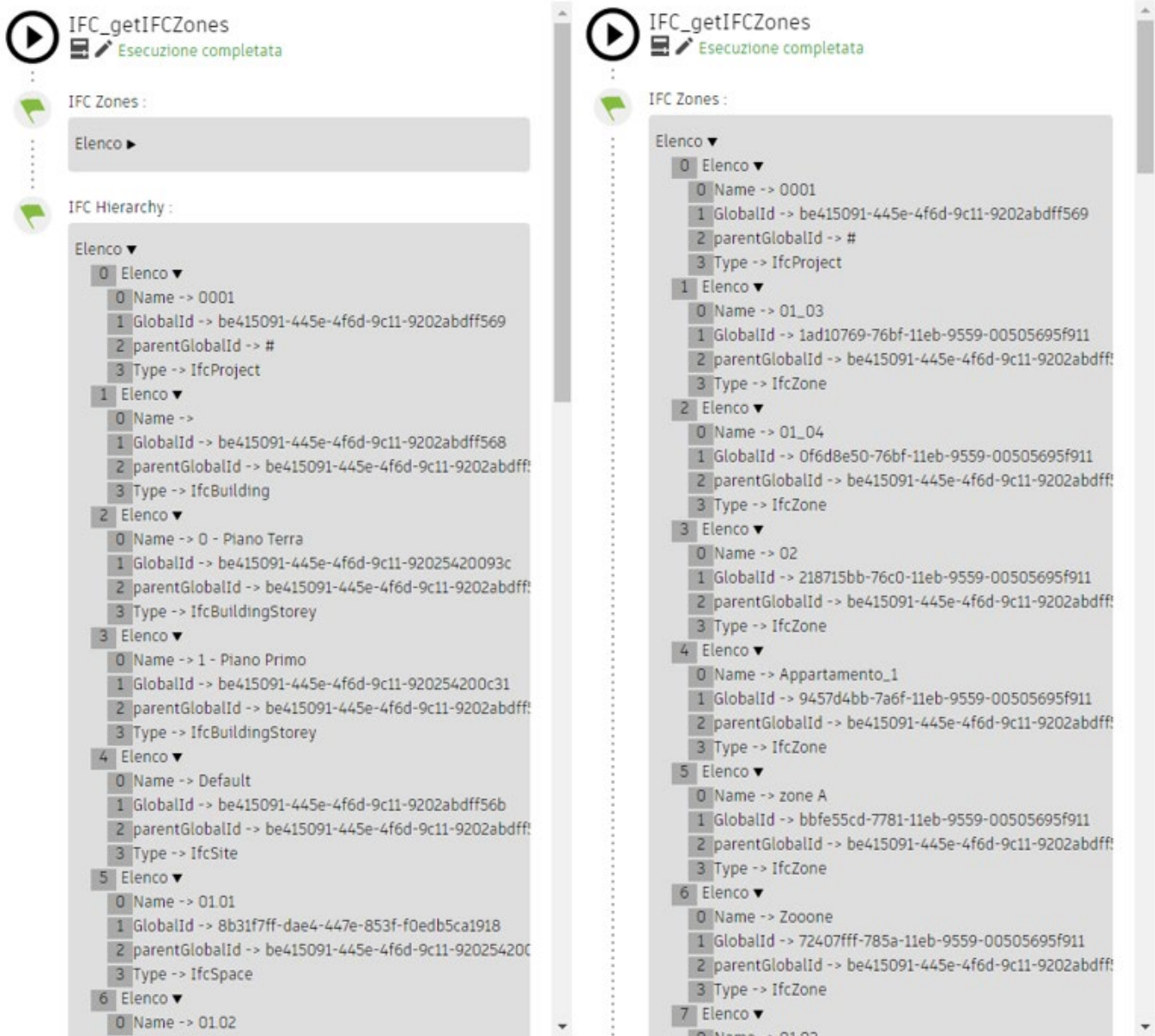


Figure 13 – Retrieve existing IfcZones, IfcSpaces, and IFC Hierarchy in BIM authoring tool

2.3.4 Create and manage the IfcGroups in the BIM authoring tool with the BIMMS

“To manage the model elements related to an activity can be used the IfcGroup entity. This entity helps to define who are the elements involved in an activity: a group of windows, walls, façade elements, etc. Other entities, like the IfcProcess and IfcTask, can be used to define further when an activity is planned (or already done, or still in progress) and what kind of activity is. The IFC Groups, together with Spaces, Zones and Tasks, can be used to manage use cases in planning activities, where is already known who are the elements involved in the activity but is still unknown where is he work location (or maybe is not defined as sub locations) and when the activity is planned or its status” (One Team, 2021).

Table 14 - Create IfcGroups in BIM authoring tool

TEST CASE NAME	Create IfcGroups in BIM authoring tool
BRIEF DESCRIPTION	The user can create IfcGroups in the BIM authoring tool selecting one or more room/space/zone in the existing native model, or in the IFC model linked as external reference
GOAL	Create new IfcGroups in the IFC model shared in the BIMMS, using the native model or the IFC model set as external reference
SUCCESS MEASUREMENT	The IfcGroups is defined in the BIM authoring tool and recorded in the shared IFC model to be also retrieved by other tools from the BIMMS
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /ifc/setIfcGroup
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user creates a new IfcGroup selecting the existing element\room\sapce\zone in the native BIM Model or in the IFC file set as external resource. 3. The user defines the IfcGroup name and description. 4. The BIMMS will create a new IfcGroup for the selected element\room\sapce\zone.

Table 15 - Create work locations in BIM authoring tool

TEST CASE NAME	Create work locations in BIM authoring tool
BRIEF DESCRIPTION	The user can create work locations in the BIM authoring tool to be used to define later the activities that can be performed in the work location. The work location can be defined starting from the selection of existing geometric elements in the native model, or in the IFC model linked as external reference.
GOAL	Create new work location in the IFC model shared in the BIMMS
SUCCESS MEASUREMENT	The work location is defined in the BIM authoring tool and recorded in the shared IFC model.
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs. The native BIM model
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /ifc/setIfcZone
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user opens the BIM model in his\her authoring tool

2. The user can define some working zones in the native BIM model. The zones can be defined using 2D or 3D geometry using the tools available in the authoring tool.
3. In Revit, a generic model family and a Dynamo script are used to define a work location based on the elements selected by the user
4. The user exports the BIM Model as IFC with the native work locations set to be exported as IFCSpaces
5. The user shares in the BIMMS a new version of the IFC file using “Edit resource” feature in the BIMMS’ “Resource List” and uploading the exported IFC.
6. The new version of the BIM Model resource is available in the BIMMS with the new IFCSpaces defined in the model.
7. The user connects his/her authoring tool to the BIMMS using the REST APIs. The following steps are done using Autodesk Revit and Dynamo player.
8. The user logs in to the BIMMS in the authoring tool, select the BIMMS’ Project and the IFC file (created in the step 5) used as reference stored in the BIMMS.
9. The user selects an existing room\space\zone in the BIM Model and create a new IFCZone, defining the zone name and the zone description.
10. The BIMMS will return the new IFCZone set for the selected room\space\zone.

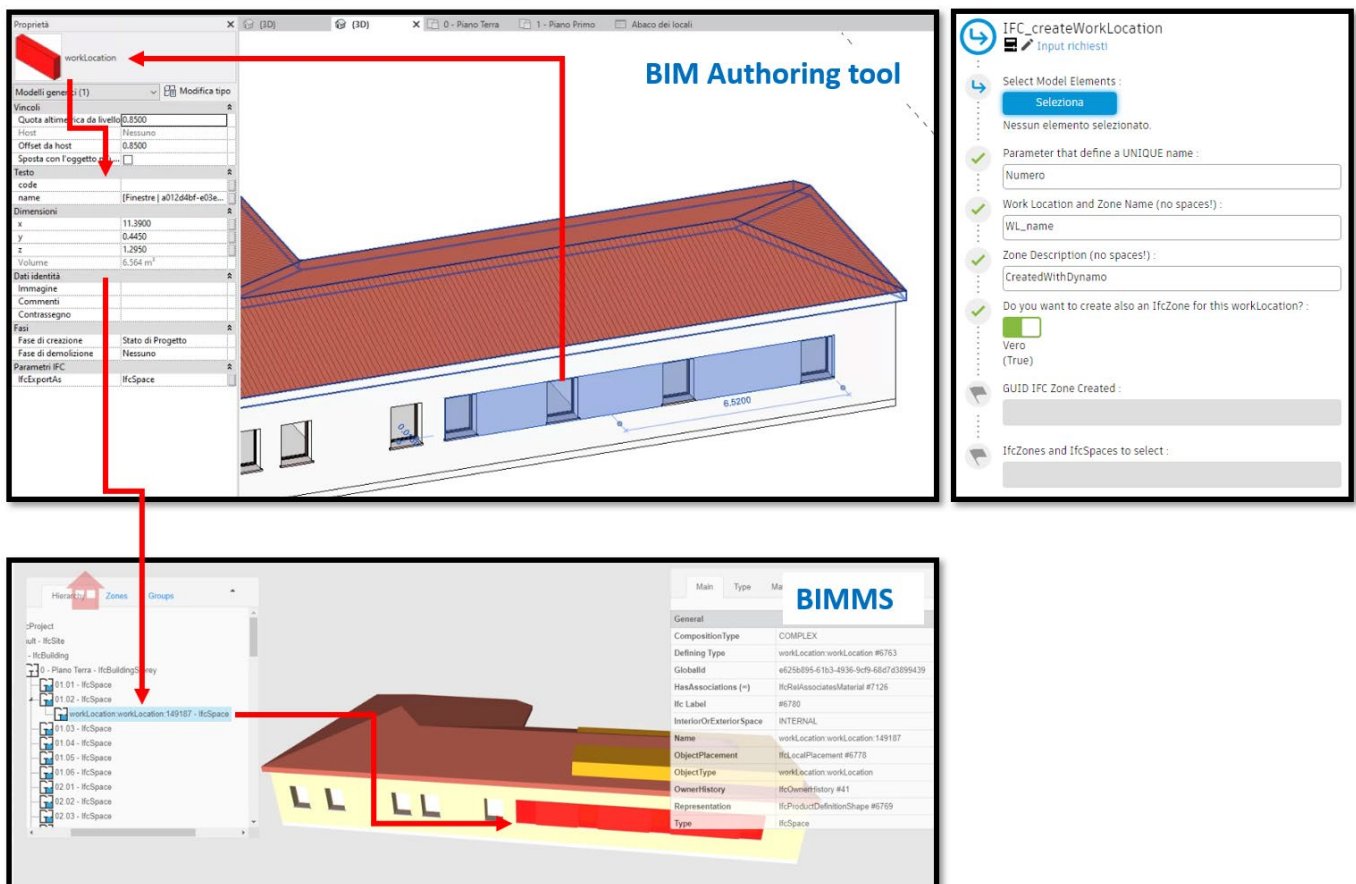


Figure 14 – Create work locations in BIM authoring tool

2.3.5 Create and manage Activities in the BIM authoring tool with the BIMMS

In the renovation works the definition, management, and the tracking of the site operations is crucial to improve the cost and time performance of the project. The planning tools are used to manage activities that can be assigned to areas and spatial locations at site. The spatial elements defined in BIM Models can be used to set the activities and track changes in planning and execution phases.

Usually the designer creates and shares the BIM model with the definition of the spatial elements. A planner, or a user in charge of definition of the project execution planning, defines the tasks and the timing in his\her planning tool. The tools can be used to link the tasks with the BIM elements defining the activities and then share the working plan with the design and construction teams. The activities saved in the BIMMS are then available in the BIMMS for any other tool used to further manage the tasks, to review (i.e. by other professional roles), keep informed, or to give feedbacks and propose changes (i.e. by Inhabitant\End-user, Client\Owner roles).

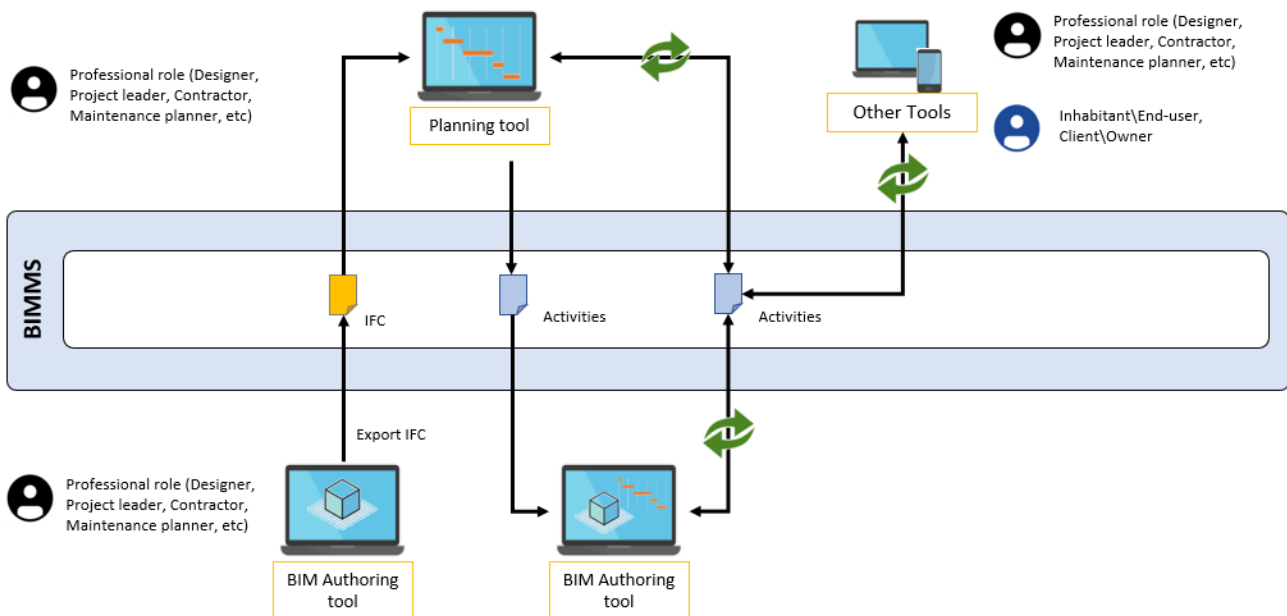


Figure 15 – The creation and management of the Activities using the BIM authoring tool and the BIMMS

Table 16 - Create Activities in BIM authoring tool

TEST CASE NAME	Create Activities in BIM authoring tool
BRIEF DESCRIPTION	The user can create activities in the BIM authoring tool selecting one or more spatial elements in the existing native model, or in the IFC model linked as external reference
GOAL	Create new activities in the IFC model shared in the BIMMS, using the native model to select the work locations
SUCCESS MEASUREMENT	An activity is defined in the BIM authoring tool and recorded in the shared IFC model can be retrieved by other tools from the BIMMS
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /activity/setActivity
SPARQL ENDPOINT	

TYPICAL FLOW OF EVENTS

These events can be done by one or more users, that can create, edit and manage the resources according to their permissions (as single author with exclusive permission on the resource or multiple authors with a team permission on resource). A single event can be done multiple times in a single designing task by one or more users.

1. The user uses his\her authoring tool to create a BIM Model and design documents
2. The user exports the BIM model in IFC file format
3. The User logs in to the BIMMS
4. The user uses the BIMMS' "New Resource" functionality to create a new BIM Model resource in the BIMMS uploading the BIM model IFC file
5. The user leaves the resource (BIM Model) in "check-out" in the BIMMS to complete the next activities locking the file to prevent concurrent editing from other users.
6. The user uses the "Info" feature in the BIMMS' "Resource List" functionality to define permissions on the resource and share the resource with other users. Other users can download the resource, but they cannot edit and add a new revision until it is checking-out by another user.
7. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2.
8. The user creates a new Activity in one existing room\space\zone selecting the model spatial element that represent the work location of the activity, defining the activity name, the activity start date and end date, the activity duration, the activity state, and the origin activity ID (if some other tool already defined an activity related to these items).
9. The BIMMS will create a new activity in the selected room\space\zone.

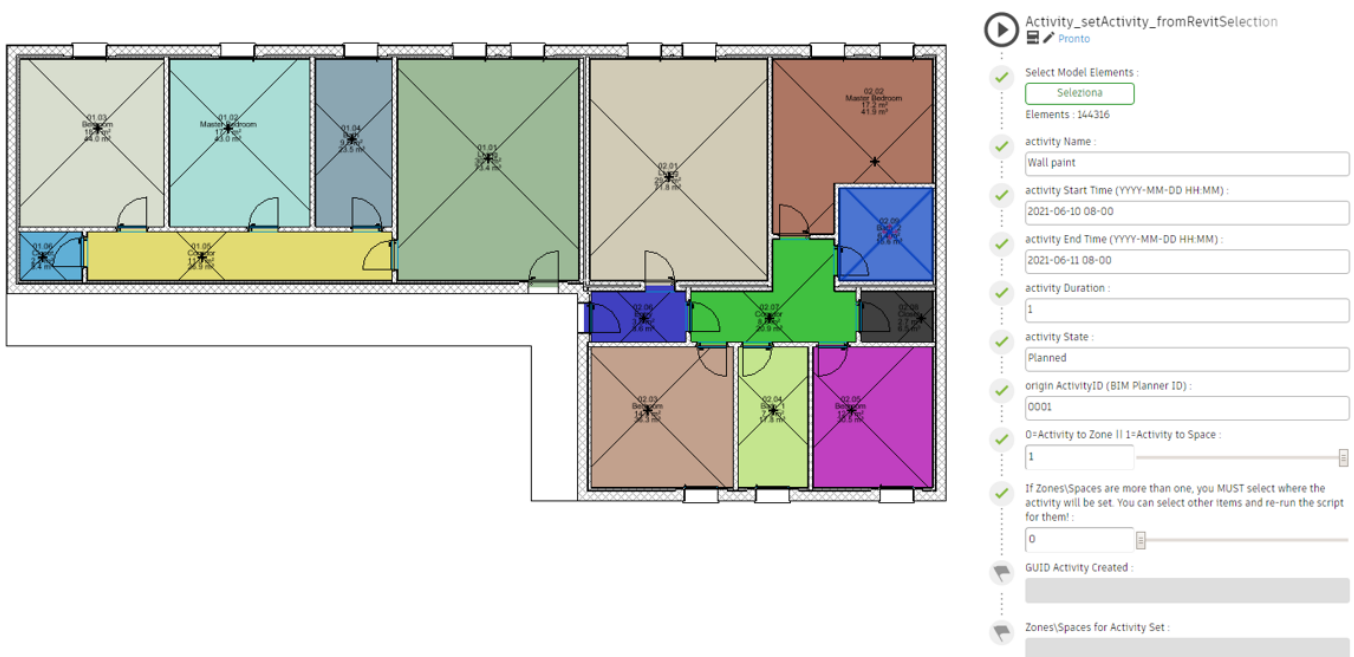


Figure 16 – The Dynamo script to create Activities in BIM authoring tool

Table 17 - Retrieve Activities in BIM authoring tool

TEST CASE NAME	Retrieve Activities in BIM authoring tool
BRIEF DESCRIPTION GOAL	The user can retrieve in the BIM authoring tool, the activities stored in the BIMMS, set by other users using other tools (planning tools or similar). Visualize the activities set in the IFC model shared in the BIMMS, directly in the BIM authoring tool. The activity data can be also stored in the native BIM model
SUCCESS MEASUREMENT	The user can visualize the activity data in the BIM authoring tool
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	GET /activity/getActivityFromLocation
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user selects an existing room\space\zone in the BIM Model and run the script. 3. The BIMMS returns the activities set for the selected room\space\zone. The Activity data is shown in a new window in the authoring tool 4. The user can save or update the activity data in the selected room\space\zone item in the BIM model

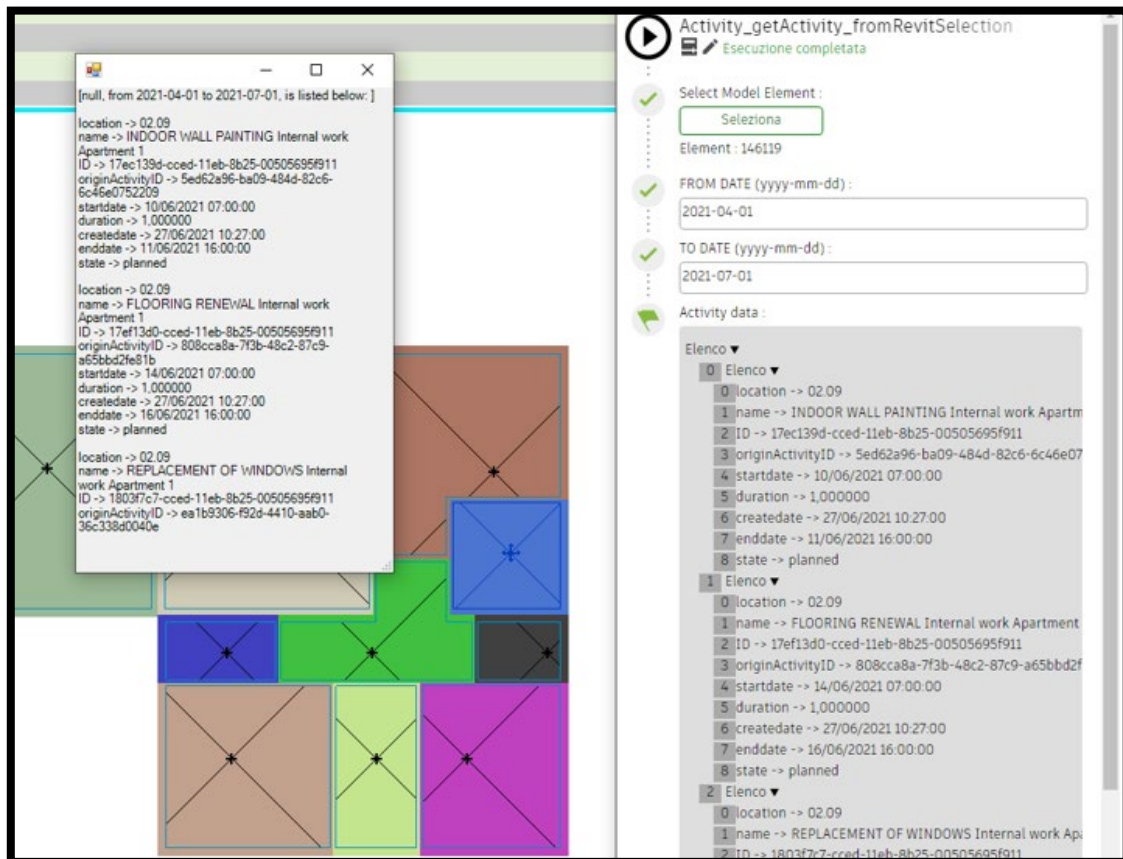


Figure 17 – The BIMMS activity data shown in the BIM authoring tool

2.3.6 Create and manage Alerts in the BIM authoring tool with the BIMMS

The alerts can be used to notify with messages and notifications about the renovation activities that took place in a location. The content type of the alert can inform the users about the scheduled activities, and can be also used to give security and safety recommendations with Health and Safety (H&S) instructions (Suite5, 2020).

Table 18 - Create Alerts in BIM authoring tool

TEST CASE NAME	Create Alerts in BIM authoring tool
BRIEF DESCRIPTION	The user can create alerts in the BIM authoring tool selecting one or more spatial elements in the existing native model, or in the IFC model linked as external reference
GOAL	Create new alerts in the IFC model shared in the BIMMS, using the native model to select the spatial locations
SUCCESS MEASUREMENT	An alert is defined in the BIM authoring tool and recorded in the shared IFC model can be retrieved by other tools from the BIMMS
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /alert/setAlert
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user creates a new Alert in one existing room\space\zone selecting the model spatial element, defining the alert type, the alert topic, the alert subject, the alert description, the alert time, the alert owner, the importance 3. The BIMMS will create a new alert in the selected room\space\zone

Table 19 - Retrieve Alerts in BIM authoring tool

TEST CASE NAME	Retrieve Alerts in BIM authoring tool
BRIEF DESCRIPTION	The user can retrieve in the BIM authoring tool, the alerts stored in the BIMMS, set by other users using other tools (planning tools or similar).
GOAL	Visualize the alerts set in the IFC model shared in the BIMMS, directly in the BIM authoring tool. The alert data can be also stored in the native BIM model
SUCCESS MEASUREMENT	The user can visualize the alerts data in the BIM authoring tool
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	GET /alerts/getAlertFromLocation
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user selects an existing room\space\zone in the BIM Model and run the script. 3. The BIMMS will return the alerts data for the selected room\space\zone. The Alerts data is shown in a new window in the authoring tool 4. The user can save or update the alerts data in the selected room\space\zone item in the BIM model

2.3.7 Retrieve sensor data and measurements in the BIM authoring tool with the BIMMS

Table 20 - Retrieve sensor data and measurements in the BIM authoring tool

TEST CASE NAME	Retrieve sensor data and measurements in the BIM authoring tool
BRIEF DESCRIPTION	The user can retrieve the data measured by the sensors defined in the BIMMS directly to the BIM authoring tool. The user can select one room\space\zone and retrieve the measurements available or the selected item.
GOAL SUCCESS MEASUREMENT PRE-CONDITION	Retrieve the data measured by the sensors in the selected room\space\zone The sensors data and measurements are shown in the BIM authoring tool
TRIGGER API ENDPOINT SPARQL ENDPOINT TYPICAL FLOW OF EVENTS	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs. Resource management and BIM Models functionalities GET /sensor/getSensorsFromLocation, GET /sensor/getSensorData <ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user selects an existing room\space\zone in the BIM Model and run the script. 3. The BIMMS will return the sensors data and the measurements available in the selected room\space\zone. The measurements are shown in a graph window in the authoring tool

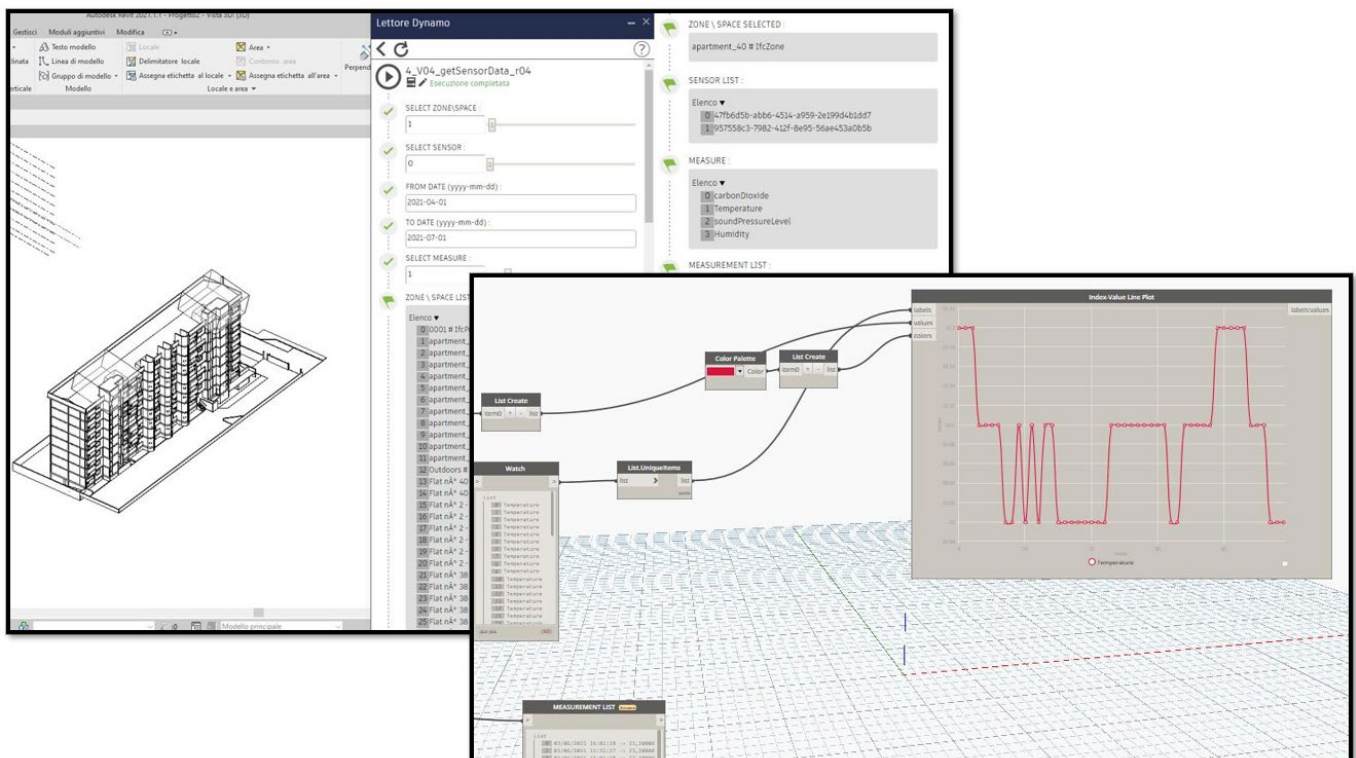


Figure 18 – Retrieve sensor data and measurements in the BIM authoring tool

2.3.8 Set and visualize the occupancy data in the BIM authoring tool with the BIMMS

Table 21 - Set the occupancy data in the BIM authoring tool

TEST CASE NAME	Set the occupancy data in the BIM authoring tool
BRIEF DESCRIPTION	The user can set the occupancy, occupancy schedule, and the occupancy schedule data directly in the BIM authoring tool. The user can select one room\space\zone to define the occupancy data for the selected item.
GOAL	Define occupancy data for the selected room\space\zone
SUCCESS MEASUREMENT	The occupancy data is set and is available in the BIMMS
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /occupancy/setOccupancy, POST /occupancy/setOccupancySchedule, POST /occupancy/setOccupancyScheduleData
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user selects an existing room\space\zone in the BIM Model and run the scripts to set Occupancy, Occupancy Schedule, and Occupancy Schedule Data 3. The BIMMS will return the occupancy data available in the selected room\space\zone. The measurements are shown in a graph window in the authoring tool

Table 22 - Get and save the occupancy data in the BIM authoring tool

TEST CASE NAME	Get and save the occupancy data in the BIM authoring tool
BRIEF DESCRIPTION	The user can get the occupancy data in the BIM authoring tool. The user can select one room\space\zone to get the occupancy data for the selected item and save the data on it
GOAL	Get and save the occupancy data for the selected room\space\zone
SUCCESS MEASUREMENT	The occupancy data is shown in the BIM authoring tool and can be saved on the room\space\zone
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs. The occupancy data is available for the room\space\zone
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	GET /occupancy/getOccupancyFromLocation
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user selects an existing room\space\zone in the BIM Model and run the scripts to get Occupancy data. 3. The occupancy data is shown in a window in the BIM authoring tool. 4. The user can save the occupancy data in the selected room\space\zone

2.3.9 Retrieve data from the SPARQL Endpoint in the BIM authoring tool with the BIMMS

Table 23 - Retrieve data from the SPARQL Endpoint in the BIM authoring tool

TEST CASE NAME	Retrieve data from the SPARQL Endpoint in the BIM authoring tool
BRIEF DESCRIPTION	The user can retrieve data from the SPARQL Endpoint directly in the BIM authoring tool. The data retrieved can be saved to one or more elements selected by the user.
GOAL	Retrieve data from the BIMMS' SPARQL Endpoint directly in the BIM authoring tool
SUCCESS MEASUREMENT	The SPARQL Query results are displayed in the BIM authoring tool
PRE-CONDITION	Users must be registered in the BIMMS. The authoring tool can connect and use the BIMMS REST APIs.
TRIGGER	Resource management and BIM Models functionalities
API ENDPOINT	POST /sparql/getSPARQLData
SPARQL ENDPOINT	
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user connects his\her authoring tool to the BIMMS as described in use test case 2.3.2. 2. The user starts the script: <ol style="list-style-type: none"> 2.1. Retrieves the list of the resources shared in the BIMMS (for the selected project) 2.2. Filters the resource by file extension 2.3. Selects the resource 2.4. Selects the model element in the BIM authoring tool 2.5. Confirms the selection (set true to create the link) and runs the script 3. The BIMMS will create a RDF triple using the ICDD Container ontology (a Link class). The relationship between the two RDF resources (the IFC model element and the document resource) will be available through the BIMMS' SPARQL Endpoint 4. The script can create a hyperlink in the selected element of the BIM model.

2.4 Detailed use test cases

The following use cases evaluates the functionalities available in the BIMMS Web portal, that is the front end interface for all users and stakeholders.

2.4.1 Manage permissions and roles of the BIM4EEB

Table 24 - Manage permissions and roles

TEST CASE NAME	Manage permissions and roles of the BIM4EEB
BRIEF DESCRIPTION	BIMMS' Administrators want to manage permissions and roles defined in the BIMMS
GOAL	Define BIMMS roles and manage a set of permissions to enable BIMMS' functionalities for specific roles.
SUCCESS MEASUREMENT	Create new role, edit role name, assign a role to user groups, set read and write permission to specific functionalities
PRE-CONDITION	A BIMMS' Administrator role and user exist in the BIMMS.
TRIGGER	The BIMMS' Administrator clicks on "Permission" and "Management System Roles" menus
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The BIMMS' Administrator logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ . 2. To manage permissions: <ol style="list-style-type: none"> a. The BIMMS' Administrator clicks on the "permission" menu b. Assigns the BIMMS System role to a user group c. For every BIMMS' functionality: enables the role to access to the functionality clicking on on/off button (green: enabled, red: disabled) 3. To manage BIMMS' roles: <ol style="list-style-type: none"> a. The BIMMS' Administrator clicks on the "Management System Roles" menu b. Creates a new BIMMS' Role clicking on "New" button <ol style="list-style-type: none"> i. Sets a role name ii. Saves changes c. Edits an existing BIMMS' Role clicking on "Edit" button <ol style="list-style-type: none"> i. Changes role name ii. Saves changes

2.4.2 Register a new user in the BIMMS

Table 25 – Register a new user

TEST CASE NAME	Register a new user in the BIMMS
BRIEF DESCRIPTION	A new user wants to access to the BIMMS and manage its projects and resources
GOAL	Register a new user in the BIMMS and give access to the projects
SUCCESS MEASUREMENT	The user is registered to the BIMMS, is able to manage his/her profile, and access to his/her project' data.
PRE-CONDITION	The user has an email, an internet connection, and a device with an internet browser. A BIMMS' Administrator has already set projects and roles.
TRIGGER	The user clicks on Login button in the BIMMS' Portal starting page

TYPICAL FLOW OF EVENTS

1. The user logs in clicking on the login button in the BIMMS' Landing page at <https://bim4eeb.oneteam.it/BIMMS/>
2. The user creates a new account using the "Create account" link
3. The user gives username, e-mail, and set the password. The user reads the notification and consent of treatment of personal data and gives the confirm.
4. The user receives a welcome email with a link to confirm the registration.
5. The user can login as guest user (with limited permissions) in the BIMMS.
6. A BIMMS' Administrator role assigns a specific role to the new user
7. The user can manage his/her profile, projects, and resources.

2.4.3 Manage users in the BIMMS

Table 26 - Manage users

TEST CASE NAME	Manage users in the BIMMS
BRIEF DESCRIPTION	BIMMS' Project Administrators want to manage users and their roles and project association
GOAL	Invite new users in the project, assign roles, remove role assignment, assign projects, assign zones (for Inhabitant\Owner user role)
SUCCESS MEASUREMENT	Users can access to a project through invitation, role assignment, building's zone assignment.
PRE-CONDITION	The users have an email, an internet connection, and a device with an internet browser. A BIMMS' Administrator has already set projects and roles.
TRIGGER	The BIMMS' Project administrator clicks on Roles and Rules \ Users functionality
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The BIMMS' Project Administrator clicks the Roles and Rules \ Users button and access to the https://bim4eeb.oneteam.it/BIMMS/UserAdministration.aspx page. 2. To invite users: <ol style="list-style-type: none"> 2.1. click on "Add User" button, 2.2. insert user email, 2.3. select one or more roles (optional), 2.4. save to confirm. <p>The invited user will receive an email with an invite to access to the project and, if the user is not already registered, a link to register to the BIMMS.</p> 3. To manage user' role assignment: <ol style="list-style-type: none"> 3.1. click on "edit user role" button, 3.2. select one or more roles clicking on active (to assign), requested (to leave pending), remove (to remove). 3.3. save to confirm. <p>The role will be set to the user profile immediately. No action from the user is requested.</p> <p>The BIMMS' Project Admin role is assigned by a BIMMS' Administrator role selecting the Project Admin option in the User Management interface https://bim4eeb.oneteam.it/BIMMS/UserAdministration.aspx .</p> 4. To manage building's zone assignment (available only for inhabitant\owner users' roles): <ol style="list-style-type: none"> 4.1. click on "Zones" button,

- 4.2. select the IFC file of the building with IfcZones. To manage zone assignment, the selected IFC file must contain IfcZones.
 - 4.3. select one or more IfcZones available for the IFC file selected.
 - 4.4. Save to confirm.
- The user can access to his\her building's zones data in the enabled tools.

2.4.4 Manage projects in the BIMMS

Table 27 – Manage projects

TEST CASE NAME	Manage projects in the BIMMS
BRIEF DESCRIPTION	BIMMS' Project Administrators want to manage projects
GOAL	Creation of new projects in the BIMMS or change names and cities in the exiting projects
SUCCESS MEASUREMENT	A new project is available in the BIMMS. A existing project was edited (project's name or city is changed)
PRE-CONDITION	A BIMMS' Administrator role exist in the BIMMS.
TRIGGER	The BIMMS' Administrator clicks on Roles and Rules \ Projects
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The BIMMS' Administrator click on Roles and Rules \ Projects https://bim4eeb.oneteam.it/BIMMS/ProjectsAdministrator.aspx 2. To add a new project: <ol style="list-style-type: none"> 2.1. Click on "New" button 2.2. Add a project Name and City 2.3. Save changes 3. To edit an existing project: <ol style="list-style-type: none"> 3.1. Click on "Edit Project" 3.2. Edit project Name and City 3.3. Save changes

2.4.5 Manage ontologies in the BIMMS

Table 28 - Manage ontologies

TEST CASE NAME	Manage ontologies in the BIMMS
BRIEF DESCRIPTION	BIMMS' Project Administrators want to manage the ontologies that can be used in the Resource creation wizard.
GOAL	Define and modify the list of ontologies that can be used to create Linked Data resources in the BIMMS
SUCCESS MEASUREMENT	A list of ontologies is available in the BIMMS. A existing list can be modified.
PRE-CONDITION	A BIMMS' Administrator role exist in the BIMMS. An ontology available in its repository.
TRIGGER	The BIMMS' Administrator clicks on Roles and Rules \ Ontologies
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. BIMMS' Administrator click on Roles and Rules \ Ontologies https://bim4eeb.oneteam.it/BIMMS/OntologyAdministrator.aspx 2. To add a new ontology: <ol style="list-style-type: none"> 2.1. Click on "New" button, 2.2. Add the shortname, fullname, prefix, URL, and IRI,

- 2.3. Save changes.
- 3. To edit an existing project:
 - 3.1. Click on “Edit ontology”,
 - 3.2. Edit shortname, fullname, prefix, URL, and IRI,
 - 3.3. Save changes.

2.4.6 Create a document resource in the BIMMS

Table 29 - Create a document resource

TEST CASE NAME	Create a document resource in the BIMMS
BRIEF DESCRIPTION	A user wants to create a resource in the BIMMS’ CDE with an attached document (datasheet, report, specification, QTO, etc)
GOAL	Create a new resource with an attached document (datasheet, report, specification, QTO, etc).
SUCCESS MEASUREMENT	The new resource is available in the BIMMS’ Resource List. The user will be able to attach a resource document in the file formats listed in Table 30:
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the “new resource” functionality
TRIGGER	The user clicks on “New resource” functionality button
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/ 2. The user clicks on “New resource” 3. The user defines scope as “BIM4EEB scope”, category as “Documents” and typology as one of choices available in the dropdown list 4. The user defines the resource “Title” and “Description” 5. (optional) The user defines the Linked Data to be associated to the resource 6. (optional) The user defines the GeoLinked data to set the location of the resource 7. (optional) The user defines the link to existing IFC file in the project 8. The user uploads a file that represent the resource 9. The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).

The use case was tested with all kind of file formats supported to store in the BIMMS’ CDE and listed in the Table 30

Table 30 – BIMMS resource documents tested

Resource document file format	UC result
CSV - Comma Separated Values	Success
XML - eXtensible Markup Language	Success
gbXML - Green Building XML schema	Success
JSON - JavaScript Object Notation	Success
RDF - Resource Description Framework (in RDF/XML and Turtle serialization)	Success
OWL - Web Ontology Language (in RDF/XML and Turtle syntax)	Success
IFC - Industry Foundation Classes version IFC2x3 TC1 and IFC4 ADD2 TC1	Success
BCF - BIM Collaboration Format	Success
PDF - Portable Document Format	Success

Images and Media files JPEG, PNG, MP4	Success
ICDD (ISO 21597)	Success
XLS, XLSX Microsoft Excel	Success
DOC, DOCX Microsoft Word	Success
PPT, PPTX Microsoft Power Point	Success
LAS – LASer Point cloud data	Success
E57 – 3D Point cloud data	Success

2.4.7 Create a BIM IFC resource in the BIMMS

Table 31 - Create a BIM IFC resource

TEST CASE NAME	Create a BIM IFC resource in the BIMMS
BRIEF DESCRIPTION	A user wants to create a BIM IFC resource loading a BIM model in the BIMMS' CDE
GOAL	Create a new BIM model resource.
SUCCESS MEASUREMENT	The new IFC BIM model resource is available in the BIMMS' Resource List and in the BIM Models. The IFC model is stored in the RDMS database, converted in ifcOWL and BOT ontologies and available for download in the BIMMS' BIM Models functionality.
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "new resource" functionality
TRIGGER	The user clicks on "New resource" functionality button
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ 2. The user clicks on "New resource" 3. The user defines scope as "BIM4EEB scope", category as "Models" and typology as "IFC model" 4. The user defines the resource "Title" and "Description" 5. (optional) The user defines the Linked Data to be associated to the resource 6. (optional) The user defines the GeoLinked data to set the location of the resource 7. (optional) The user defines the link to existing IFC file in the project 8. The user uploads the IFC file that represent the resource 9. The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).

2.4.8 Create a point cloud resource in the BIMMS

Table 32 - Create a point cloud resource

TEST CASE NAME	Create a point cloud resource in the BIMMS
BRIEF DESCRIPTION	A user wants to create a point cloud resource loading a point cloud in LAS or E57 file format in the BIMMS' CDE
GOAL	Create a new point cloud resource.
SUCCESS MEASUREMENT	The new point cloud resource is available in the BIMMS' Resource List.
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "new resource" functionality

TRIGGER	The user clicks on “New resource” functionality button
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/ 2. The user clicks on “New resource” 3. The user defines scope as “BIM4EEB scope”, category as “Models” and typology as “Point Cloud Scan” 4. The user defines the resource “Title” and “Description” 5. (optional) The user defines the Linked Data to be associated to the resource 6. (optional) The user defines the GeoLinked data to set the location of the resource 7. (optional) The user defines the link to existing IFC file in the project 8. The user uploads the IFC file that represent the resource 9. The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).

2.4.9 Create a Logbook resource in the BIMMS

Table 33 - Create a Logbook resource

TEST CASE NAME	Create a Logbook resource in the BIMMS
BRIEF DESCRIPTION	A user wants to create a Logbook resource in the BIMMS’ CDE and manage (edit\change) its content
GOAL	Create a Logbook resource, update information in the Logbook.
SUCCESS MEASUREMENT	The new Logbook resource is available in the BIMMS’ Resource List and Logbook Data List.
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the create Logbook functionality (available only for Client\Owner, Local authority).
TRIGGER	The user clicks on “New resource” functionality button
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/ 2. The user clicks on “New resource” 3. The user defines scope as “BIM4EEB Logbook”, category as “Logbook” and typology as “Logbook details” 4. The user defines the resource “Title” and “Description” 5. The user compiles Logbook’s values. 6. (optional) The user defines the Linked Data to be associated to the resource 7. (optional) The user defines the GeoLinked data to set the location of the resource 8. (optional) The user defines the link to existing IFC file in the project 9. (optional) The user can upload a document that represent the whole Logbook resource (i.e. a digital copy of paper document representing a Logbook record) 10. The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).

2.4.10 Create a ICDD resource in the BIMMS

Table 34 - Create a ICDD resource

TEST CASE NAME	Create a ICDD resource in the BIMMS
BRIEF DESCRIPTION	A user wants to create a ICDD resource in the BIMMS' CDE
GOAL	Create a ICDD that contain one or more resources stored in the BIMMS' CDE.
SUCCESS MEASUREMENT	A ICDD file is created. The file and its contents are compliant with ISO 21597.
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "Resource list" functionality. One or more resources must be available in the BIMMS' CDE and listed in the Resource List. To download the ICDD container the pop-up blocker on the internet browser must be disabled.
TRIGGER	The user selects one or more resources and clicks on "Create ICDD" functionality button
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ . 2. The user clicks on "Resource list" 3. The user selects one or more resources, clicking on ICDD selection box. 4. The user defines the "ICDD Version", "Version Description", and "ICDD Description". 5. The user confirms the creation of the ICDD with the "Create ICDD" button. 6. The BIMMS creates and downloads the ICDD container.

2.4.11 Filter resources in the BIMMS

Table 35 - Filter resources

TEST CASE NAME	Filter resources in the BIMMS
BRIEF DESCRIPTION	A user wants to filter and search the resources by title and description, date, status, and revision.
GOAL	Retrieve a filtered results of resources based on specific search terms.
SUCCESS MEASUREMENT	Obtain the resources corresponding to the search term
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "Resource list" functionality. One or more resources must be available in the BIMMS' CDE and listed in the Resource List.
TRIGGER	The user input a search term in the Resource List interface header
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ 2. The user clicks on "Resource list" <ol style="list-style-type: none"> a. Free text search: <ol style="list-style-type: none"> i. The user inputs a free text in the search box ii. The BIMMS shows only the resources that include the text in one of the parameters visible in the Resource List. b. Title\Description filter: <ol style="list-style-type: none"> i. The user inputs a free text in the search box ii. The user clicks on "search" button

- iii. The BIMMS shows only the resources that include the text in the title or description of the resource.
- c. Date From and Date To filter:
 - i. The user inputs a date in the search box
 - ii. The user clicks on “search” button
 - iii. The BIMMS shows only the resources that were created in the time interval defined by the user.
- d. Status filter:
 - i. The user selects a status in the search box
 - ii. The user clicks on “search” button
 - iii. The BIMMS shows only the resources that include the selected status.
- e. Revision filter:
 - i. The user selects or deselect the “Show Last Version” option
 - ii. The user clicks on “search” button
 - iii. The BIMMS shows only the resources in the last version (Show last version selected) or all version of the resources (Show last version deselected).
- f. Review filter:
 - i. The user selects or deselect the “My Review” option
 - ii. The user clicks on “search” button
 - iii. The BIMMS shows only the resources in under review by the current user (“My Review” selected) or resources unfiltered (“My Review” deselected).

2.4.12 Create a new resource revision in the BIMMS

Table 36 - Create a new resources revision

TEST CASE NAME	Create a new resources revision in the BIMMS
BRIEF DESCRIPTION	A user wants to create a new revision of the resource
GOAL	Create a new revision of the resource
SUCCESS MEASUREMENT	A resource is modified, and changes are saved in a new revision of the resource.
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the “Resource list” functionality. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List.
TRIGGER	The user selects one resources to check-out and edit its contents
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.onetteam.it/BIMMS/ 2. The user clicks on “Resource list” 3. If not already set, the user check-out a resource clicking on the padlock icon 4. (optional) the user can insert a comment for the new revision 5. The padlock icon become open and green 6. The user clicks on “edit resource” 7. The user edits the resource 8. Completed the changes, the user can update the resource

9. (optional) the user can check-in the resource during the update
10. Resource's history records the changes done and the revision counter is updated

2.4.13 Change ISO 19650 resource status in the BIMMS

Table 37 - Change ISO 19650 resource status

TEST CASE NAME	Change ISO 19650 resource status in the BIMMS
BRIEF DESCRIPTION	A user wants to change the status of the resource (in compliance with ISO 19650 CDE's resources status)
GOAL	Change the resource status to any combination of WIP, SHARED, and PUBLISHED status
SUCCESS MEASUREMENT	The resource changed its status
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "Resource list" functionality. One or more resources must be available in the BIMMS' CDE and listed in the Resource List.
TRIGGER	The user clicks the change status button of the resource in the Resource List
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ . 2. The user clicks on "Resource list". 3. The user clicks on "Change status button" for a resource. 4. The user selects the status from statuses available in the list. 5. The user inserts a comment for the new status (required). 6. (optional) the user can start an approval workflow selecting the option. 7. The user saves changes. 8. Resource's history records the status changes done and the revision counter is updated.

2.4.14 Start and manage a resource approval workflow in the BIMMS

Table 38 - Start and manage a resource approval workflow

TEST CASE NAME	Start and manage a resource approval workflow in the BIMMS
BRIEF DESCRIPTION	A user wants to start and manage an approval workflow for the resource
GOAL	When the resource changes the status to any combination of WIP, SHARED, and PUBLISHED, the user can request an approval workflow.
SUCCESS MEASUREMENT	The resource is approved or rejected before the status change
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "Resource list" functionality. One or more resources must be available in the BIMMS' CDE and listed in the Resource List. The resource must be defined using the ISO 19650 statuses. The reviewer must have permission to edit the resource in approval status
TRIGGER	The user clicks the change status button of the resource in the Resource List
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ .

2. The user clicks on “Resource list”.
3. The user clicks on “Change status button” for a resource.
4. The user selects the status from statuses available in the list.
5. The user inserts a comment for the new status (required).
6. The user selects the option “Do you want to start an approval workflow?” to start the approval workflow.
7. The user inputs one or more usernames of the users to be notified for the approval workflow (the reviewers).
8. The user inserts a comment for the approval workflow (required).
9. Resource’s history records the status changes done and the revision counter is updated.
10. The resource change its approval status in “In progress to..” with the name of the status of approval pending.
11. (optional) The reviewer can filter the resource with approval workflow enabled selecting “My review” option in the Resource List interface header.
12. The reviewer can approve or reject the resource clicking on the “approval” button.
13. (optional) the reviewer can insert a comment.
14. The reviewer approves or rejects the resource clicking on the buttons.
15. The resource approved change its status, the resource rejected maintain the existing status.

2.4.15 View the resource history of changes in the BIMMS

Table 39 - View the resource history of changes

TEST CASE NAME	View the resource history of changes in the BIMMS
BRIEF DESCRIPTION	A user wants to view and check the resource history of changes
GOAL	View all changes occurred in the resource, including the comments, the status changes, the versioning details, the chekin and chek-out status changes
SUCCESS MEASUREMENT	Visualize the resource history list
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the “Resource list” functionality. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List.
TRIGGER	The user clicks the info button of the resource in the Resource List
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.onetteam.it/BIMMS/ 2. The user clicks on “Resource list” 3. The user clicks on the resource’s “info” button 4. The user selects the “history” tab 5. The BIMMS shows a window with all resource changes details listed under a table with version, date, status, username, operation, previous value, updated value, and comments

2.4.16 Change the resource permissions in the BIMMS

Table 40 - Change the resource permissions

TEST CASE NAME	Change the resource permissions in the BIMMS
BRIEF DESCRIPTION	A user wants to view and manage the resource permissions.
GOAL	The user wants to change the resource permissions to allow one or more users to edit a resource and define work teams
SUCCESS MEASUREMENT	The resource permission is changed, and the enabled users can access to the resources according to the permissions set.
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the “Resource list” functionality. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List.
TRIGGER	The user clicks the info button of the resource in the Resource List
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/ . 2. The user clicks on “Resource list” . 3. The user clicks on the resource’s “info” button. 4. The user selects the “permission” tab. 5. The BIMMS shows a table with the permissions set for every resource’s status. 6. To add one or more user to with editor permissions (can view and modify the resource and its contents): the user inputs one or more usernames (separated by a semicolon) in the username field, select the status, and click the “Add user button” . 7. Users will be added to the selected status.

2.4.17 Delete a resource in the BIMMS

Table 41 - Delete a resource

TEST CASE NAME	Delete a resource in the BIMMS
BRIEF DESCRIPTION	A user wants to delete a resource.
GOAL	Delete one or more resources in the BIMMS
SUCCESS MEASUREMENT	The resource selected is deleted from the BIMMS’ Resource list
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the “Resource list” functionality. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List.
TRIGGER	The user clicks the info button of the resource in the Resource List
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/ . 2. The user clicks on “Resource list” . 3. The user clicks on the resource’s “delete” button. 4. The resource is deleted from the Resource List.

2.4.18 Create Linked Data resources in the BIMMS

Table 42 - Create Linked Data resources

TEST CASE NAME	Create Linked Data resources in the BIMMS
BRIEF DESCRIPTION	A user wants to create Linked Data resources.
GOAL	Create Linked Data resources
SUCCESS MEASUREMENT	A new Linked Data is created, is available in the Resource List, and retrievable through a SPARQL query
PRE-CONDITION	A The user is registered to the BIMMS, and his\her role is enabled to use the “Resource list” functionality. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List. An ontology is available in its repository.
TRIGGER	The user clicks on “New Linked Data Object”
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/ . 2. The user clicks on “New Linked Data Object”. 3. The user defines scope as “BIM4EEB Logbook”, category as “Logbook” and typology as “Logbook details”. 4. The user defines the resource “Title” and “Description”. 5. The user selects and set one or more ontologies. 6. The user selects and set one or more classes. 7. The user selects and set one or more properties and values. 8. (optional) The user defines the GeoLinked data to set the location of the Linked Data Object. 9. The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).

2.4.19 Create a Geo-Linked Data resource in the BIMMS

Table 43 - Create a GEO-Linked Data resource

TEST CASE NAME	Create a GEO-Linked Data resource in the BIMMS
BRIEF DESCRIPTION	A user wants to create Geo Linked Data resources.
GOAL	Create Geo Linked Data resources
SUCCESS MEASUREMENT	A new Geo Linked Data is created, is available in the Resource List, and retrievable through a SPARQL query
PRE-CONDITION	A The user is registered to the BIMMS, and his\her role is enabled to use the “Resource list” functionality. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List. An ontology available in its repository.
TRIGGER	The user clicks on “New Resource” (the same workflow can be applied on “New Linked Data Object”)
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/. 2. The user clicks on “New Resource”. 3. The user defines scope, category, and typology. 4. The user defines the resource “Title” and “Description”.

5. (optional) The user defines the Linked Data to be associated to the resource.
6. The user defines the GeoLinked data to set the location of the resource
 - a. The user clicks a point in the map to define the location of the resource.
 - b. The BIMMS shows the latitude and Longitude coordinates of the selected point.
 - c. The user gives a name to the location.
7. (optional) The user defines the link to existing IFC file in the project
8. The user uploads a file that represent the resource.
9. The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).The user defines the status of the resource (public resource or subject to ISO 19650): set status, prefix (only for ISO 19650), and check in (optional).

2.4.20 View BIM Models in the BIMMS

Table 44 - View BIM Models

TEST CASE NAME	View BIM models in the BIMMS
BRIEF DESCRIPTION	A user wants to view BIM Models.
GOAL	View and navigate through the BIM Models loaded in the BIMMS
SUCCESS MEASUREMENT	The BIM Model geometries and properties are shown in the BIM Viewer
PRE-CONDITION	A The user is registered to the BIMMS, and his\her role is enabled to use the “BIM Models” functionality. One or BIM Model resources must be available in the BIMMS’ CDE and listed in the Resource List and BIM Models.
TRIGGER	The user clicks on “BIM Models” and “View Model” button of the selected BIM resource
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/. 2. The user clicks on “BIM Models”. 3. The user clicks on “View model” button of the BIM Model resource selected. 4. The user uses the mouse buttons (left, center, right) to rotate, pan and zoom the model. 5. The user uses the buttons in the BIM viewer toolbar to view properties, hide and show elements, clip and unclip the model, hide and show ifcSpaces. 6. The user can select model items in the Hierarchy view and in the 3D canvas. 7. The user can select model items to see its properties in the property panel. 8. The user can select the model tree hierarchy mode to view the standard IFC hierarchy, the IfcZone hierarchy, and ifcGroup hierarchy.

2.4.21 Add sensors and measurements in the BIMMS

Table 45 - Add sensors and measurements

TEST CASE NAME	Add sensors and measurements in the BIMMS
BRIEF DESCRIPTION	A user wants to add sensors and measurements in the BIMMS
GOAL	Define a new sensor in a location and import its measurements saved in a CSV file.
SUCCESS MEASUREMENT PRE-CONDITION	The sensor and the measurements are available for the location and visible in Sensor and Measurement functionality The user is registered to the BIMMS, and his\her role is enabled to use the “Import Sensor”, “Import Measurement”, “Sensors” and “Measurement” functionalities. One or more BIM Model resources must be available in the BIMMS’ CDE and listed in the Resource List and BIM Models. The BIM Model must contain the location defined in the sensor as lfcZone. One or more CSV files with sensors and measurement data are available. The CSV file must have the same data structure defined in “Import sensors” and “Import measurements” template.
TRIGGER	The user clicks on “import Sensors” and “Import measurements” in the “Data Streaming” menu
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS’ Landing page at https://bim4eeb.oneteam.it/BIMMS/. 2. The user clicks on “Import Sensor”. 3. The user clicks on “Choose file” button and select the CSV file with sensors data. 4. The user clicks on “Import” button. 5. If import succeeded, the BIMMS give a response message with the details on how much rows of data were imported. 6. The user clicks on “Import Measurements”. 7. The user clicks on “Choose file” button and select the CSV file with measurements data. 8. The user clicks on “Import” button. 9. If import succeeded, the BIMMS give a response message with the details on how much rows of data are imported.

2.4.22 Run SPARQL queries in the BIMMS

Table 46 - Run SPARQL queries

TEST CASE NAME	Run SPARQL queries in the BIMMS
BRIEF DESCRIPTION	A user wants to run SPARQL queries in the BIMMS
GOAL	Run a SPARQL query to retrieve project data
SUCCESS MEASUREMENT	The query return results about the data queried
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the “SPARQL Endpoint”. One or more resources must be available in the BIMMS’ CDE and listed in the Resource List.
TRIGGER	The user clicks on “SPARQL Endpoint”

TYPICAL FLOW OF EVENTS

1. The user logs in clicking on the login button in the BIMMS' Landing page at <https://bim4eeb.oneteam.it/BIMMS/>.
2. The user clicks on "SPARQL Endpoint".
3. The user input a SPARQL query in the text box.
4. The user clicks on "Run" button.

2.4.23 Access to the tools of the BIM4EEB Toolkit

Table 47 - Access to the tools

TEST CASE NAME	Access to the tools of the BIM4EEB Toolkit
BRIEF DESCRIPTION	A user wants to access to the tools of the BIM4EEB toolkit
GOAL	Access and use the toolkit developed in the BIM4EEB project
SUCCESS MEASUREMENT	The user access to the list of the tools and is able to follow the links to the main page of the specific tools
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to use the "Tools".
TRIGGER	The user clicks on Tools
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/ 2. The user clicks on "Tools" 3. The user choose a tool and click on the button "Go to Tool" to access to the specific tool. If a direct link is not available the user can click on the button "Go to Video" to view a tool presentation video. 4. The user is redirected to the selected tool web page or (for the videos) to the BIM4EEB project's Youtube Channel.

2.4.24 Access to the REST API of the BIMMS

Table 48 - Access to the REST API

TEST CASE NAME	Access to the REST API of the BIMMS
BRIEF DESCRIPTION	A user wants to access to the REST API of the BIMMS
GOAL	Access and use the REST API
SUCCESS MEASUREMENT	The user access to the list of the REST API available in the BIMMS Web Services. The user can GET, POST, DELETE and PUT data using the endpoints provided in the REST API
PRE-CONDITION	The user is registered to the BIMMS, and his\her role is enabled to access to the "Endpoints" functionality. To use the REST APIs the user must be enabled as "Developer" role
TRIGGER	The user clicks on Endpoints
TYPICAL FLOW OF EVENTS	<ol style="list-style-type: none"> 1. The user logs in clicking on the login button in the BIMMS' Landing page at https://bim4eeb.oneteam.it/BIMMS/.

2. The user clicks on “Endpoints”.
3. The list of the endpoints is available in the page. The user can select an endpoint to get the documentation of the endpoint.
4. The user can click on Swagger link to be redirected to the BIMMS’ APIs Swagger UI (<https://bim4eeb.oneteam.it/BIMMSWS/swagger/ui/index>) that list the endpoints available.
5. From the Swagger UI, the user can select the endpoints to visualize and interact with the API resources.

3 BIMMS platform updates in M30

The tested version of the BIMMS platform released in M30 (June 2021) includes the updates and the new functionalities developed since the release of the preliminary toolset in M18 (June 2020). In this section the functionalities added or updated with changes available in the BIMMS Web portal and in the BIMMS’ API Services are described.

The full list and detailed description of the BIMMS’ functionalities and features is available in the public deliverable published in M18 (June 2020) D4.7 “API, Master end-user front end”, that specify and document the APIs and providing an End User manual of the BIM Management System. The deliverable D4.8 “Guidelines for the integration of new tools in the BIM management system” (published in M18-June 2020) provides the reference documentation to the developers to integrate new tools in the BIM management system.

3.1 BIMMS’ Platform Front-End updates

The BIMMS Front-end is accessible from a HTTPS web address at <https://bim4eeb.oneteam.it/BIMMS/>. From the main page, the user can access to the platform using the Username and Password created during registration process and use all the functionalities enabled for his/her role.

The major updates of the functionalities and features are listed in the following Table 49.

Table 49 – BIMMS functionalities major updates in M30

BIMMS functionalities updated in M30 (June 2021)	Description
Resource management	<ul style="list-style-type: none"> • Compliance with ISO 19650 resource status and versioning, • Document check-in and check-out, • ICDD (ISO 21597) Information container creation, • Search and filter resources by properties
New Resource	<ul style="list-style-type: none"> • ISO 19650 Status • Approval status
Resource List	<ul style="list-style-type: none"> • Approval workflows • History of changes • Resource permissions management
BIM Models	
Geo Linked Data	<ul style="list-style-type: none"> • Real time weather information • Linked data from Wikidata Services
Logbook Data List	<ul style="list-style-type: none"> • Direct access to the Digital Logbook Data
BIM Viewer	<ul style="list-style-type: none"> • Direct access to the Digital Logbook linked to the model (if available) • IfcGroup hierarchy tree view
SPARQL Endpoint	<ul style="list-style-type: none"> • Display the execution time • Save query results in a file
Administration	<ul style="list-style-type: none"> • Roles and permission management

The detailed description of the updated and added functionalities is available in the Annex I in Section 6.1 “BIMMS Front End Updates” at the end of this deliverable.

3.2 BIMMS' REST API updates

The BIMMS REST API Service allows to put, edit and get data from and to the BIMMS. The added or updated API endpoints are listed in the following Table 50.

The major updates are related to:

- simplify the access to the file list in the projects,
- the management of the IFC files and their hierarchy to include additional endpoints to manage IfcGroup entities and to get the BIM objects in the hierarchy,
- include endpoints to edit and delete existing data in occupancy, activities and alerts,
- get resource information from Virtuoso graph database.

Table 50 – BIMMS API Endpoints added in M30

API group	Description	Changes in M30 (June 2021)	Endpoints added\updated
OTMySQL-User API	Access to authentication services, the definition of user access profiles and the projects accessible to the user who uses the API.	No	n.a.
OTMySQL-Project API	Access to the structure of each project and graphs associated with the project	Yes	Added: <ul style="list-style-type: none"> • getProjectData • getProjectNamedIFC • getProjectFiles • getProjectNamedFile
OTMySQL-IFC API	Access the IFC files and structure (remembering that BIMMS also converts IFC files into data within the SQL database tables to optimize access to data).	Yes	Added: <ul style="list-style-type: none"> • getResourceFile • getIFCHierarchyWithObjs • getIFCGroups • setIFCGroup • modIFCGroup • delIFCGroup
OTMySQL-Resource API	Interact with the resources (documents) of the BIMMS system.	No	n.a.
OTMySQL-Sensors API	Upload and access to raw data of the sensors and associated measurements	No	n.a.
OTMySQL-EndUser API	Manage the End-User (Owner or Inhabitants) and the IFC Zones, to associate the apartments with the individual end-users.	No	n.a.
OTMySQL-Occupancy API	Access and management of the definition of the occupancy profiles of each Zone	Yes	Added: <ul style="list-style-type: none"> • modOccupancy • delOccupancy • modOccupancySchedule

			<ul style="list-style-type: none"> • modOccupancyScheduleData
OTMySQL-Activity API	Manage (reading and creation) the Activities related to the lfc Zones	Yes	Added: <ul style="list-style-type: none"> • getActivityFromOriginActivityID • modActivity • delActivity
OTMySQL-Alerts API	Manage the Alerts (reading and creation) linked to the lfc Zones	Yes	Added: <ul style="list-style-type: none"> • modAlert • delAlert
OTSPARQL	Query the data stored in Virtuoso Graph Database	Yes	Added: <ul style="list-style-type: none"> • getSPARQLData
OTVirtuoso	Load and delete data (Triples) within the Virtuoso Graphs Database, including the creation and deletion functions of the Graphs (created by connected user).	Yes	Added: <ul style="list-style-type: none"> • OTVirtuoso/{id}
OTGeoLinkedData	Query the geographic data stored in Virtuoso Graph Database, associated with the resources of the BIMMS	No	n.a.
OTRdf	Load RDF file within Virtuoso Graph databases	No	n.a.

The detailed description of the updated and added endpoints is available in the Annex I in Section 6.2 “BIMMS REST API Updates” at the end of this deliverable.

4 Conclusions

This document describes the activities done to test and evaluate the BIMMS platform in its final implementation. The result of these activities is the tested version of the platform that can be used in the project demonstration sites as part of the BIM4EEB toolkit.

The testing activities evaluated the fulfilment of the requirements defined in the beginning of the BIM4EEB project. The requirements have been documented in the previous activities of the WP4, that collected and analysed the stakeholder needs defined in WP2, the ontologies framework in WP3, the tools' data exchange requirements in WP5, 6, and 7, and the specific demonstration pilot sites' needs in WP8.

The tests have been done with a set of use test cases that simulate the most common renovation works workflows and are suitable to be repeated to confirm the results and the conclusions of this document. The result of the testing activities are successful and in conformity with the target defined in the test cases about the success measurement description. The demo test project¹ stores the data used for testing, recording the changes done applying the test cases.

The BIMMS' CDE offer all the functionalities to manage documents in compliance with the BIM standards ISO 19650 series in a web environment with an IFC viewer that allows the user to share and check documents and models anywhere and anytime using their desktop and mobile devices.

The Linked Data features of the BIMMS platform allows the users to use their tools to share and exploit the richness of the Semantic Web. End users can benefit of the same features using the web interfaces to define and retrieve the Linked Data resources (Valra, 2020).

Moreover, the rising adoption of the BIM as new paradigm in the design and operations phase is resulting in a high demand of tool integration and interoperability. The workflow proposed in the implementation of the BIMMS goes toward the integration of the new and existing authoring tools (the BIM4EEB Toolkit and other existing tools) and the interoperability of data through data exchange services. The tools and the BIMMS platform can work as client-server configuration. The BIMMS' APIs allows to integrate the BIM4EEB Toolkit in the platform and also any other external tool to exchange data with the BIMMS and then improve the collaboration between the users in the renovation project. The testing activities demonstrated that the endpoints developed are suitable and useful in the most common renovation works data workflows. Some API endpoints can be used to update interactively the IFC BIM model to avoid some bottleneck tasks (export-upload-download-import) demonstrating that the technology available is ready to support the data exchange instead of traditional file exchange methods. These results can be improved further to include methods to update the model geometry and other features that could improve the data exchange between different tools.

The BIMMS' SPARQL Endpoint can be used in the operation phase as point of presence to share the project data to the authorized and authenticated stakeholders as interface to query all the data about the building lifecycle and get fine analysis about the building performance, monitoring operations and maintenance in the years and compare the results with the other datasets available online. In the design phases it can improve the knowledge about the surroundings (environmental, social and administrative data) and can be used to retrieve additional data to enrich the BIM models (multiobjective simulation results, materials components, equipment characteristics, etc). As the SPARQL queries can be complex and tricky to understand, it is advisable to configure interfaces that allow end users to define search terms in a simplified and familiar syntax (leaving the elaborate jargons in the backend of the application). Moreover, the availability of public SPARQL endpoints to retrieve data is very limited and often do not cover the needs of the professionals involved in the renovation project. At time of writing (June2021) the LinkedGeoData, one of the most important initiative in the Semantic Web about spatial information, just coming back online restoring their servers down since January 2021 (some regional endpoints are still down), resulting in a server downtime of almost 50%, not suitable for working purposes. However, there are also reliable services, mostly available and hosted by European Commission agencies or by well know

¹ One Team Demo

foundations like Wikimedia Foundation that host Wikidata services. Unfortunately the number of these services is still very limited.

Finally, the platform will be tested in the real demonstration environment where all the functionalities and the features will be further tested and the results will be used to further improve the BIMMS.

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6 Annex I

The following sections details the BIMMS functionalities updated in the tested version of the platform released in M30 (June 2021). The added functionalities in the BIMMS Front End are described in Section 6.1 and the new REST API endpoints are listed in Section 6.2. These additions constitute an update to the Deliverable D4.7 “API, Master end-user front end” published in M18 (June 2020) that specify and document the APIs and provide the End User manual of the BIM Management System (One Team, 2020).

6.1 BIMMS Front End Updates

As defined in development roadmap, in M24 (December 2020) were implemented some updates to fully implement in the BIMMS’ CDE the resource management according to the international BIM standard ISO 19650 Series. The following sections describe the major updates available for the users and were described first in the deliverable D4.4 CDE Services, Interoperability Services, Exchange Layer Services, I/O Protocols and Data specification” (One Team, 2021), published in M29 (May 2021). As the deliverable D4.4. is confidential, some descriptions of the functionalities are a quote of the original deliverable.

6.1.1 Resource Management - New Resource

The creation of a new resource in the BIMMS’ CDE, in the last step of the creation wizard, allows to define the resource as “public resource” or as “ISO 19650-2 resource”.

“The public resources, as the name recalls, are visible to all project’s users (they can see, open, and download) but changes and editing permissions are exclusively to the resource owner (the creator user can edit). The resource cannot be subject to any approval workflows, cannot be locked with check-in and check-out, and its status and changes are not monitored to be notified by email. Public resources support versioning and the ISO 19650 status code property that define the “suitability of the content of an information container” (ISO, 2018). The “ISO 19650-2 resource” include the possibility to manage the resources in full compliance with the ISO 19650-2 standard (ISO, 2018). The major improvements are the approval workflows, the resource’s status code management, the edit permissions, and the check-in and check-out functionalities. In Table 51 there is a summary comparison between the features of the generic public resources and the ISO 19650-2 resources in the BIMMS’ CDE” (One Team, 2021).

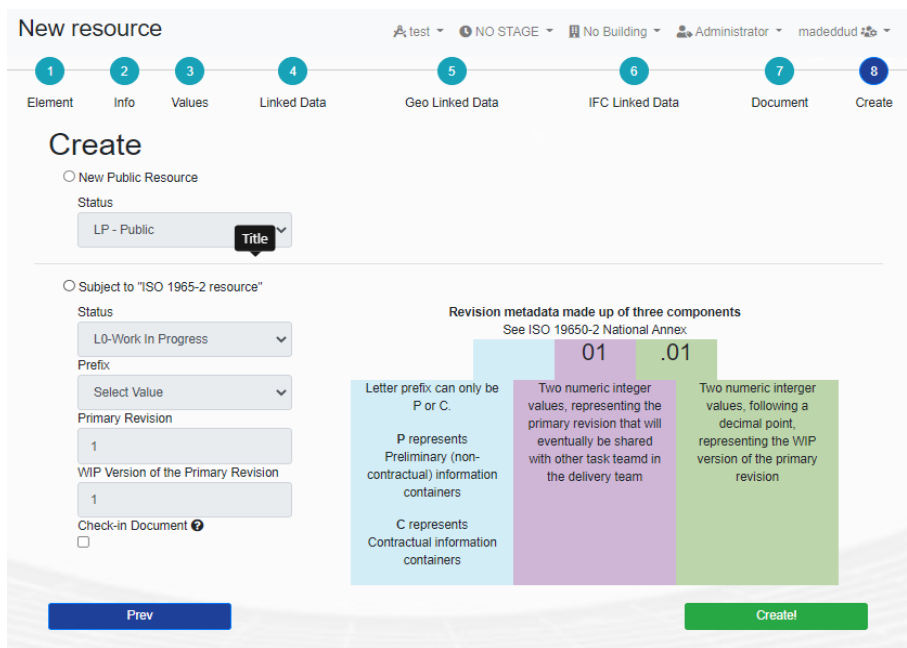


Figure 19 – BIMMS’ New resource – status set (One Team, 2021)

Table 51 – Comparison between “public resources” and “ISO 19650-2 resource” types in the BIMMS’ CDE – (One Team, 2021)

Features	New Public Resource	Subject to “ISO 19650-2 Resource”
Can be set user permissions on the resource?	NO	YES
The resource is visible to all users by default?	YES	NO
The resource can be checked-in or checked-out?	NO	YES
The resource has the ISO 19650 Status Code property?	YES	YES
The resource can change the ISO 19650 Status Code property?	YES	YES
The resource can be subject to the “Approval Workflows”?	NO	YES
The change of resource’s status and permission can be notified by email?	NO	YES
The resource supports versioning?	YES	YES

“The “public resources” functionalities were deployed in the first phase of the WP4 – Task 4.4 as result of the first milestone of the BIMMS’ CDE development in M18 (June 2020). The “ISO 29650-2 resource” functionalities were deployed first in M24 (December 2020) as result of the second milestone of the BIMMS’ CDE development. The “public resources” will be maintained in the final deployment of the BIMMS’ CDE to assure the backward compatibility and to allow a simplified method to share data to all project’s users without any additional setup (permissions) or when is not required to implement any approval workflow. The “ISO 19650-2 resources” remain the best choice to implement a full compliance workflow with this BIM standard in the context of BIM4EEB” (One Team, 2021).

6.1.2 Resource Management – Resource list

“The BIMMS’ “Resource list” functionality (Figure 27) lists and manages all the resources stored in the BIMMS. The interface shows the main resource properties and a set of buttons that allows to view and manage the contents. Most of the properties can be also used to search and filter the resources using the fields on the header of the interface. A set of icons and colors inform the user about the status code of the revisions and the check-in/check-out status” (One Team, 2021).

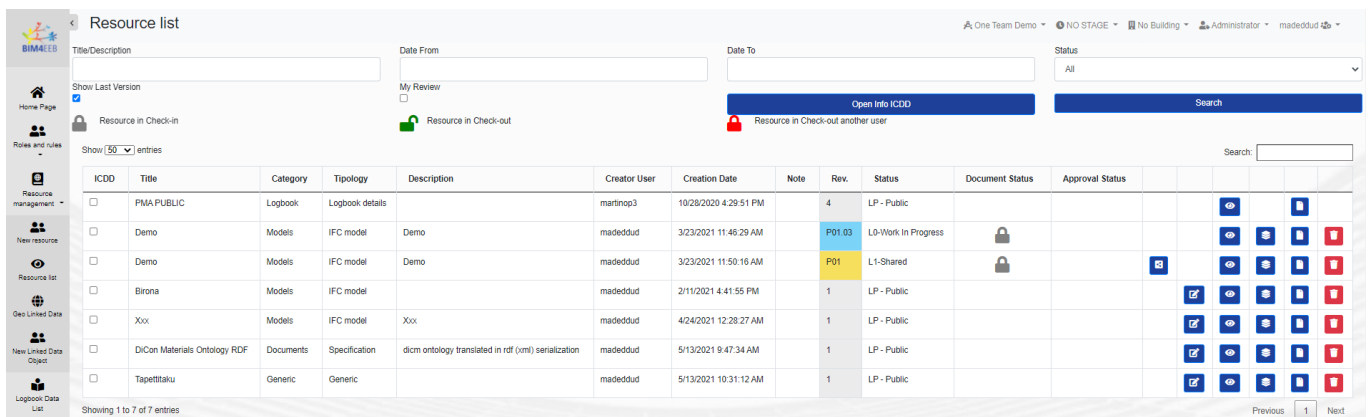


Figure 20 – BIMMS Resource list (One Team, 2021)

As defined in development roadmap, in M24 (December 2020) was implemented the internal structure of the CDE that can be managed according to the ones contained in the international standards as the ISO 19650. Therefore, the tested version of the BIMMS' CDE "implements a set of metadata to manage the resources as information container:

- Resource GUID (hidden in the web portal user interface, available in SPARQL and APIs endpoints),
- Resource\container title (name),
- Scope (used for classification),
- Category (used for classification),
- Typology (used for classification),
- Description (used for classification),
- Creator user (Author),
- Creation date,
- Revision code,
- Status code,
- Document status (for check-in\out),
- Approval status.

The revision, status, and classification code are the three metadata recommendation in ISO 19650-1 (clause 12.1) (ISO, 2018). All of them are implemented with additional metadata used for the specific purposes of the BIMMS' CDE. The classification code is defined with the concatenation of scope, category, typology, and description metadata available in the resources. As the settings for category and typology are defined as parametric (can be set and customized without hardcoding the BIMMS' source code), they can be customized to align the organization requirements" (One Team, 2021).

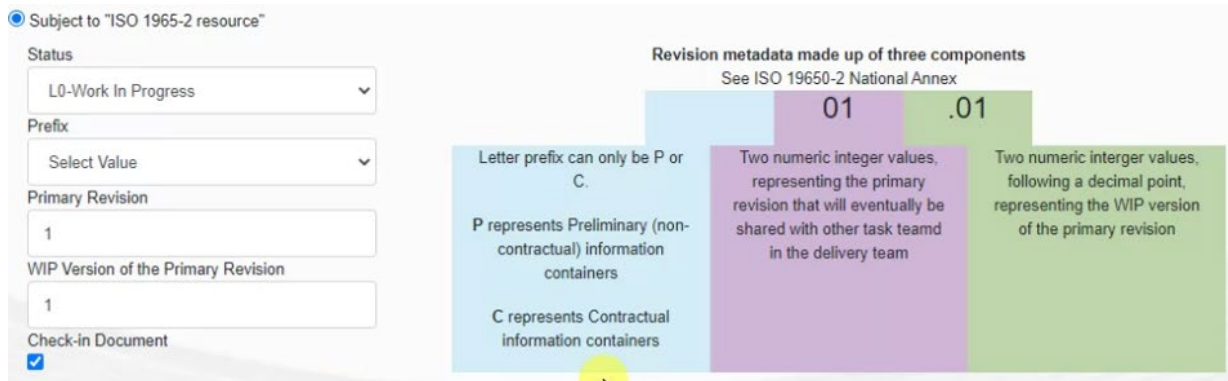
6.1.3 Resource Management - Versioning and status code

"To take track of the historical changes of the resources, the BIMMS' CDE implement a versioning system managed by a revision code. As the resource is developed in different states and shared multiple times in different states, was necessary to implement a coding standard based on two elements that track changes in L0-WIP and the other states when shared.

In M24 (December 2020) was implemented the new versioning system based on some well-known versioning and revision standards available in AEC (Architecture, Engineering, Construction) context and referenced in the official UK BIM Framework guidance to BS EN ISO 19650 (UK BIM FRAMEWORK, 2020). The Figure 10 shows the last step of the wizard used in the definition of a new resource with the "New resource" functionality. The BIMMS' CDE revision code is composed by three elements:

- one letter prefix (A, B, C, etc.), used to define the kind of information contained in the containers (i.e.: P for preliminary and C for contractual information container),
- two integers (01, 02, 03, etc.), representing the primary revision: this setting allows to share the revision with internal task teams,
- two integers (01, 02, 03, etc.), representing the WIP version of the primary revision.

The primary and WIP versions are automatically defined by the BIMMS, and the user must select only the prefix" (One Team, 2021).



Subject to "ISO 1965-2 resource"

Status: L0-Work In Progress

Prefix: Select Value

Primary Revision: 1

WIP Version of the Primary Revision: 1

Check-in Document:

Revision metadata made up of three components
See ISO 19650-2 National Annex

01 .01

- Letter prefix can only be P or C.
 - P represents Preliminary (non-contractual) information containers
 - C represents Contractual information containers
- Two numeric integer values, representing the primary revision that will eventually be shared with other task team in the delivery team
- Two numeric interger values, following a decimal point, representing the WIP version of the primary revision

Figure 21 – BIMMS’ CDE revision code definition (One Team, 2021)

6.1.3.1 Resource Management - Check-in and check-out

“The “check-in” and “check-out” properties refer to the common document management system functionality that add a temporary write protection on a resource to avoid conflicts when changes are done by other users in contemporary editing. The “check-in” status make a resource available in the BIMMS’ CDE, and means that no other users are modifying the resource. The “check-out” status, on the contrary, make the resource unavailable for editing to the other users. A set of coloured icons on the BIMMS’ Resource list give an indication of the status of the check of the resources” (One Team, 2021) (Figure 22).

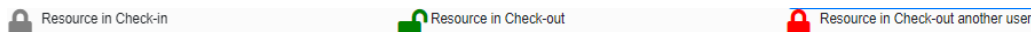
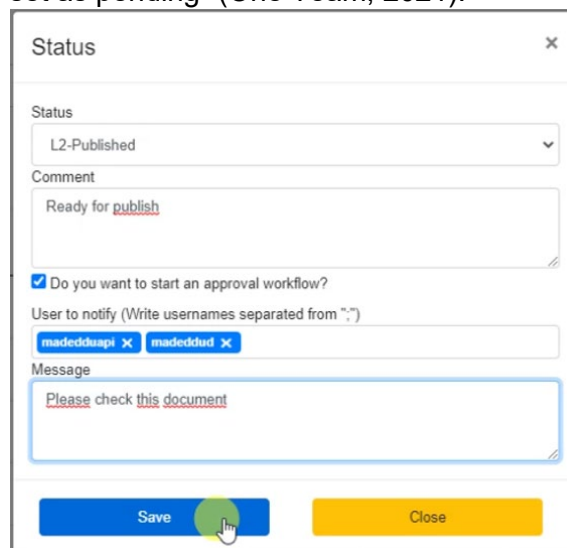


Figure 22 - Resource check-in/out status icons (One Team, 2021)

6.1.3.2 Resource Management - Approval workflows

In M24 (December 2020) was implemented a functionality that allows to start an “approval workflow” on a resource. “When a user changes status on a resource (i.e. a resource in L0-WIP is ready to be shared in L1-SHARED, or in the next combination of the statuses allowed by the ISO 19650 standard), he or she can start an approval workflow as shown in Figure 23 and Figure 24. The resource owner (who starts the approval workflow) can notify the users that review the resource contents to approve or reject the change of status. The reviewers receive an email notification and they can see also the resource in the resource list panel with approval status set as pending” (One Team, 2021).



Status

Status: L2-Published

Comment: Ready for publish

Do you want to start an approval workflow?

User to notify (Write usernames separated from ";")

madeddnapi x madeddnad x

Message: Please check this document

Save Close

Figure 23 – Resource status change with approval workflow (One Team, 2021)

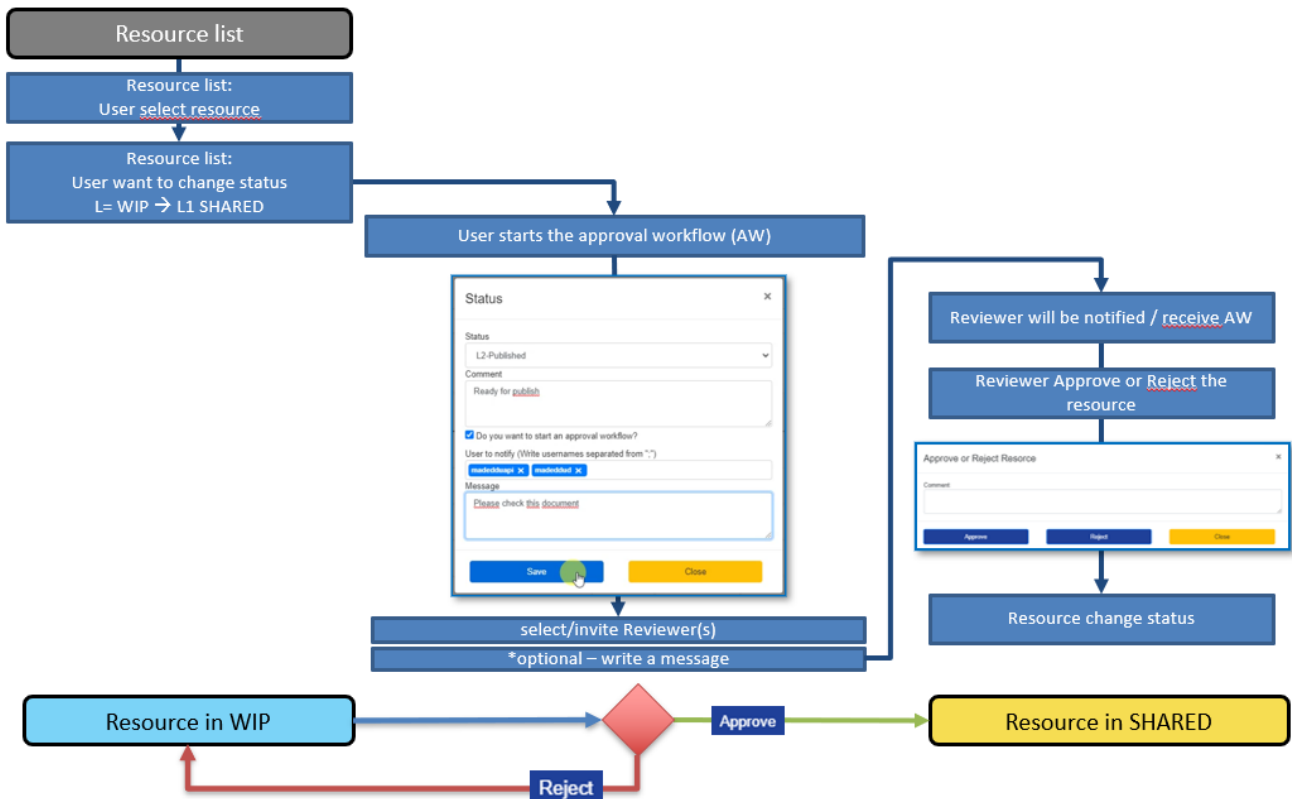


Figure 24 – The approval workflow (One Team, 2021)

Reviewers can approve or reject the resource giving also a comment using the panel shown in Figure 25.

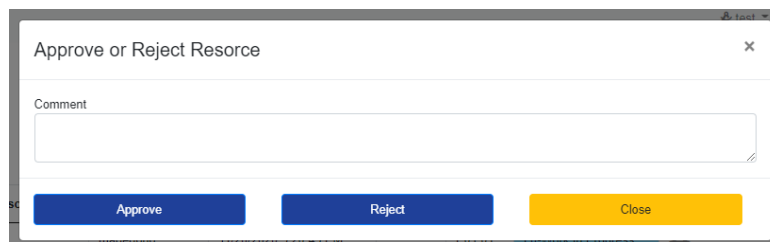


Figure 25 – Approve or reject a resource dialog box (One Team, 2021)

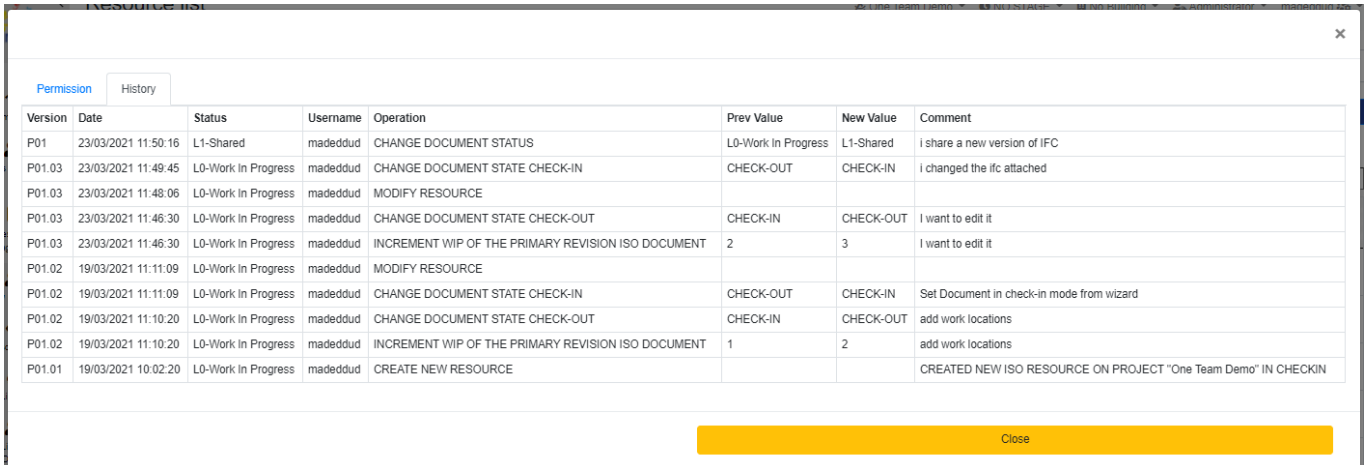
The resource status is visible to all users in the approval status field, in the resource list panel as shown in Figure 26.

Title	Category	Tipology	Description	Creator User	Creation Date	Note	Rev.	Status	Document Status	Approval Status
myProject_20201120_02	Models	IFC model		madeddud	11/23/2020 12:19:10 PM		P01	L1-Shared	🔒	
myProject_20201120_02	Models	IFC model		madeddud	11/20/2020 3:20:49 PM		P01.01	L0-Work In Progress	🔒	Approved to L1-Shared
public	Documents	Datasheet		farinad	11/19/2020 12:33:13 PM		4	LP - Public		

Figure 26 – Resource approved (One Team, 2021)

6.1.3.3 Resource Management - History of changes and permissions on resources

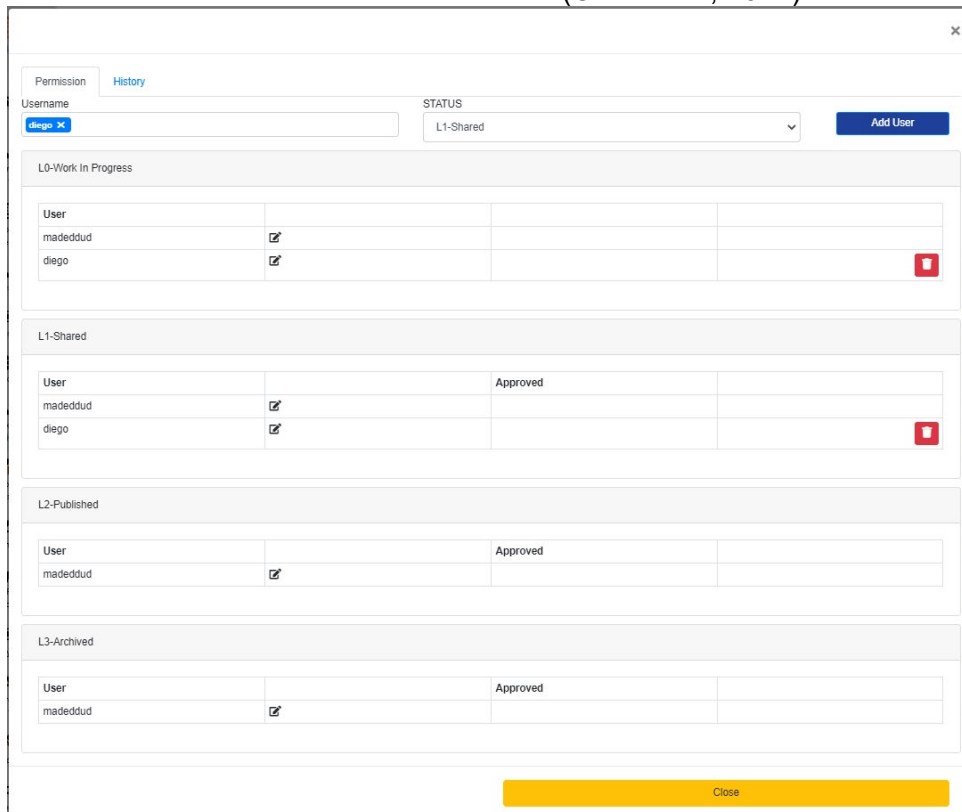
The resource history of changes (Figure 27) allows to check which users have done changes, when changes happened, and which changes has done. Comments can be added by users or can be set by default by the BIMMS when the resource change status, or is checked-in\out” (One Team, 2021).



Version	Date	Status	Username	Operation	Prev Value	New Value	Comment
P01	23/03/2021 11:50:16	L1-Shared	madeddud	CHANGE DOCUMENT STATUS	L0-Work In Progress	L1-Shared	i share a new version of IFC
P01.03	23/03/2021 11:49:45	L0-Work In Progress	madeddud	CHANGE DOCUMENT STATE CHECK-IN	CHECK-OUT	CHECK-IN	i changed the ifc attached
P01.03	23/03/2021 11:48:06	L0-Work In Progress	madeddud	MODIFY RESOURCE			
P01.03	23/03/2021 11:46:30	L0-Work In Progress	madeddud	CHANGE DOCUMENT STATE CHECK-OUT	CHECK-IN	CHECK-OUT	I want to edit it
P01.03	23/03/2021 11:46:30	L0-Work In Progress	madeddud	INCREMENT WIP OF THE PRIMARY REVISION ISO DOCUMENT	2	3	I want to edit it
P01.02	19/03/2021 11:11:09	L0-Work In Progress	madeddud	MODIFY RESOURCE			
P01.02	19/03/2021 11:11:09	L0-Work In Progress	madeddud	CHANGE DOCUMENT STATE CHECK-IN	CHECK-OUT	CHECK-IN	Set Document in check-in mode from wizard
P01.02	19/03/2021 11:10:20	L0-Work In Progress	madeddud	CHANGE DOCUMENT STATE CHECK-OUT	CHECK-IN	CHECK-OUT	add work locations
P01.02	19/03/2021 11:10:20	L0-Work In Progress	madeddud	INCREMENT WIP OF THE PRIMARY REVISION ISO DOCUMENT	1	2	add work locations
P01.01	19/03/2021 10:02:20	L0-Work In Progress	madeddud	CREATE NEW RESOURCE			CREATED NEW ISO RESOURCE ON PROJECT "One Team Demo" IN CHECKIN

Figure 27 – Resource history of changes (One Team, 2021)

“The BIMMS’ CDE allows to set permissions on the single resources and for all container statuses. This feature allows to define task teams with more than one user (Figure 28). The concurrent editing on the same resource is avoided using the check-in\out functionality that locks the resource and can be edited only by the user that have first checked-out the resource” (One Team, 2021).



The screenshot shows a 'Permission' panel with a 'History' tab. At the top, there is a 'Username' field with 'diego' selected and a 'STATUS' dropdown menu set to 'L1-Shared'. An 'Add User' button is visible. Below this, there are four sections corresponding to different resource statuses: 'L0-Work In Progress', 'L1-Shared', 'L2-Published', and 'L3-Archived'. Each section contains a table with columns for 'User', 'Approved', and a red stop button. In the 'L0-Work In Progress' section, users 'madeddud' and 'diego' are listed with checkmarks in the 'Approved' column. In the 'L1-Shared' section, 'madeddud' and 'diego' are listed with checkmarks, and the 'Approved' column contains the text 'Approved'. The 'L2-Published' and 'L3-Archived' sections also show 'madeddud' with a checkmark and the text 'Approved' in the 'Approved' column.

Figure 28 – BIMMS’ CDE Permission panel (One Team, 2021)

6.1.4 Geo Linked Data

“The Geo Linked Data step in the New resource’s wizard define the geographic location of the resource. This step allows to set, in an interactive map, a point that represent the position retrieving the latitude and the longitude that are recorded in the BIMMS’ database using the geoWGS84” (One Team, 2021). In the tested version of the platform, the functionality was updated, in line with the Linked Data principles, to enable the “BIMMS’ Geo Linked Data to use by default the Wikidata Query Services (Wikidata, 2020) to retrieve the points of interest and the cities around 1Km from the resource’s location. Wikidata is one of the main free knowledge bases available on Internet with almost 100 million data items, used mainly in well-known Wikipedia web pages. The Geo Linked Data functionalities uses a preconfigured query that can be edited to retrieve any other kind of data available on Wikidata Services (Wikidata, 2020). Wikidata was used as main service endpoint thanks to the high availability of its datasets and the very low server outage. Moreover, the BIMMS’ SPARQL Endpoint can be also used to perform similar query requests against other public endpoints, taking as input the geo Linked Data definitions stored in the BIMMS” (One Team, 2021).

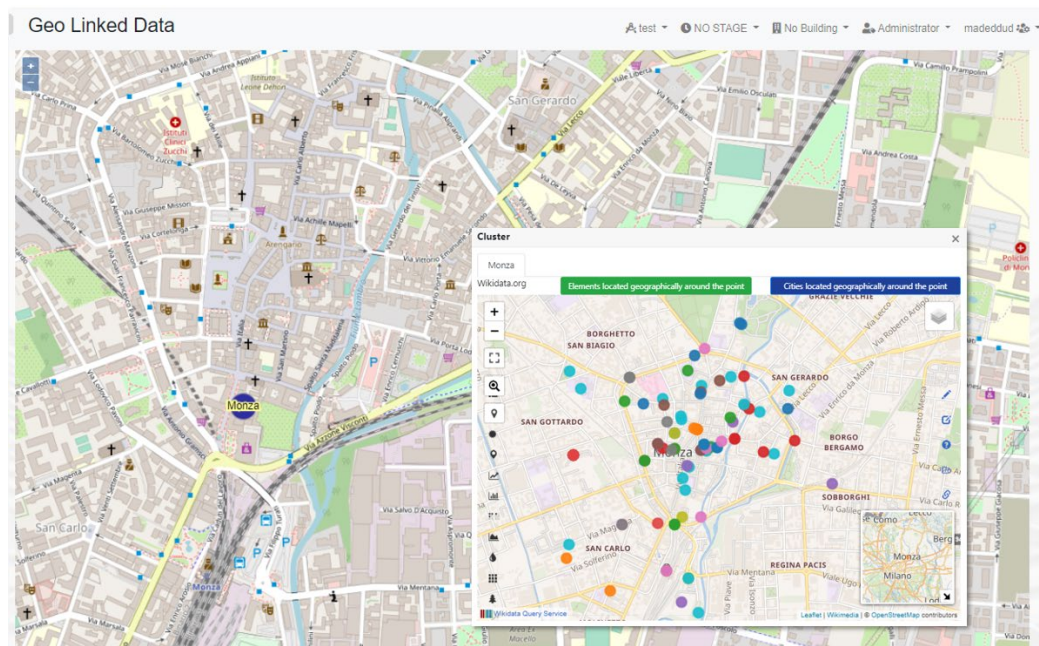


Figure 29 – BIMMS’ Geo Linked Data functionality: the points of interest near the resource location (One Team, 2021)

“The GeoLinked Data are then available for consultation through the BIMMS’ “Geo Linked Data” functionality that shows all the locations in a map with single points or clusters depending on how much locations are defined near each other. When the point is selected (clicking on it), a new panel will be shown. This panel shows a map with the results of a federated query done using the Wikidata Query Service to retrieve information about geographic elements located near the location. This feature allows to exploit the data distributed on the Web and improve the knowledge of the neighbors where the project resource is located. The query uses the wikibase service in Wikidata Query Service, passing the Latitude and Longitude of the dice:Location as center of interest that, combined with a radius (by default 1Km), will get the results shown in the map as colored points. This feature allows to select the points that will open a descriptive label with a few links to the main Wikidata web page where are listed all the property statements available” (One Team, 2021). The Figure 30 shows a few examples of the data that can be retrieved using the functionality.

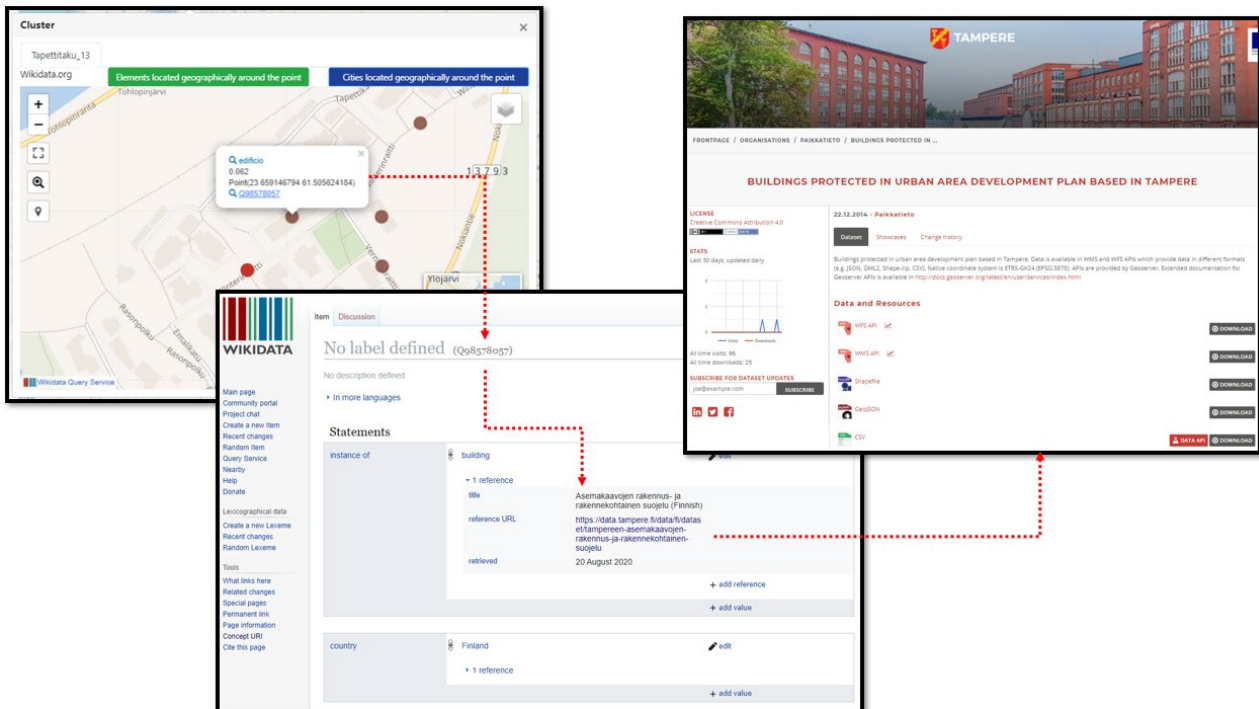


Figure 30 – Point of interest additional information, retrieved with GeoLinked data functionalities and Wikidata services (One Team, 2021)

6.1.5 Digital logbook

In M24 (December 2020) was implemented the BIMMS’ Digital logbook functionality (Figure 29). “The Logbook resource is used to store all data related to the building and will be used mostly in the operational phase of the building as it stores important data associated to the maintenance. The Logbook contains data stored in multiple tables with categorized field that can be manually filled by the users depending on the roles associated. All data fields in the logbook have permissions set for certain kind of users’ role that enable or disable the editing and the visualization. For example, a local authority role can read some of the fields, edit a few related the cadastral data, and cannot see other data related to specific private information” (One Team, 2021).

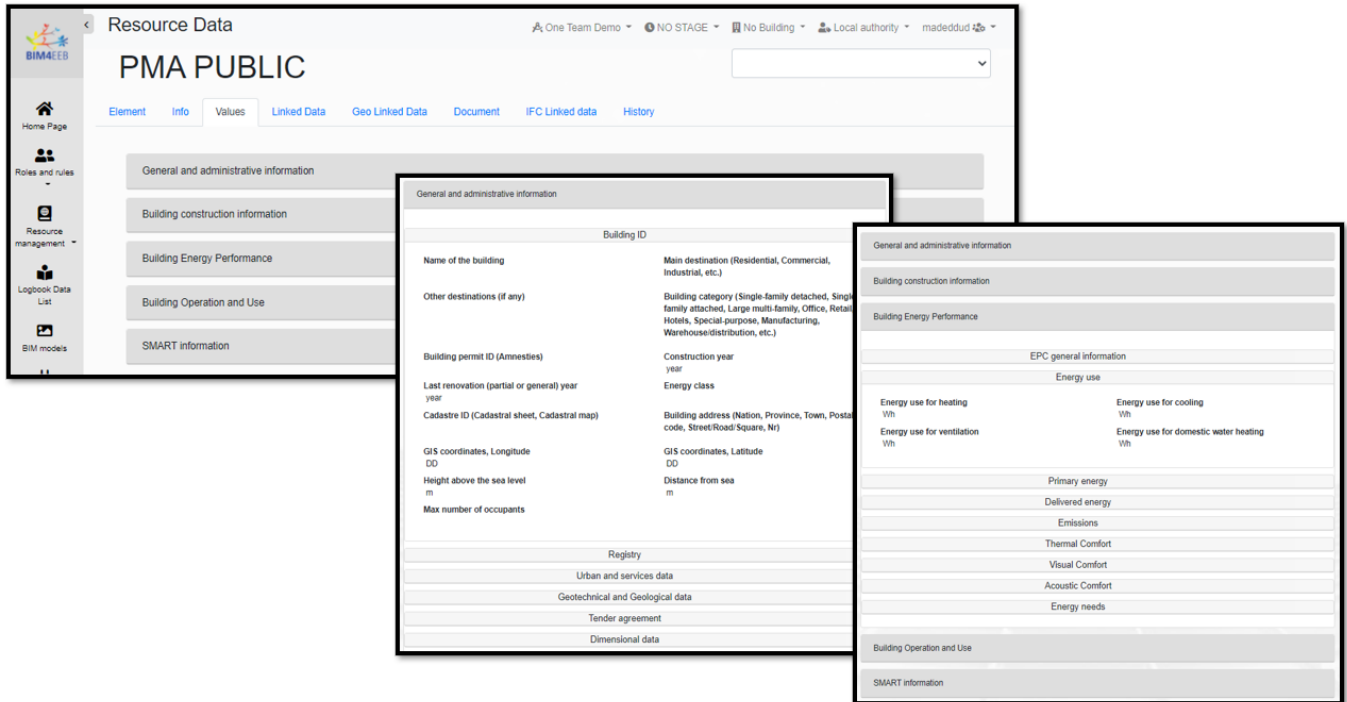


Figure 31 – BIMMS’ Digital Logbook (One Team, 2021)

6.1.6 Create ICDD containers

The tested version of the BIMMS platform includes the functionality “Create ICDD” available in the “Resource list” panel that allows to create ICDD containers that conform to the ISO 21597. The container can contain one or more resources already stored in the BIMMS (Figure 30).

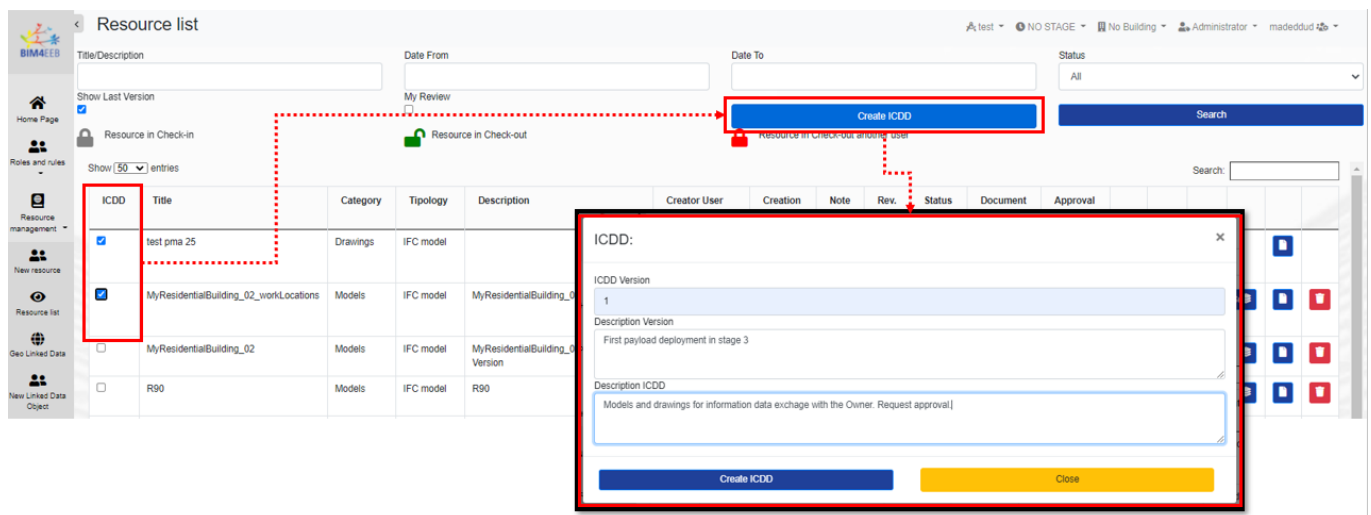


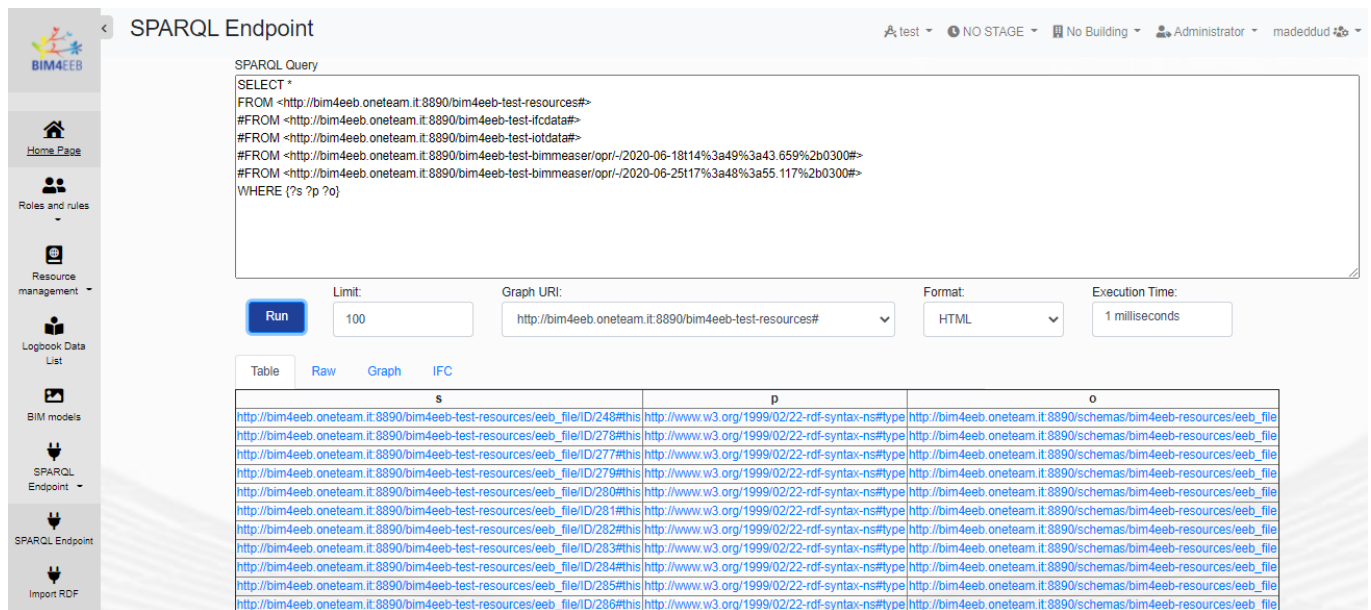
Figure 32 – The BIMMS’ Create ICDD (One Team, 2021)

“The functionality creates a ICDD container file based on the ISO/IEC 21320-1 (ZIP64). The file is saved with the standard pre-defined folder structure described in ISO 21597-1, with a index.rdf file that describe the contents of the container (document list, file names, references to other datasets, etc.), the author, the versioning, and the description. The files that belong to the selected resources, are saved in the payload

documents folders” (One Team, 2021).

6.1.7 SPARQL Endpoint

“The SPARQL Endpoint is a point of presence on an HTTP network that can receive and processing SPARQL Protocol requests (Idehen, 2018). It is identified by a URL commonly referred to as a SPARQL Endpoint URL and enables users to explore the resources stored in the CDE using SPARQL queries” (One Team, 2021). The tested version of the platform released in the M30 (June 2021) updated the BIMMS SPARQL Endpoint functionality including the visualization of the query execution time and the possibility to download and save the query results in various file formats.



The screenshot shows the BIMMS SPARQL Endpoint interface. On the left is a navigation sidebar with icons for Home Page, Roles and rules, Resource management, Logbook Data List, BIM models, SPARQL Endpoint, and Import RDF. The main area is titled 'SPARQL Endpoint' and contains a text area for a SPARQL query. Below the query area are controls for 'Run', 'Limit' (set to 100), 'Graph URI' (http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources#), 'Format' (HTML), and 'Execution Time' (1 milliseconds). Below these controls are tabs for 'Table', 'Raw', 'Graph', and 'IFC'. The 'Table' tab is active, displaying a table with three columns: 's', 'p', and 'o'. Each row contains URIs for subject, predicate, and object.

s	p	o
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/248#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/278#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/277#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/279#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/280#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/281#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/282#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/283#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/284#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/285#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file
http://bim4eeb.oneteam.it:8890/bim4eeb-test-resources/eeb_file/D/286#this	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://bim4eeb.oneteam.it:8890/schemas/bim4eeb-resources/eeb_file

Figure 33 – The BIMMS SPARQL Endpoint (One Team, 2021)

6.1.8 Administration – Permission and Management system roles

In M24 (December 2020) was implemented the functionality to manage the management system roles and set the permissions to enable or disable specific functionalities to roles. The access to this functionality is reserved only to BIMMS Administrators.

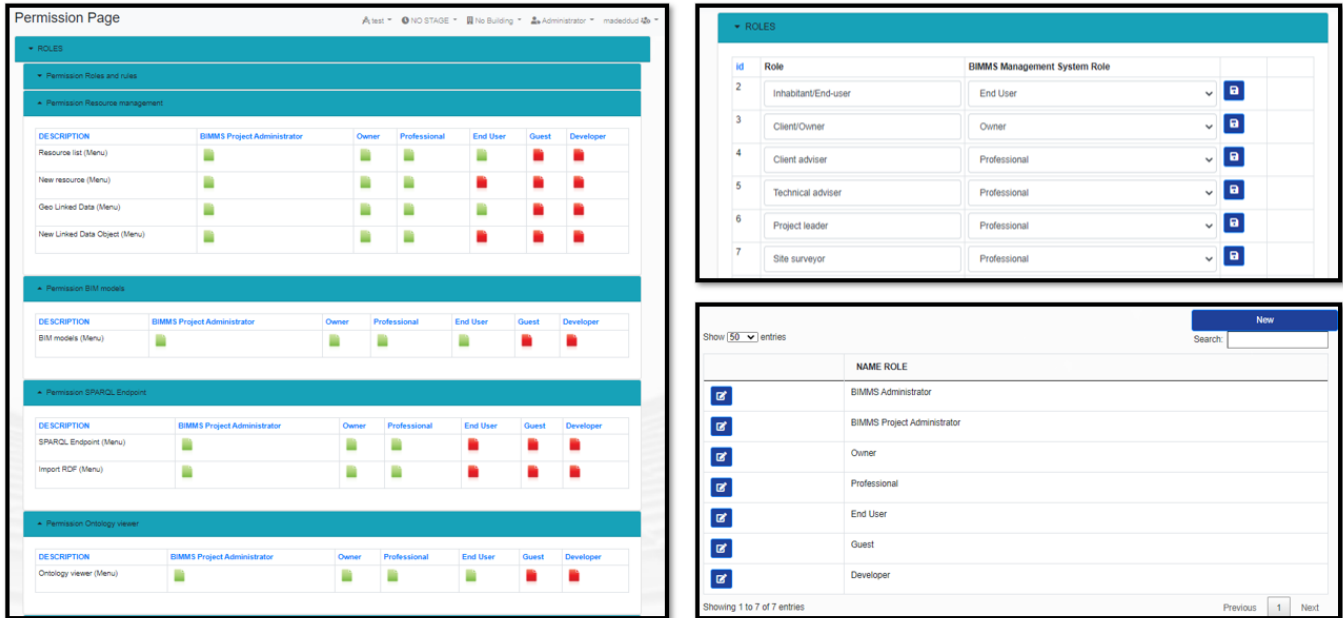


Figure 34 – BIMMS' Administration functionalities (One Team, 2021)

6.2 BIMMS REST API Updates

The Table 52 shows the BIMMS' API endpoints updated in the tested version of the platform released in M30. The full list of the REST APIs is available on the BIMMS Web Portal under the Endpoints in the left side menu². The endpoints can be also tested through the Swagger UI service³.

Table 52 – Updated BIMMS API endpoints

API Endpoint	Description
GET /project/getProjectNamedIFC	Get the IFC file data for the given filename, project, and user token
GET /project/getProjectFiles	Get all files for the given project and user token
GET /project/getProjectNamedFile	Get the file data for the given filename, project, and user token
GET /ifc/getResourceFile	Get the file for the given file name, project, and user token
GET /ifc/getIFCHierarchyWithObjs	Get the IFC hierarchy with entities objects for the given file name, project, and user token
GET /ifc/getIFCGroups	Get the IFC groups for the given file name, project, and user token

² <https://bim4eeb.oneteam.it/BIMMSWS/Help>

³ <https://bim4eeb.oneteam.it/BIMMSWS/swagger/ui/index>

POST /ifc/setIFCGroup	Create new IFC groups for the given file name, project, and user token
PUT /ifc/modIFCGroup	Modify IFC group for the given file name, project and user token, group name
DELETE /ifc/delIFCGroup	Delete IFC group for the given file name, project and user token, group name
PUT /occupancy/modOccupancy	Modify occupancy data for the given ID, project, and user token
DELETE /occupancy/delOccupancy	Delete occupancy data for the given ID, project, and user token
PUT /occupancy/modOccupancySchedule	Modify occupancy schedule for the given occupancy schedule ID, project, and user token
PUT /occupancy/modOccupancyScheduleData	Modify occupancy schedule data for the given schedule data ID, project, and user token
GET /activity/getActivityFromOriginActivityID	Get the activity data for the given originActivityID, project and user token
GET /activity/getActivityFromLocation	Get the activity data for the given location, project, and user token
PUT /activity/modActivity	Modify activity data for the given ID, project, and user token
DELETE /activity/delActivity	Delete activity data for the given ID, project, and user token
PUT /alert/modAlert	Modify alert data for the given ID, project, and user token
DELETE /alert/delAlert	Delete alert data for the given ID, project, and user token
GET /api/OTVirtuoso/{id}	Get EEB resources info values
POST /sparql/getSPARQLData	Get SPARQL data from graph name and query, with limit and result type (Table, Raw) format