BIM SPEED

Strategies for user acceptance, collaboration support, and BIM data maintenance

Deliverable Report D6.3

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BIM-SPEED
Harmonised Building Information Speedway for Energy-Efficient Renovation

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Strategies for user acceptance, collaboration support, and BIM data maintenance

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Publishable executive summary

Deliverable D6.3 is associated to task T6.2 (User acceptance, collaboration support, BIM data maintenance) which aims to investigate and define the conditions for improving the use of the BIM-SPEED platform and fostering its adoption by the largest community of stakeholders.

Two complementary aspects have been investigated in this task:

- Based on the feedback provided by the first end-users of the BIM-SPEED cloud platform, the necessary functionalities required to be implemented in the future versions of the platform to support renovation projects have been collected and synthesized;
- By using end-user expectations regarding BIM content and update during operation and maintenance (O&M) of buildings, general recommendations have been provided for maintaining BIM up-to-date and guaranteeing its usability over time.

The first aspect was developed through an online survey by the end-users of the 13 demonstration sites of the BIM-SPEED project, complemented with some face-to-face interviews. The main result of the survey was that the BIM-SPEED platform, in its current version (i.e. the launch version with mainly collaborative features and a limited set of BIM-based renovation-oriented services), was mainly used as a file repository and document sharing service, and did not show significant innovative features compared to many other products available on the market. However, very valuable information on the expected developments has been collected during the survey, amongst which the most demanded ones are predefined folder structure specific to renovation projects, workflow management, online IFC viewer, and integration of BIM services for renovation (scan to BIM, energy simulation, checklist of BIM object properties at different stages of the renovation process, connection with BIM objects libraries, etc.). Specific feedback was provided on the level of information needed for some BIM objects (e.g., HVAC system components) during the building operation phase, which allowed to make the link with the second part of the task.

This second part was about the update of BIM during building operation and maintenance (what and how to update in practice), and the central role that BIM is called upon to play during the operation of a building, in relation to traditional O&M tools and emerging initiatives like Logbooks or BIM Passports. The study was informed by a desk review combined with the contributors' own experience. It resulted in a set of recommendations for updating BIM during renovation operations, even for smaller changes.

List of acronyms and abbreviations

AEC: Architecture, Engineering & Construction

AI: Artificial Intelligence

API: Application Programming Interface

BAS: Building Automation System

BCF: BIM Collaboration Format

BIM: Building Information Model (or Modelling)

BMS: Building Management System

CAFM: Computer-Aided Facility Management

CDE: Common Data Environment

CMMS: Computerized Maintenance Management Systems

DL: Deep Learning

EDMS: Electronic Document Management System

EEB: Energy-Efficient Building

gITF: Graphics Library Transmission Format

GUID: Globally Unique Identifier

IDM: Information Delivery Manual

IFC: Industry Foundation Classes

ISG: Implementation Support Group

LCA: Life Cycle Analysis

LoD: Level of Detail (or Development)

LoIN: Level of Information Needs

MEP: Mechanical, Electrical & Plumbing

ML: Machine Learning

O&M: Operation & Maintenance

PDT: Product Data Template

VR / AR / MR: Virtual Reality ¨ Augmented Reality / Mixed Reality

Definitions

Logbook

A digital traceable container for all the data of a building, including all the documents and information regarding design, structure calculation, system implementation, materiality, costs, maintenance, energy efficiency (including possible certifications), LCA, urban conditions, property, etc.

BIM Passport

A concept allowing to assess the quality and completeness of a digital equivalent and related data of an existing building to support the planning of an upcoming EEB renovation, the maintenance and the evaluation before handover of a building.

CMMS

A Computerized Maintenance Management System (or CMMS software) helps asset-intensive organizations plan, track, measure, and optimize everything to do with maintenance digitally.

ifcOWL

OWL version of the Building Information Model standard

Triplestore (or RDF store)

A purpose-built database for the storage and retrieval of triples through semantic queries.

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1. Introduction

This deliverable is associated to task T6.2 (User acceptance, collaboration support, BIM data maintenance) which aims to investigate and define the conditions for improving the use of the BIM-SPEED platform and fostering its adoption by the largest community of stakeholders. It is part of WP6 (Implementing BIM cloud platform and data management) whose objective is to develop and deploy an operational cloud platform for collaboration and exchange of BIM data and other project documentation between all stakeholders in the whole cycle of EEB renovation projects.

For this purpose, there are several points that need to be analysed:

- The functionalities or services offered by the platform and how they meet the needs of the different profiles of end-users to support renovation projects;
- The user-friendliness of the platform, in particular the user interface and ease of use;
- The robustness, reliability, performance (e.g. response time for certain actions), security of data (e.g. in case of system failure);
- The flexibility and evolution of the platform (its capacity to adapt to the real needs of the end-users);
- The availability of a user support service;
- And finally, the data maintenance and update in the long term during the building operation.

2. Methodological approach

The followed methodology relies on a two-step approach:

- In a first step, conduct a survey among the users of the platform to better know how they use the platform in practice, and what are their expectations in terms of data organisation, work progress monitoring, functionalities, and required BIM content for renovation projects. The results of this survey are used, on the one hand, to inform future developments of the platform, and on the other hand, as input to the second step.
- The second step consists in setting up recommendations for the BIM update and maintenance. This work relies on a desk review of relevant techniques, standards, and initiatives such as the building Logbook, the BIM Passport, IFC annotation mechanisms, on-site information acquisition, etc.

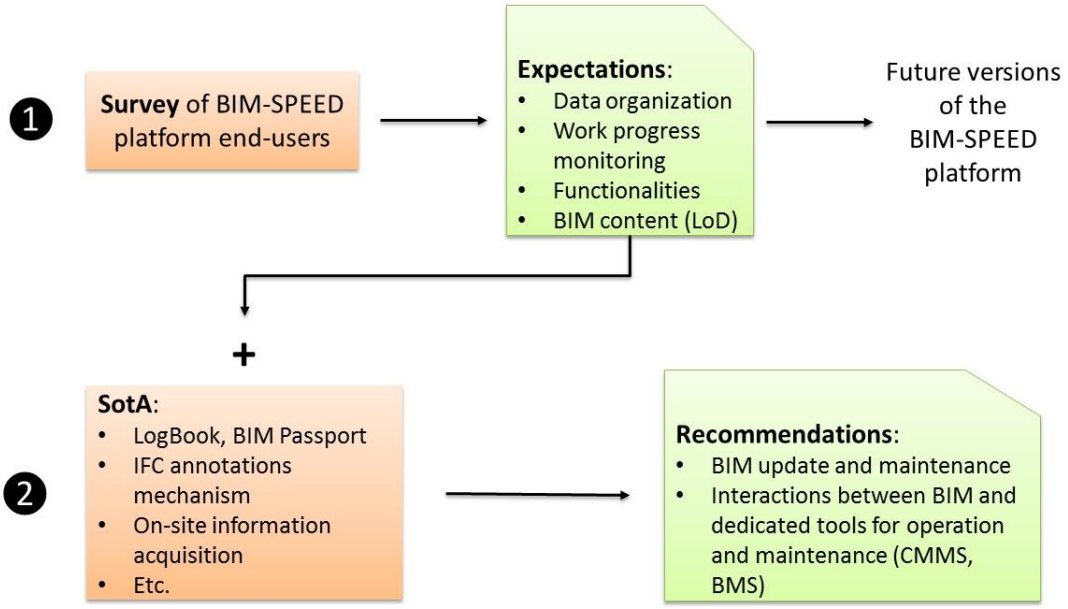

Figure 1 - Followed methodology

3. User survey

3.1 Online questionnaire

3.1.1 Set-up

An online questionnaire was the first tool used for this user survey. It was set up in April 2020. The questionnaire was re-launched in March 2021 for additional answers. The objective is:

- To collect data on how end-users practically use the BIM-SPEED cloud platform;
- To get some qualitative information on their level of satisfaction;
- To identify current strengths and weaknesses;
- And to collect their expectations for future versions of the platform.

Two main target groups were identified:

- The BIM-SPEED partners who are the contacts for the 13 demo projects;
- The registered users of the platform outside the BIM-SPEED consortium.

In all, this represents 41 people.

This online questionnaire consisted of some 30 questions organized in 6 sections (see details in Annex 1):

A – YOUR IDENTITY

B – YOUR BIM-SPEED PROJECT

C – YOUR BACKGROUND IN BIM

D - YOUR GENERAL APPRECIATION ON THE BIM-SPEED PLATFORM

E - HOW YOU USE THE BIM-SPEED PLATFORM

F - YOUR EXPECTATIONS

The three first sections have been asked by considering previous BIM maturity surveys, e.g. to be consistent in the choice of activity profiles or size ranges for organizations (see BIM-SPEED deliverable D2.1 - Method and Online Tool for Defining the Feasibility and Scope of BIM implementation for Renovation Projects).

The three last sections aim to know how information should be organized, how to monitor work progress, and which functions or services should be developed.

There are also a couple of more technical questions related to the requirements in terms of LoD (Level of Development) for BIM objects during the operation phase. This concept includes both the Level of Detail (in other terms, the geometry) and the Level of Information (in other terms, the properties). The answers to these questions are very useful for knowing which information should be maintained and updated in a BIM model during the building operation.

3.1.2 Results

Only a small part of the 41 identified end-users of the project has provided fully exploitable answers to the online survey. This is mainly because at the time of the survey, some of the pilots had only just started, so end-users did not have enough insight into the use of the platform to provide informed responses.

The detailed results are reported in Appendix 2. We mention below only the main outcomes.

Main characteristics of the BIM-SPEED pilot project and background in BIM

Including the 2021 re-launch, the respondents represent 12 (9 from the first questionnaire, 3 from the second) from the 13 BIM-SPEED pilot projects in Italy, Romania (x2), Poland (x2), The Netherlands, Bulgaria, Spain, Germany (x2) and France (x2). All these projects include a residential part (sometimes beside other activities like hotel or commerce). These are mostly private projects, of very different sizes (from less than 1,000 m^2 up to 20,000 m^2). Half of them have a renovation budget lower than 100,000 € but one project has a budget higher than 10,000,000 €.

Three-quarters of respondents had already good experience with BIM (through several projects), the others having participated once to a BIM project. Except in one case, all respondents' organisations have plans to develop the use of BIM internally.

It should be also noted that more than half of the respondents have also used a competing platform: Dalux Box, Aconex, Thinkproject, Trimble Connect, BIM 360, Connect & Construct (C&C), BIM Server Center (from CYPE).

Organization

Type	Company: 66,7% Research and Technology Organization: 25% Public Community: 8,3%
Size of Organization	<10 (VSE): 8,3% 11<250 (SME): 41,7% 250><5,000: 25% >5,000: 25%
Business Area	Promoter: 8,3% Building owner: 16,7% Project manager: 33,3% Architect: 25% Engineering Office: 33,3% Main contractor (builder): 8,3% Subcontractor (crafts): 8,3% Consultant (crafts): 8,3% Surveyor: 0% Real estate information manager: 8,3%
Using another platform	Yes: 66;7% (Dalux Box, BauApp, C&C, Bim Server Center, BIM 360) No: 33,3%

BIM-SPEED Project

Location	Italy, Romania, Poland, Netherlands, Bulgaria, Spain, France, Germany
Building Type	Residential: 100% Hotel: 8,3% Commercial: 25% Care point for homeless people: 8,3%
Owner of the building	Public: 16,7% Private: 83,3%
Size of project (m2)	<500: 16,7% 501<1,000: 16,7% 1,001<2,000: 25% 2,001<5,000: 16,7% 5,001<20,000: 25% >20,000: 16,7%
Budget of project (€)	<100,000: 33,3% 100,001<500,000: 25% 500,001<1,000,000: 0% 1,000,001<2,000,000: 0% 2,000,001<10,000,000: 33,3% > 10,000,000: 8,3%

Background in BIM

Participation in projects using BIM	Never: 16;7% Only once: 25% Several times: 58,3%
Organization BIM expertise/experience	No experience: 8,3% <1 year: 0% 1<2 years: 33,3% 2<5 yeas: 25% >5 years: 33,3%
Training sessions to BIM tools	No yet: 25% Yes, on need base: 41,7% Yes periodically: 25%% Yes, and every post has a BIM training roadmap: 8,3%
Have you used the BIM-SPEED platform yet?	Yes: 75% No: 25%

Appreciation on the BIM-SPEED platform.

The BIM-SPEED platform questionnaire implemented the first phase of using multiple methods or data sources to develop a comprehensive understanding of the stakeholders needs. The questionnaire, interviews and observation of the usability testing sites provided the inductive reasoning results. Whereas section 4 will outline deductive reasoning (the act of

backing up the BIM-SPEED platform applications with specific scenarios – observations learnt from existing case studies and analysis from inductive reasoning, leading the product progression to BETA stage[1]. At this current stage the respondents acknowledged that the BIM-SPEED platform service is currently at ALPHA[2] development stage (Spring 2020) and that the stakeholder's requirements were still unclear. The survey and interviews were apart incremental and iterative methods to represent a practical and useful approach to promote initial capabilities that will be followed by successive deliveries to reach the product development phase.

In summary the following results provided in the table below represents comments that contributed constructively to identifying future requirements and deductive comments that will enable the desired features and capabilities to be the target focus of future development.

Summary of future requirements	Summary of key deductive comments
No predefined folder structure specific to renovations projects. **No tool to manage the BIM workflow.** **Limited size of files that can be uploaded (e.g., large cloud points).** **Lack of business functions and support tools integrated into the platform (the platform is mainly used as a file repository).** **No online BIM viewer – eveBIM is integrated into the platform but it is a desktop application.**	In response to what features does the platform lack the most: "energy calculations, management of the document, checklist, issue tracking, cost analysis, time analysis, in fact soon every employer's information requirements specification will demand Common Data Environment platform". In response to what are the main types of tool/services to be integrated into the BIM-SPEED platform: BIM passport, model checker, energy analysis/simulation/calculation were all mentioned extensively in the survey results." And "file naming, scan to BIM tools – that creates LOD 100-200 model (also referred to as a schematic design stage), and renovation scenarios".

Of course, the overall endgame ('the final stage') is to present a platform that provides a streamlined process that overrides existing challenges, faster exchanges, easier sharing of files and managing of data. However, to reach this stage, the following summaries must be taken into consideration to identify current obstacles:

Teamwork functionalities

Document sharing is obviously the main teamwork feature used by respondents, but a few of them also used task scheduling, calendar, and meeting scheduling. The possibility for a project manager to invite other people to collaborate to the project is very welcome, although the platform does not offer today the expected functionalities, which does not justify the investment needed to get familiar with it.

[1] Generally, begins when the software is feature complete but likely to contain a number of known or unknown bugs
[2] Alpha is **an experimental stage**. It's an opportunity to use prototypes to work out the right thing to build

Impact of using the platform

The main impact perceived by half the respondents when using the platform is the improved quality of the renovation. In the current version of the platform, considering the limitations above-mentioned (esp. the lack of integrated renovation features/services), saving time is mentioned by only a quarter of respondents.

LoD requirements

One of the questions addressed the expected level of detail for BIM objects. The objective was to know if end-users need to have a detailed geometric representation of building objects like HVAC equipment, or only their "bounding box" and their location. Surprisingly, most users were expected a detailed representation. After analysis, it turns out that the question was insufficiently precise and that it may have been misinterpreted.

Most expected tools or services

The survey raised expectations for the following tools or services:

- Scan to BIM (LoD 100-200 model)
- Energy simulation
- BIM passport
- Checklist (of BIM object properties) at different stages of the renovation process
- BIM object library
- Renovation scenarios analysis / Cost and LCC analysis / Decision-making
- Issue tracking
- Automatic quantity takeoff (QTO)
- Energy simulation, structural analysis
- Structure folder, model checker, BIM passport

BIM-SPEED Satisfaction	Satisfied: 11,1% Partially satisfied: 55,6% Not satisfied: 11,1%
BIM-SPEED Platform meet expectations?	Yes: 22,2% No: 77,8%
Main teamwork features used	Document sharing: 100% Task scheduling: 33,3% Calendar: 33,3% Meeting scheduling: 33,3% Chat: 11,1% Videoconferencing: 0%
Use the invitation function to invite a partner	Yes: 55,6% No: 44,4%
Using of Basic Services	File naming convention: 80% Model checking: 60%

Using EveBim Viewer	Yes: 22,2% No: 7,8%
Time using the BIM-SPEED Platform	Every day: 0% 1 to times a week: 22,2% 3 to 5 times a week: 0% Once a month: 66,7% Once a certain period: 0%
BIM-SPEED Platform Advice	It speeds up the renovation process: 60% It reduces the renovation costs: 20% It improves the quality of the renovation: 80%

3.2 Agile Platform Development Process

The generalised comparison of commercial versus contract/task development domain is that the former requires the anticipation, innovation, developing and applying new or emerging technologies to create new products in a fast-paced time to market environment before the competition seizes on the opportunity spaces (Wasson, 2016)[3]. Whereas European H2020 projects recognise the importance of the commercial market while heavily leaning towards contract/task development domain ('the latter') which focuses on the dependency of the customer (project officer) satisfaction concerning results of performance-based outcomes (KPIs, measurement of effectiveness (MOE), and measurement of suitability (MOS)).

The Agile Platform Development Method has been adapted from the traditional contract/task schedule that is illustrated in a step sequence of events in figure 2. To-date the BIM-SPEED project has been involved in the ALPHA design stage of the platform which has partially incorporated the end-user anticipated needs. However, to further evolve the platform step 2 User defined needs required step 3 user cases, to achieve step 4, identify features & capabilities. In this deliverable, these stages are acknowledged by the questionnaire, and face-to-face meetings that were organized with professionals involved in some real-time usability testing (on specific user sites). These meetings were conducted by the BIM-SPEED partners defined as contact points for the user sites in Germany, Italy, and Spain.

In figure 2. the importance of step 3 user cases has been defined by a two-way directional arrow. This indicates that BIM SPEED development process incorporated an agile platform development method at this stage (shown by the number 3 User tested sites on the right-hand side of the diagram). The reason for implementing this technique was to allow the platform developers to perform two incremental tests. The first evaluation at step 3 and the second evaluation at step 6. The results of the first evaluation helped to advance the development of the architecture (requirements & functional) referring to step 5 as outlined in section 4. Step 6

[3] Charles S. Wasson, 2016 'System Engineering; Analysis, Design, and Development, 2nd

Rapid prototyping will be conducted after the project partners accumulate the results provided from each of the site tests and incorporates them into an updated version of the BIM SPEED platform.

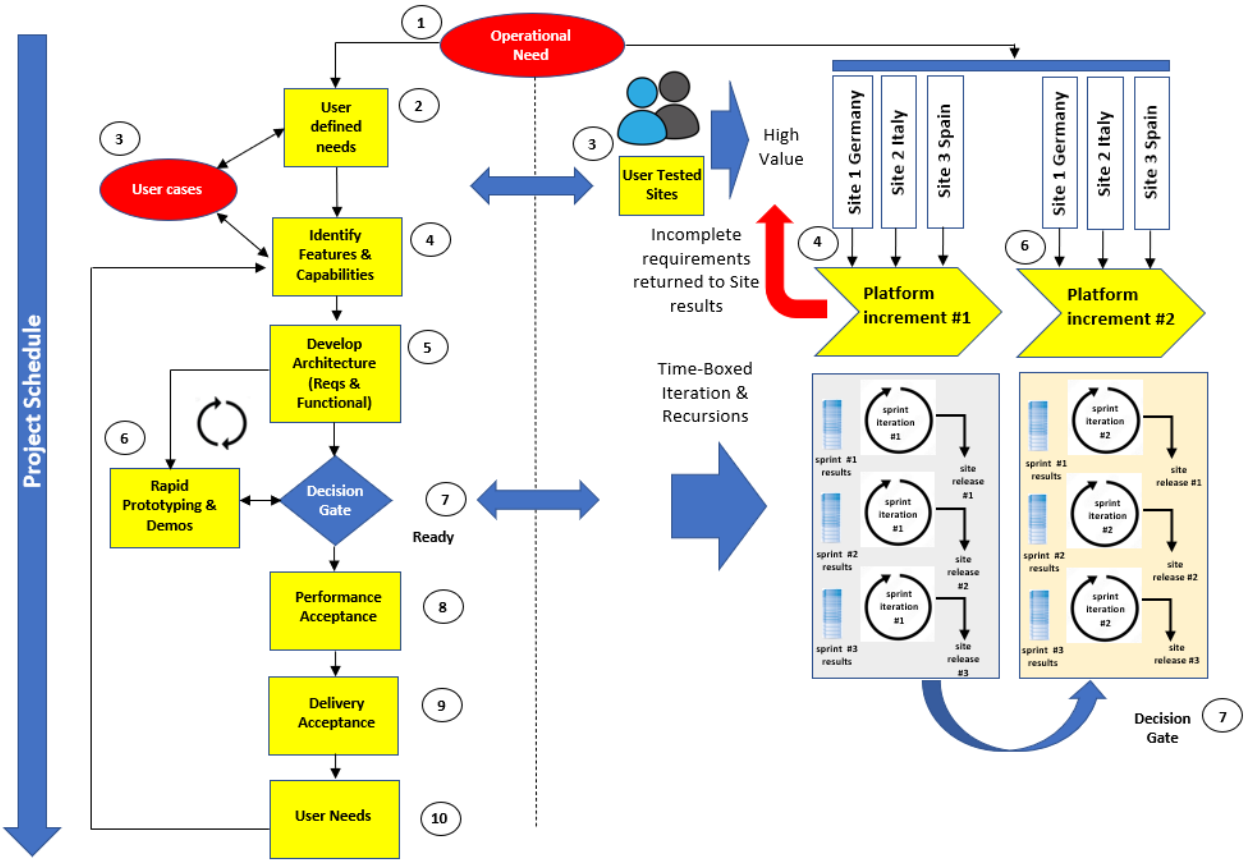

Figure 2 - Agile Platform Development Method

The identified incomplete requirements and constructive comments will be revisited and tested on the existing sites via performing rapid prototyping & Demos. The outcome of these incremental (step by step process that loops back to refine the platform - iteration) and incursion (where the outputs at one level become the inputs for the next successive level), will lead to step 7 decision gate. At this stage the consortium will decide whether the platform has advanced to BETA testing. The agile technique enables short testing cycles rather than trying to implement one final test. It allows the platform to grow/evolve in a heuristic manner after two cycles. The process also assists in achieving the technical measures; MOE – the acquirer's key indicators and the process of MOS – the most suitable applications to be provided for the BIM SPEED platform.

3.2.1 REAL-TIME USABILITY TESTING

In most cases usability testing requires four key areas to be examined: i) what features need to be improved; ii) what are the biggest obstacles to using the prototype; iii) what goals do you require when you come to the platform; iv) what did you learn from the usability test. However, as previously identified the platform was a part of an agile development process meaning that at this stage of the first incremental test CSTB created learning material to demonstrate the features available at that time such as naming conventions. The survey results had highlighted this feature as necessary component of the platform and

CSTB had responded – figure 2. According to Tardif (accessed 07 October 2021)[4] "Specifying the electronic data file format for information deliverables is critical. If the data models of the export/import applications don't match, some modification of exported BIM data may be needed before it can be imported into the CMMS/IWMS software. Analysing and addressing these data format compatibility issues before any data is created in a BIM can greatly minimize those issues. If both applications support COBie (explained in section 4), you can specify that data from the BIMs be delivered in a COBie-compliant format." The following section introduces the profile, BIM experience, execution, appreciation, first opinions, frequency of use, and findings and expectations of each of the 3 user site tests.

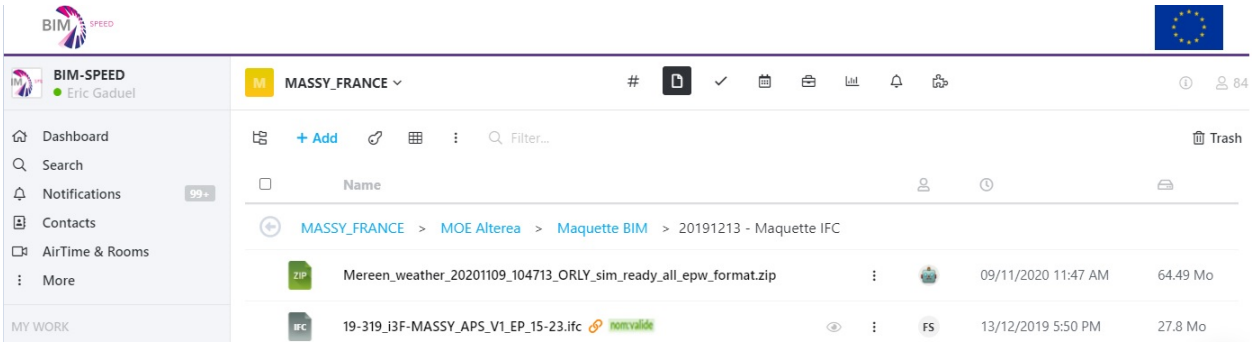

Figure 3 - CSTB DEMO Naming Files for IFC

3.2.2 BIM-SPEED Usability Test – Germany, Berlin

Profile, BIM Experience

The owner of the site in question is UTB Project management GmbH. They have participated in another BIM-project so far, which is not a renovation project though. Building and planning within a BIM environment and workflow specific for renovation is a new territory for them. The current project which serves as the German user site is a connected apartment block including 53 rental apartments which are also fully rented. It is in the very south of Berlin. It is also part of a wider upgrading of the neighbourhood through an entire area of renovations and new buildings. Since they newly switched to a new data management system themselves, they show a lot of interest in the BIM platform itself. They have plans to develop the use of BIM internally.

Execution, Appreciation, First Opinions, Frequency of Use

The face-face-to interview took place via video call at the beginning of June 2020. The current functionalities of the platform at the time (Naming Convention and Cookie Cutter[5]) were presented live and "played through". Although the layout of the platform is strongly reminiscent of SharePoint to UTB personally, it offers useful extensions through the versioning and chat function. The meta data approach e.g., from the Naming Convention tool of the platform is highly interesting for UTB. They are also fond of the idea that the platform could be very beneficial to publish data (models, reports, versions) which therefore are able to represent official, trustworthy documents. Since the project is currently just developing its renovation options, the frequency of usage of the platform is still quite low.

[4] Establish Uniform Naming Conventions to Best Use BIM for FM - Facilities Management Insights (facilitiesnet.com)
[5] "House name" of the Semantic Model Checker

Findings, Expectations

The findings refer to a large extent to the current existing functionalities. Regarding the Naming Convention tool, the following opinion has been derived:

- Old files are not validated again with new/changed rule automatically.
- While changing the name of a file, the previous name is not displayed.
- "Running the service" button is too hidden and should also apply to all files at once (e.g., on parent folders);

In addition to the changes to be made to correct the above shortcomings, it should also be possible to modify several files at the same time (e.g. all files with "nom:invalid" in one list).

Regarding the Cookie Cutter tool, the user understands the process/algorithm but fails to have actual knowledge in IFC to comprehend and find use of the resulting information. The following opinion has been derived:

- No real information about how the "SemChecker" is working in detail;
- Interface has an advance "programming" look;
- Status of Check (result) not in English.

A larger number of supporting tools is expected. There is also no (online) model viewer available yet. The presentation of the website (GUI) is described as elegant and easy to understand. Approaches to a more modern, digital working method towards a BIM workflow are comprehensible. Nevertheless, the platform is only effectively usable for data storage so far.

3.2.3 BIM-SPEED Usability Test – Italy, Frigento

Profile, BIM Experience

Frigento User site is a two-storey residential building, located in Frigento, Campania Region (Italy). It is a building of historical and artistic interest, sited in the historical centre of the city. It was built around 1700 and last renovation was made in 1981-82, after the Irpinia earthquake, providing structural improvements to the building and no improvements on the energetic side, due to the lack of existing standards. Total internal surface is around 240 m^2, and the total building volume is around 2,440 m^3.

The building is occupied by two tenants, who are also the building owners. Since they are both considered elderly, the renovation project has been performed by STRESS. STRESS SCARL, an acronym which in Italian stands for Development of Research and Technologies for Sustainable and Seismically Safe Building, is a non-profit consortium established in 2010.

STRESS itself has experience of how exactly social and urban systems can and must be transformed to promote and achieve efficient and smart planning. The BIM experience is considered high, regarding new and existing buildings. Especially since they got rewarded for different BIM project carried out in Italian projects.

Execution, Appreciation, First Opinions, Frequency of Use

The platform was mainly used as a platform for file sharing. The documents concerning the planning process were created by STRESS and loaded onto the platform. The feedback from the users is generally very good.

Tools that were used and from which data formats were also placed on the platform: AutoCad (Autodesk), Revit (Autodesk), Thermus (ACCA Software), Primus (ACCA Software).

Findings, Expectations

Not all functionalities have been tried out. However, the ideas of the tools were eagerly followed and acknowledged on the basis of various presentations.

Some of the more general findings:

- The platform is not difficult to learn;
- The platform was used frequently;
- The platform is very similar to existing data stores, nothing really new;
- The platform should suggest a way of structuring the files into already provided folders. This could also help in having similar files in similar folders, when considering all the user sites.

To justify an extended and more specific use of the platform, the following functionalities are desirable for the future from the point of view of the demo site:

- File checking for a clearer and controllable workflow;
- The LOI for objects must be between LOI E and LOI G (UNI11337) so that working with BIM for Operation and Maintenance makes sense for the users.

3.2.4 BIM-SPEED Usability Test – Spain, Vitoria-Gasteiz

Profile, BIM Experience

Demo site of Vitoria-Gasteiz involves two different buildings built in the early sixties of the 20th century. Both buildings will be renovated due to the SmarEnCity project which consists of the renewal of the envelope including full insulation (roof and façade), and the future connection to a new District Heating system. They both are owned privately and there are apartments as well as commercial locals on the ground floor. VISESA, the Public Housing Company depending on the Basque Government, is the leader of the renovation. Their previous experience with BIM was a pilot project of a new building which is under development, nevertheless, during the last four years VISESA has renovated different buildings with energy efficiency criteria. This is their first experience combining BIM methodology and rehabilitation.

Execution, Appreciation, First Opinions, Frequency of Use

Developing a platform from the beginning is time-consuming and complex, and there is a broad understanding of this, and the effort is appreciated. Due to the fact that VISESA is more advanced in their demo sites rehabilitation, the main use of the platform has mostly been like a repository to exchange information. Last month (August 2020) a BIM model viewer has been implemented which turned out to be really helpful. They can easily access it and view their models during meetings with different stakeholders through the platform. The overall opinion is therefore good in expectation of more functionalities coming soon. They frequency used the platform, and envision the future workflow being monitored as followed. The BIM model was not developed directly by the architects in charge of the rehabilitation. LKS, member of the consortium, made it. So VISESA has been reviewing the different versions and coordinating and monitoring the process itself. Supporting the users more in this direction with other functionalities would be appreciated. All in all, the tools mostly used are the viewer and the Semantic Checker despite the overall ability to storage documents.

Findings, Expectations

The platform itself is not difficult to use, if you know the languages English and/or French. Since most of the respective end users will not use these languages, other language tags, etc., are required and should be implemented.

Other findings and desirable functionalities for the future are:

- Positive: any type of documents seems to be supported, which is a great deal;
- Missing a functionality to follow the site, like a logbook which allows to register all the issues during the site through the 3D model – linked annotations inside the model to different parts of it is very desirable;
- Missing the possibility to link different documents like pdf or jpeg with different elements of the model;
- For the operation and maintenance purposes mainly, the fixtures may have a higher level of detail, but this can be reduced as long as the as-built plans are accurate enough.

3.2.5 Platform Increment #1 – Summary of Sprint Iteration

The tables below are a compilation of the three individual sprints (usability testing). These results are based on the above analysis of the problems and opportunities arising from the usability test. The following step 5 Develop Architecture incorporates the patterns (systems thinking) identified to advance the architecture of the BIM SPEED platform. The three user sites results are composed into two sections: usability study experience summary and summary of views on future changes/improvements. The results are displayed in a manner to find the patterns and traceability between the different tests user requirements and future design requirements.

Usability Study Experience Summary Germany		Usability Study Experience Summary Italy		Usability Study Experience Summary Spain
• The layout of the platform offers useful extensions through the versioning and chat function. • The meta data approach e.g., from the Naming Convention tool of the platform is highly interesting. • Very beneficial to publish data (models, reports, versions) which therefore are able to represent official, trustworthy documents. • The platform is only effectively usable for data storage so far.		• The platform was mainly used as a platform for file sharing • Tools used and from different data formats were also placed on the platform: AutoCad (Autodesk), Revit (Autodesk), Thermus (ACCA Software), Primus (ACCA Software).		• The main use of the platform has mostly been like a repository to exchange information. • The tools mostly used are the viewer and the Semantic Checker. • BIM model viewer has been implemented which turned out to be really helpful;

Summary of Usability Experience

Evidently the user experience in all three sites recognised at this stage the platform is an efficient repository for exchanging files. The use of additional extensions such as versioning and chat function for communication is beneficial. The BIM model viewer option and the semantic checker for elements etc. were also recognised as positive applications. Integrating different tools with different data formats streamlined the usability experience. Again, the naming convention was high recommended.

Views on future changes/ Improvements - Germany		Views on future changes/ Improvements - Italy		Views on future changes/ Improvements - Spain
• Old files are not validated again with new/changed rule automatically. • While changing the name of a file, the previous name is not displayed. • It should also be possible to modify several files at the same time (e.g. all files with "nom:invalid" in one list). • The Cookie Cutter tool, fails to have actual knowledge in IFC to comprehend and find use of the resulting information. • No real information about how the "SemChecker" is working in detail. • No (online) model viewer available yet.		• The platform is very similar to existing data stores, nothing really new. • The platform should suggest a way of structuring the files into already provided folders. • File checking for a clearer and controllable workflow. • The LOI for objects must be between LOI E and LOI G (UNI11337) so that working with BIM for Operation and Maintenance makes sense for the users		• Other language tags, etc., are required and should be implemented. • Missing a functionality to follow the site, like a logbook which allows to register all the issues during the site through the 3D model. • linked annotations inside the model to different parts of it is very desirable. • Missing the possibility to link different documents like pdf or jpeg with different elements of the model. • For the operation and maintenance purposes mainly, the fixtures may have a higher level of detail, but this can be reduced as long as the as-built plans are accurate enough

Summary of views on future changes/improvements

The process of validating files, changing names, and modifying several files simultaneously, structuring files into folders and file checking for clearer workflows was highlighted in both Germany and Italy usability tests as areas for improvement. The SemChecker had been previously acknowledged as a positive contribution, however for future changes it was suggested that more information be provided. Likewise, the model viewers were viewed as positive contributor but this time an online viewer is deemed essential. The site usability test in Spain produced some constructive comments such as: missing a functionality to follow the site, **like a logbook which allows to register all the issues during the site through the 3D model**; linked annotations inside the model to different parts of it; and missing the possibility to link different documents like pdf or jpeg with different elements of the model. Both Spain and Italy recommended higher level of detail for objects.

Next Steps

The information obtained from the survey and usability testing formed the basis of the key focus areas to advance the BIM SPEED platform. The following section 3 addresses the main future services.

3.3 Future developments of the BIM-SPEED platform

3.3.1 Future services

The results of the online questionnaire survey, supplemented by individual interviews, allowed us to identify the main expectations of users in terms of services integrated to the BIM-SPEED platform (whether basic services or third-party renovation services). Some of these services were already in preparation at the time of the survey. Other services will be integrated during the project. It should be noted, however, that the integration of third-party services depends on (1) the availability of such services by their suppliers and (2) their integration in the BIM-SPEED platform following the platform API specification.

The table below summarizes the tools/services already integrated, those in the process of being integrated, and those for which an integration can be considered (under the conditions set out above) at the time this deliverable is finalized.

Table 1 – Future services of the BIM-SPEED platform

Tool/service	Developing partner(s)	Status
Files naming convention management	CSTB	Integrated
Semantic model checker	CSTB	Integrated
Workflow management	CSTB	First version integrated
Mereen (weather data service)	CSTB	Integrated on the development platform, soon to be integrated into production
BACN2BIM (linking IoT data to BIM)	CARTIF	Integrated on the development platform, soon to be integrated into production
GIS data collector	CSTB, TUB	Integrated on the development platform, soon to be integrated into production
"Material" service (enrichment of IFC4 files with material properties)	CSTB	Integrated on the development platform, soon to be integrated into production
LoDlifter (enrichment of IFC files with object properties and values)	CSTB	Integrated on the development platform, soon to be integrated into production
Comfort Eye (IEQ monitoring system for assessing building performance)	UNIVPM	Indirectly integrated through the BACN2BIM service with Comfort Eye driver
BIMtoBEPS (prediction of energy performance)	CARTIF	Being integrated
BIM Object Database	STRESS	Integration to be discussed
CYPETHERM Eplus (energy performance assessment)	CYPE	Integration to be discussed
CYPETHERM Improvements (energy audit and analysis of improvement measures)	CYPE	Integration to be discussed
Indoor environmental quality KPIs (assessment of as-built thermal comfort with simulated data)	UNIVPM	Integration to be discussed
ECOtool (assessment of operational energy costs using measured data)	CARTIF	Being integrated
Crowdsourcing of inhabitants input	DMO	Integration to be discussed
BIM-based Life Cycle Cost and Asset Management	DMO	Being integrated
BIM Passport	PB40	Integration to be discussed
3DASH Tool (3D modelling of existing asset based on points clouds)	CARTIF	Being integrated

3.3.2 Risk Management Plan

The future developments envisaged for the BIM-SPEED platform are in line with the expectations expressed during the survey and are likely to boost the use of the platform. The table below, however, evaluates the risks of unsuccessful use of the platform and proposes measures to avoid or mitigate them.

It is important to keep in mind that the platform is constituted by the electronic document management system from KROQI plus all the integrated services from the BIM-SPEED partners. The risks should then be evaluated on the entire platform and not only on the integration system around the KROQI document management system.

Table 2 – Risks identification and mitigation measures

Risk description	Consequence	Responsibility	Proposed strategy
Not enough services are integrated into the platform	Construction end-users are not interested in using the platform	The entire consortium	Define clearly use cases that BIM-SPEED can fulfil and list the consortium tools that can leverage these cases
BIM-SPEED partners' services are not integrated enough	The workflow for the use of the different renovation tools is too complex	Each tool provider	Propose to WP6 some useful use cases to integrate these services WP6 proposes a workflow system based on folders to implement proposed workflows
End-users don't understand how to use the platform	They are disappointed with the user experience of the platform and do not want to use it.	CSTB + consortium	Work closely with testers to understand usage bottlenecks and resolve them
The integration platform does not support the workload (e.g. EU competition): need to mitigate R&D and production	End-users can' t properly use the platform to provide feedback	CSTB + consortium	Closely monitor the technical resources required, organize if necessary money transfer to improve stability of back-end systems

4. BIM update during building maintenance and renovation operations

The main objective of this second methodological step is to define recommendations and possible scenarios for updating BIM during Platform increment #2 Step 6 Rapid Prototyping & Demos .

Once the Level of Development has been defined (first sub-task), it is crucial to have an efficient process to initialize and update all information during renovation operations. Indeed, a process that would be too complicated can make this data structure unusable. On another hand, when smaller changes have been made to the building, there are often not integrated into the model. This issue can be linked to the development and management of the building Logbook which must list all operations made on the building. In this context, the use of BIM is often seen as a data sink for initializing CMMS software. But we also must think of the opposite way, it means, how to update BIM following operations directly managed in the CMMS software. Indeed, if we can use BIM as an operational support of the Logbook (two ways communication between BIM and dedicated tools for maintenance), this will ensure the transmission of information about building operation including when the operator changes (using possibly different asset management tools).

We also looked at how BIM can be used to provide information to Logbooks or maintenance management systems, or conversely, how BIM can be updated from them. The challenges are to keep the BIM up to date during maintenance/renovation operations, even for small changes, and to ensure the transmission of information on building operations, even when the building operator changes and uses a different asset management tool.

4.1 Building Logbook

The successful administration of the increasing amount of data is an essential step in the consequent development of all current industries, including those related to the AEC sector (Architectural, Engineering and Construction). The “Building Logbook” is defined as a digital traceable container for all the data of a building, including all the documents and information regarding design, structure calculation, system implementation, materiality, costs, maintenance, energy efficiency (including possible certifications), LCA, urban conditions, property, etc.

The Building Logbook belongs to the building owner and can be shared with public entities (e.g. municipalities), AECOM professionals, energy certifiers, etc. to facilitate processes of review and management of the building, as well as to carry out future renovations on it. In more advanced scenarios it is also possible to use the logbook as a container for energy measurement data from the building, so that results that differ from the numbers in the digital twin's energy analysis can be a symptom of a breakdown in the air conditioning systems or a problem in the thermal envelope.

Due to the relevance of this topic, some European initiatives related with the Building Logbook are already being developed in Germany (*Gëbaudepass*), Portugal (*CASA+*), France (*Carnet numérique du logement*) or Belgium (*Woningpas*), with the aim of bringing building owners and stakeholders together. The urge to establish a common framework that harmonises these initiatives is proven, as it is being studied by the European commission in the context of a study launched by the Executive Agency for Small and Medium-sized Enterprises (EASME)[6]. The aim of the study is to identify the taxonomy of public and private initiatives

[6] https://ec.europa.eu/easme/en/tenders/study-development-eu-framework-buildings-digital-logbook

that promote the use of the digital logbook to identify business models, key points and important challenges that still need to be resolved in this context, with an approximate funding of 260,000 Euros. The building logbook is already starting to be implemented in countries such as France, Germany, or Belgium, as detailed in the European study BUILDING RENOVATION: Customised roadmaps toward deep renovation and better homes[7].

According to this study, public bodies in these three countries have taken an interest in the concept and actively supported its development. In Germany, it is supporting the preliminary work for the implementation of renovations on an individual scale at national level (based on the pilot case in Baden-Württemberg), while in France the Energy Transition Act "Loi de Transition Energétique et pour la Croissance Verte" ensured that the digital logbook would start being introduced in 2017.

At the same time, the growing use of Open BIM technology in the AEC sector and the digital instrumentalization of tools in all phases of a building project development in the last decade has been the natural response to the increasing complexity of projects, to an industry with tighter deadlines and budgets and to the great advance of digital tools, democratising the use of state-of-the-art technology with affordable devices.

Therefore, in a scenario where all projects are carried out through software that automates the generation of information, the implementation of an international framework that encourages the mandatory use of logbooks for new projects must necessarily consider that this information is precisely what is generated with these tools. "Building Log" only makes sense in a digital environment where the information is globally accessible, and in the AECOM sector this means integration with the various Open BIM processes.

"Open" means that the technology does not depend on a particular software developer. The development of a project covers such a wide field that there is no commercial house with an integral solution that can respond to all requirements. For that reason, the collaboration between tools from different software houses is an unavoidable step in the development of any BIM project, with the consequent appearance of internationally recognized and extended open exchange formats, such as the IFC. It is in this process of digital industrialization that numerous online CDE platforms (Common Data Environment) have appeared for the more efficient management of all the information generated in a BIM project. The three-dimensional development of a building by means of geometry associated with information in the form of parameters is only coherent in a collaborative environment with automated management of the associated GUIDs (Globally Unique IDentifier), including factors such as traceability, entity authoring, federation of models developed with different tools, data security, registered version control and permission management.

Since common data management for development purposes through open formats is already an international reality, only those building logbook implementations capable of integrating with Open BIM technology and CDEs will have options to build a holistic, international and upgradeable system containing all project data to date.

The consistency control between the building logbook and the BIM project cannot depend, in any case, on proprietary formats, because that means making the data (including those belonging to the building owner) dependent on the persistence of the developer. In other words, the change of policy or closure of that entity would compromise the security of such data. Nor can such control depend on the agents developing a project, since it is impossible to guarantee the coordination and standardization of workflows in very disparate countries and the systematic rigour of all individual professionals, including studios, builders and installers of all scales.

[7] http://bpie.eu/wp-content/uploads/2017/01/Building-Passport-Report_2nd-edition.pdf

The CDEs are, therefore, the most appropriate means to carry out such control, since it is the only tool capable of accessing the information generated by all the others and not only guaranteeing its consistency, but also making such consistency visible in a technologically agnostic way. This means that it is not necessary to have specific software tools or computer installed, since the geometry and associated parametric data of the projects are accessible from any client applications (including mobile devices or tablets). In this sense, the issue is no longer just the formalization of the building logbook standard as an approved legal entity, but its compatibility with the current BIM market ecosystem of CDEs and the approved and extended formats in order to be able to persist during the building lifetime, being able to register it's updated data and information about costs, performance and further renovations.

4.2 BIM Passport

The automated evaluation of information contained in the aforementioned Building Logbook holds great potential in supporting (future) building owners and operators to assess the quality and completeness of the given information to implement certain use cases related to deep building renovation. There are several (research) projects developing BIM-based Material Passports to increase the efficiency and sustainability in the construction sector, promoting circular solutions for building design and operation, as proposed by the HOUSEFUL project[8], which is supported by the MADASTER[9] platform, a cloud platform that allows the generation of Material Passports for buildings.

In the BIM-SPEED project, the BIM Passport, under development in task T2.4 (As-built BIM Passport of existing building stock) of WP2 (Creating As-Built BIM, BIM Passport, Family & Library), will make it possible to assess the quality and completeness of a digital equivalent and related data of an existing building to support the planning of an upcoming EEB renovation, the maintenance and the evaluation before the purchase or handover of a building. For instance, if a BIM model has a higher level of geometry (LoG) and a lower Level of Information (LoI) regarding the semantic information of its HVAC system, it might be useful to support a fire-plan simulation, whereas it might be rather less useful for an energy-simulation.

The concept of the BIM Passport would be applicable to any type of construction project, however, in BIM-SPEED the focus lies on enabling (future) building owners and service providers to make informed decisions based on the information contained in the Building Logbook regarding the implementation of certain use cases presented in D4.1 (Baseline and Use Cases for BIM-Based renovation projects and KPIs for EEB renovation)[10]. The results of the assessment will be presented, similar to a building energy certificate, as a PDF file rating the quality and completeness of the given information for the respective use cases to be considered in an evaluation matrix.

To evaluate the initial version of the BIM Passport and its integration in the BIM-SPEED platform, it is envisaged that for increment #2 Step 6 Rapid Prototyping & Demos and possibly for suitable demonstration cases and submissions to the EU Competition for BIM-based renovation[11], BIM Passports will be created and made available on the BIM-SPEED platform.

Example of an existing BIM Passports case study, extracted from the article 'Concept for a BIM-based Material Passport' (Honic et al, 2019)[12] is presented as a best practice case study where its functions have been observed and will be taken into consideration.

[8] https://houseful.eu/solutions/development-of-4-material-passports-based-on-advanced-3d-model/
[9] https://www.madaster.com/en/our-offer-2/Madaster-Platform
[10] https://www.bim-speed.eu/en/results
[11] See task T8.3 (EU competition for BIM-based renovation plans) of WP8 (Demonstrating best practices of BIM for renovation)
[12] M Honic et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 225 012073, BAMB Building as Material Banks, this project received funding from the European Union's H2020 research and innovation Programme

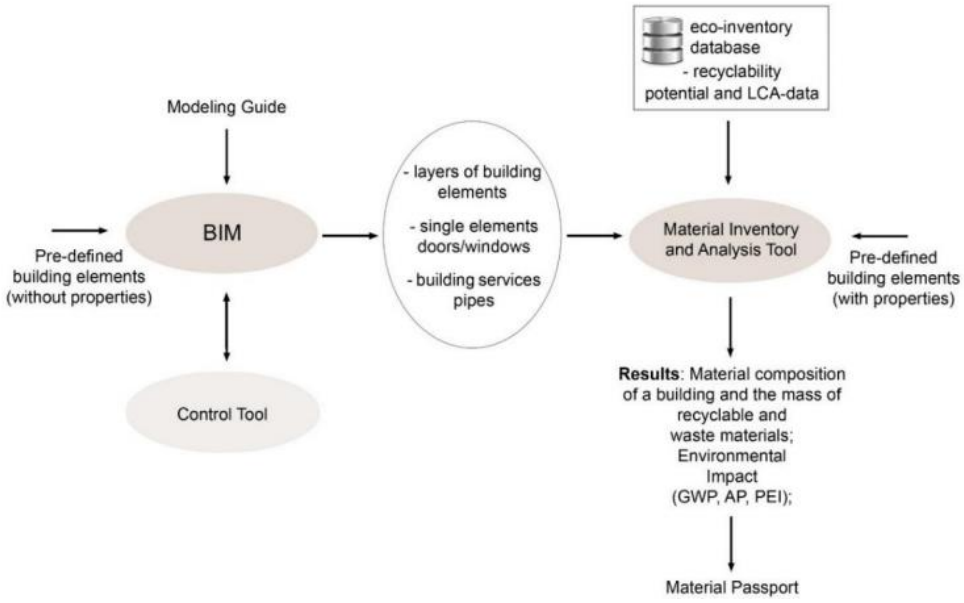

Figure 4 - Workflow for the Compilation of the MP (Sourced from Honic et al., 2019)

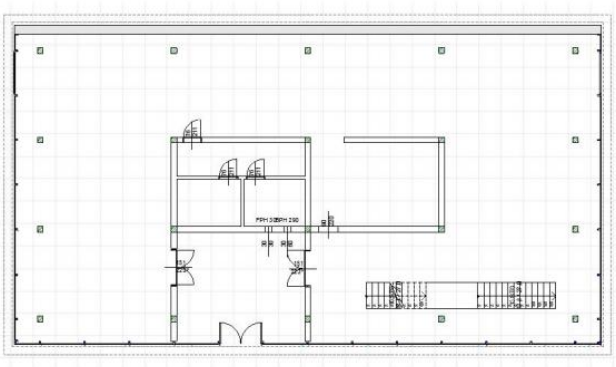

Figure 5 - Pre-existing Model of the Use Case (Sourced from Honic et al, 2019)

- For the compilation of the BIM-based MP, Honic et al. developed the attached workflow, which is based on coupling of the BIM-Model with the material inventory and analysis tool BuildingOne (BO).
- BIM-Software is used for modelling the building and BO for matching of MP-relevant data to materials and subsequently for carrying out the necessary assessments.
- As BO has a bi-directional connection to the BIM-model, it enables an automated synchronization of model changes (e.g., change in height or thickness of a wall is automatically updated in BO through synchronization). Figure 3 illustrates the proposed workflow for the generation of the BIM-supported MP.
- The case study used an office building consisting of three storeys. The conceptualised building was planned in concrete construction and already modelled with mono-layered elements in BIM, as shown in figure 4.

According Honic et al. for a first analysis, the mono-layered elements were assigned to pre-defined elements in BO. In this phase it was important, that the geometry and classification of the elements was correct to achieve accurate results and enable the assignment of elements. The next step replaced the layered elements by multi-layered and pre-defined elements in BIM and the thicknesses of the pre-defined elements were adapted to the thicknesses of the pre-existing model. Through the bidirectional data-synchronization, the changes on the model were easily updated in BO. In figure 5. The building has a total mass of 1338 tonnes and a recycling grade of 2.5, whereby 48% (638 tonnes) of the materials incorporated is recyclable and 52% (700 tonnes) leads to waste.

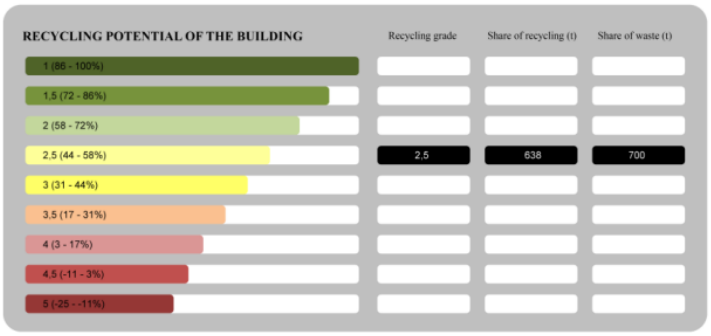

Figure 6 - Recycling Grade of the Use Case out of Concrete (Sourced from Honic et al., 2019)

The case study further advanced it analysis by assessing two variants of the same building. Building A was concrete variant and building B was a timber variant. Upon analysing the LCA using the Primary Energy Intensity (PEI), concrete was high 3000 GJ (one-kilogram concrete accounts for 1.14 MJ (IBO). Global Warming Potential (GWP) and Acidification Potential (AP) impact was considerable low due to the low initial impact per kilogram (GWP=0.13 kgCO2/kg; AP=0.0003 kgSO2/kg; IBO) in comparison with PEI. The case study analysed in this paper was utilising BIM-supported MP in the optimization at an early design stage and it referenced future research to introduce BIM to GIS to generate a material cadastre for cities by using laser-and ground penetrating radar scan technologies.

4.3 BIM Collaboration Format (BCF - IFC annotations)

As with construction projects, a renovation scenario involves many actors, usually for long periods of time. As work progresses, many issues are identified, particularly during BIM coordination meetings, i.e. in the collaborative environment.

BIM also has great added value in renovation projects, especially for optimizing the collaboration process and maintaining the BIM model of project up to date.

The BIM Collaboration Format, or BCF, is one of the simplest and useful standards in a collaboration process. BCF aims to track issues as they are identified, reported on and resolved during the BIM process.

To give an idea of the need to use a collaborative and interoperable exchange format during interactions between project actors, some scenarios can be envisaged: suppose a BIM model of the project is sent from the architect to the structural engineer. In such a scenario, the architect may want to state that all the constructive elements (slabs, beams, walls, columns, etc.) in the model are to be considered as "Definitive", except for the columns located in the basement of the building whose

dimensions are to be revised. Alternatively, the architect wants to express that parts of a building being modelled should have the status "Proposal" for the structural engineer to evaluate. In addition to the status of individual objects, the Project Manager and Client may require an aggregated overview of how many objects are considered as "Definitive", and how many objects have yet "To be Approved". Furthermore, they may want an overview of the priority of outstanding issues and which project partners are responsible for most of the unresolved issues, etc.

BIM Collaboration Format (BCF) is a buildingSMART International openBIM standard to communicate about the “issues” of a BIM model during its live cycle. The development of BCF started in 2009 and was originally conceived by two members of the buildingSMART International Implementation Support Group (ISG), Solibri and Tekla, along with the Institute for Applied Building Infomatics (iabi) at the Munich (Germany) University of Applied Sciences. Their desire to leverage open communication technology for IFC-based workflows led to prototyping, and eventually fully developing, BCF with other ISG members[13].

BCF allows software to activate interoperable information workflows. The exchange of information in construction projects already benefits from the ISO 29481 IDM (Information Delivery Manual) standard. BCF's assessment of compliance with this ISO standard will help to further expand its use when quality management involves full adoption of ISO standards. Discussions within the buildingSMART association are underway to define BCF as a standard compliant with ISO 29481.

BCF was introduced to allow an intelligent communication workflow between BIM tools and a workflow communication capability connected to IFC formats, where the purpose was to separate the virtual communication from the model into a BCF format based on XML schemas. BCF makes it possible to communicate with total transparency effectively and methodically since all steps in a BIM related process is visible for all involved parts which all will be combined in several reports with attached messages/comments in all parts of the process. The interoperability is focusing on how the various BIM tools are operating together instead of focusing on the single tool(s), this gives a strength to the whole BCF process because it focuses on the support to comments and status of issues across platforms instead of focusing on a single discipline and its own product (see [1]).

The BCF concept is rather simple to implement and navigate. It is basically to create a description of the issue (messages/comments), a status, a picture of the issue with a camera orientation and link them to a building component(s) by using the IFC formats Global Unique ID (GUID). BCF issues are packed into a ZIP file (bcfzip) and sent to project partners.

[13] https://technical.buildingsmart.org/standards/bcf/

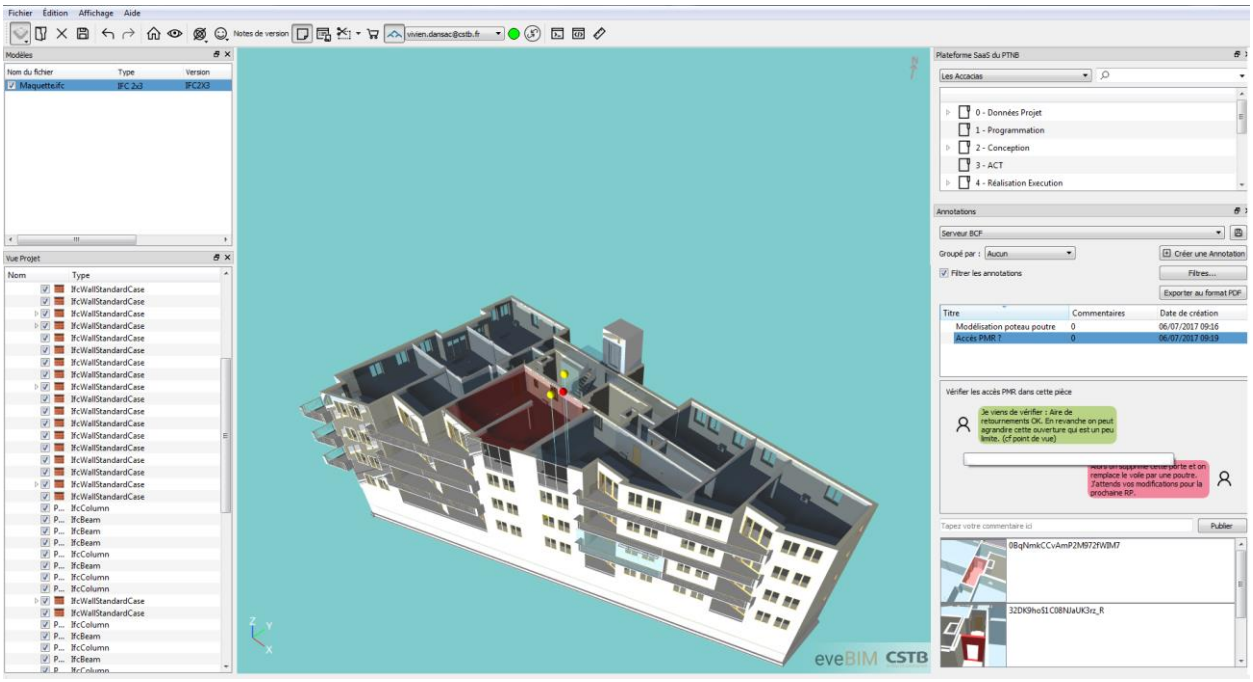

Figure 7 - IFC Model with BCF annotations (eveBIM. Viewer)

In a BIM approach applied to a construction or renovation project, the coordination process using BCF allows actors to exchange issues, proposals or change requests on a particular topic. These exchanges are usually aimed at understanding (description, note title, adding images, documents...), collaboration (creation of notes, issuing reports, email notifications) and management (users (author, attribution, approval, validation), status of detected conflicts (status, priority, type), dates (creation, modification, deadline, closure)).

A classical workflow of "issue management", using the BCF methodology, describes a file-based transmission of issues, say e-mail based, and does not propose means to centrally organize the communication that pertains to a model (see [2]).

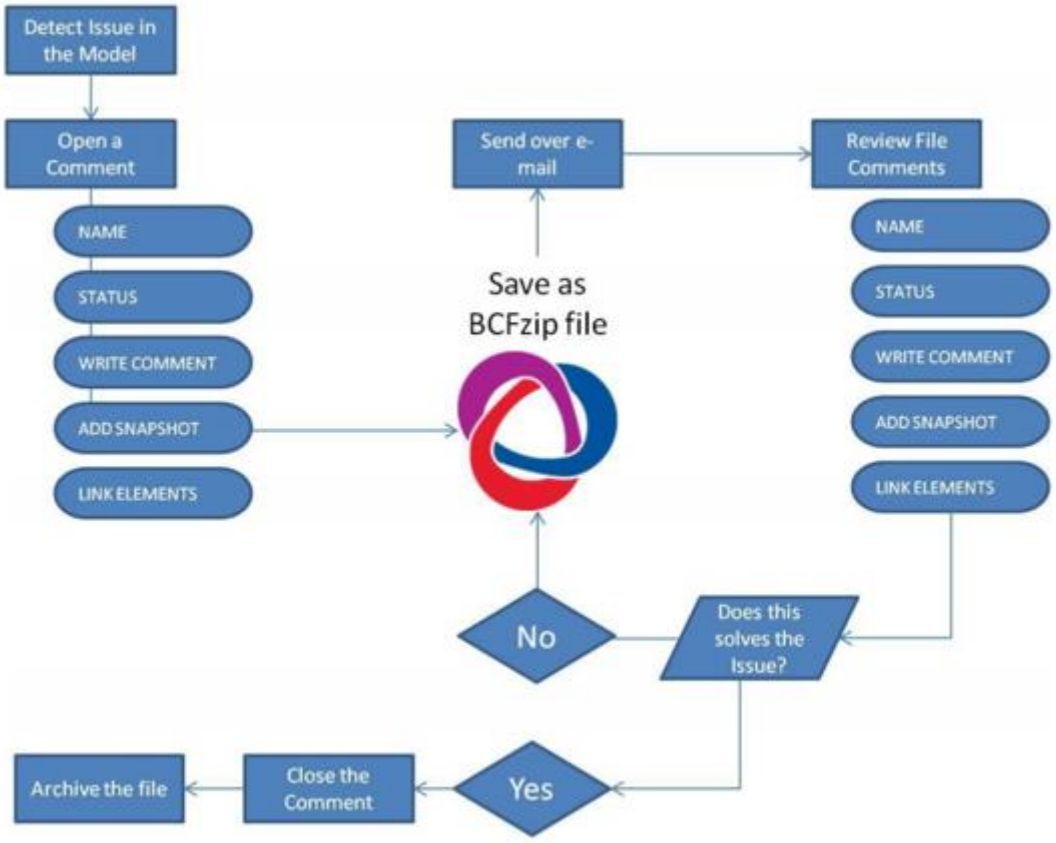

Figure 8 - Typical BCF Workflow

This makes it difficult for stakeholders to analyse the entire body of issues and get a quick overview of the whole project. Note that these comments and issues contain valuable insights into how the design team functions and about the performance of families of products and suppliers. By not relying on a central agent to process the flow of issues, this valuable information cannot be easily retrieved. In addition, the number of open issues gives an indication of the progress of the design project, but without a central registration of issues, this number is not easily accessible. Furthermore, in general, this approach of simply storing issues and comments in files and sending them is prone to error as issues are not recorded and might slip through the cracks (see [3]).
Therefore, an approach with a centralized project management interface based on a central BCF server is highly recommended. It allows to communicate the real-time overview of the status of the overall project to all project members. In addition, central storage allows for easy notification to project members when a new issue is reported and can be easily delegated to the appropriate person.

It is possible to customize the implementation of a BCF server, according to the chosen topology, based on the RESTful API, developed by the Institute of Applied Building Informatics (IABI). Two kinds of topologies are proposed by buildingSMART[14]:

[14] https://github.com/buildingSMART/BCF-API

In the first topology, model collaboration is handled through a shared file server or a network file sharing service such as Dropbox. The BCF server handles authentication and BCF issues.

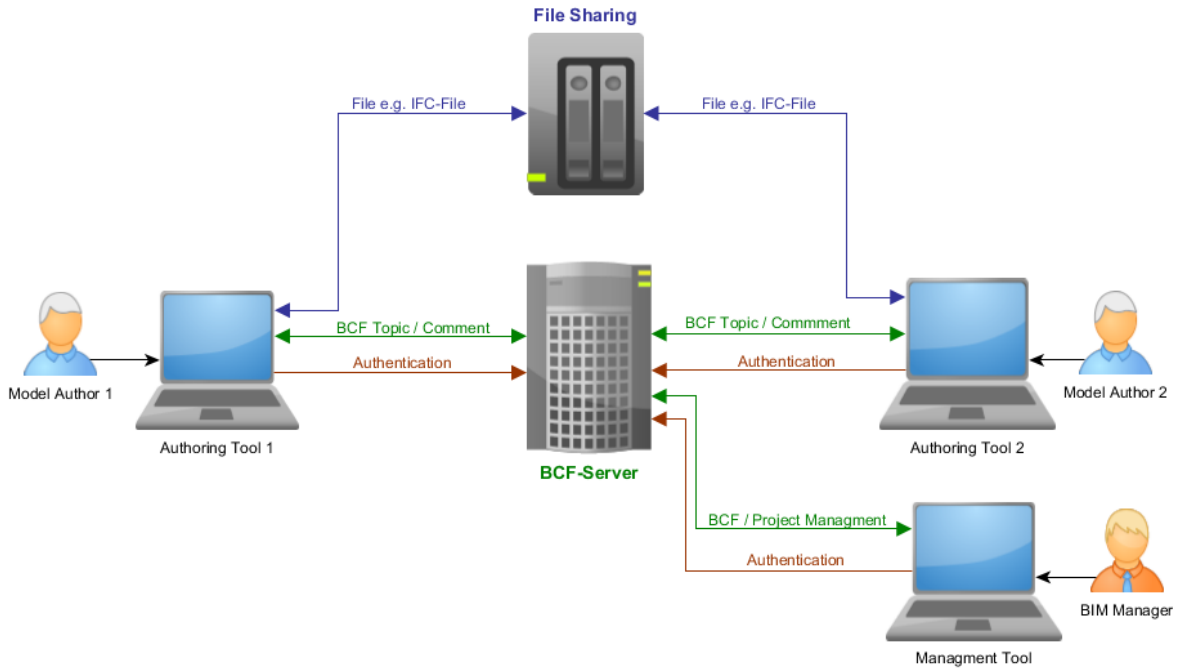

Figure 9 - Topology 1: BCF Server Only

In the second topology, the BCF and the model server are located on the same hosts.

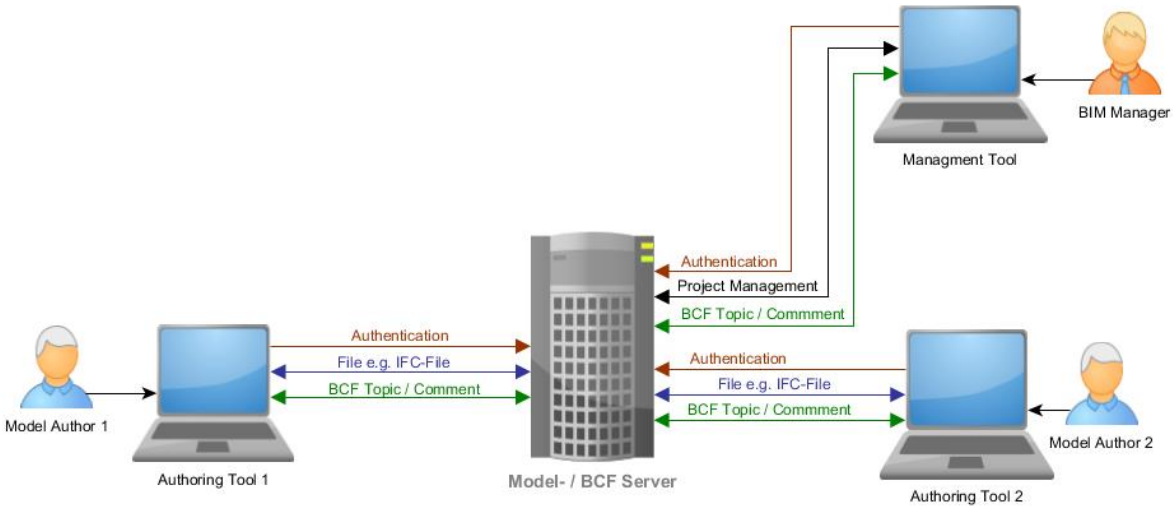

Figure 10 - Topology 2: BCF Server and Co-located Model Server

By default, the BCF schema proposes some enumeration fields such as: TopicTypes, TopicStatus, "TopicLabel" and "Priority" that can be defined upon on a per-organization or per-project level. And for example, the TopicType field includes the following enumeration values: Comment, Issue, Request, Solution. To properly manage problems in a BCF environment, it is important to define an efficient set of values for these enumeration fields, so that they are adapted to the project actors' processes. In order to give an idea of how to use these fields and their values here are some examples: "Status" can be used to facilitate the communication between project actors and urge partners to hand over their models earlier by allowing them to state which parts of the model are not fully finalized yet. Used enumerations for "TopicStatus" can be "Open", "Closed", "Under Consideration", "Concept", and "Definitive". For "TopicLabels" enumerations values can be "Architecture", "MEP", "Construction", "Specs". The BCF standard proposes the use of integers to define the priority enumeration (e.g.: 1=Low, 2=Moderate, 3=High).

It is also important to note that the BCF format has a disadvantage in that any BCF issue is paired with an IFC file. Indeed, at the current state of development, it is not possible to decide what to do with older issues associated with a revision, after a new revision is created on the same object of the IFC model. Therefore, it becomes interesting to consider a more intelligent system where problems are not automatically rejected with each new revision. For example, options can be proposed to the user such as: automatically deprecate all the previous BCF topics or leave all the previous topics open and give permission to the user who made a modification to remove the corresponding annotation in the later version.

4.4 Mobile technologies

The portability of BIM models has increased considerably in recent years due to three reasons, the first being the advancement of image capture technology, which is increasingly able to read in real time additional information from the environment it captures, such as the depth of objects. The technique of reconstruction from multiple photographs has given way to interactive dynamic capture from video, where the level of detail of three-dimensional models generated by mobile home devices is unprecedented. High-precision reality capture equipment is still more accurate but is priced at 4 or 5 digits; for example,

a Leica BLK360 costs around $20,000. On the other hand, advances in AI (Artificial Intelligence) and DL (Deep Learning) promise increasingly accurate results in affordable hardware, to the point that anyone have free VR/AR/MR (Virtual Reality / Augmented Reality / Mixed Reality) technology at their disposal.

The second reason is that the intensive use of augmented reality in large platforms such as Facebook, Instagram or TikTok has meant the implementation of this technology in profusely documented APIs, democratizing not only the use of cutting-edge technology for capturing reality at the user level, but also at the development level. Consequently, small development companies have flooded the market with virtual, augmented, and mixed reality solutions of all kinds, also in the AEC sector, where there are numerous solutions capable of reading standard BIM formats and placing them in augmented reality on site like BIMserver.center AR, Augin, TwinBim, GAMMA AR, etc.

The third reason is the release of the large video game engines (e.g., Unreal Engine, Unity) and their free use, making their graphic and functional power available to users free of charge. The race to take control of the visualization market gives these tools a dizzying speed of development, automating processes and improving features that multiply the possibilities of development with an increasingly lower investment of time.

The result is a market with an ecosystem of mobile applications that implement the functionalities of these APIs. There are, therefore, numerous free BIM applications that allow, for example, to visualize a BIM model as a mock-up to be shown to the client or on the building site on a 1:1 scale as a control or communication mechanism between the agents involved.

Here, again, two fundamental factors come into play: open formats and information management through an CDE. Open formats are necessary because they decouple the information from specific software houses and particular licenses; this is essential, since there are many agents outside the instrumental ecosystem of the BIM but who must be able to read the information generated (e.g., building users). The CDEs are necessary because the only representative AR model is the one that is synchronized in real time with the BIM model on which all the collaborators are working, so that the updating and traceability of the information being displayed is guaranteed. The bidirectionality of the information is fundamental, so that the BIM model not only has a BIM use of verification with the built work but also becomes a system of communication between the work and the architecture or engineering studies, where the errors indicated in the model have one or more elements with an associated GUID, with which the CDE is able to track the author of these entities and know when they were modelled, what permissions they had and even send that user a multi-platform notification informing him of that error, as is the case with the CYPE BIMserver.center augmented reality application[15].

[15] https://blog.bimserver.center/cypecads-structural-models-in-augmented-reality-with-bimserver-center-ar/

Figure 11 - BIMserver.center AR application (CYPE)

All current large BIM software vendors have a CDE associated with an augmented reality visualization tool as an on-site control mechanism: TrimbleConnect (Trimble), BIMserver.center (CYPE), BIM360 (Autodesk), etc. In all cases the technology used is similar, insofar as it depends on the technological advance of the portable hardware. In matters of AR, the main current limitation is accuracy, since it is not easy to reference a point of view whose rotation depends on the gyro of a mobile phone or tablet at 1:1 scale. There are several referencing systems (locating points in space, reading a QR code at a specific point in the building, etc.). Even with these systems, the numerical accuracy achieved by all current solutions is greater than the actual centimetre and is less accurate if the user who has the device is moving. In addition, the lack of standardization of modelling, products and information management makes it still difficult to automatically recognize specific elements on site without the need to implement an ad hoc QR code system.

The procedure to square a BIM model in AR and a real building is to find a common point between the model and the building. This is usually achieved by means of a QR code. However, the main problem is when the user moves from position or turns the device.

The mobile phone is only able to know the location and point of view of the user through the GPS locator and the gyroscope. While the gyroscope is capable of accurately detecting the direction in which the device is facing, current GPS technology in mobile operating systems has a horizontal accuracy of approximately 3 meters in a 95% confidence interval.

This means that while placing the virtual building in its location is a simple task, being able to accurately recognize the movements of the device user so that the AR model adapts to the movement and rotation of the device is not. The error of placing AR models in mobile is cumulative, which means that even if at the beginning the errors made in the location estimation are small, the model will move more and more from the correct position. This is particularly serious with a margin of error of 3 metres, since the expected accuracy in the construction world (except for steel structure construction) is centimetres.

McKinsey's study[16] of the level of digitization of various industries (2015) showed that the architecture was one of the least digitized, second only to agriculture. Although the industry is advancing by leaps and bounds, it will take some time before augmented reality becomes a fundamental tool accessible to all agents in a project. The increasingly rapid advance of mobile technologies, the decoupling of reality-capture techniques by means of ML and DL (with the consequent lowering of the hardware required to achieve accurate AR representations) and the growing extension of the BIM promote this line of progress.

An example of free applications of this type of technology applied to the maintenance of BIM models are the virtual reality and augmented reality applications of BIMserver.center. These applications are highly recommended to keep the BIM model updated. For example, BIMserver.center AR has a record of the list of projects of the user who is using the application, and within each project the BIM models (IFC and glTF) are updated. In this way, any participant in a BIMserver.center project would be able to visualize in augmented reality a model anywhere, just with a mobile device and wifi. In that visualization it is possible to measure, to navigate through the model, to select elements, etc. In addition, BIMserver.center has a notification system via email, so that any user who has the mobile application of BIMserver.center will receive notifications with the changes in the project, being able to instantly visualize these changes through the augmented reality application.

This is just one example, but the fundamental thing is the use of open formats that allow the exchange of information between the BIM model and the augmented reality application. Therefore, it will be essential to take into account the export capacity to open formats (such as IFC or glTF) of the BIM applications used in projects if we want to have a fluid and flexible information flow that allows the integration of these mobile technologies in the development of a BIM project.

While the use of open formats is not imperative (for example, Autodesk has augmented reality tools in its BIM 360 environment), it should be noted that almost all the application development effort of small and medium sized developers is taking place using open formats that do not depend on specific SDKs. In other words, the choice of proprietary environments has the risk of dependence on a particular software house, which may stop supporting or change the licensing conditions of the software at any time.

4.5 Operation and Maintenance (O&M) systems

One of the main roles of the Operation and Maintenance (O&M) process of existing buildings is to evaluate the current state of their installations and components. BIM, modelled from 2D plans or 3D physical laser scanning, provides a data-rich, object-oriented model that is used or implemented for discrete practices where existing facilities need to be captured, such as renovation, rehabilitation, or restoration activities.

However, to utilize BIM in those areas, building information needs to be integrated with Operation and Maintenance (O&M) systems. Widespread systems used to support Operation and Maintenance (O&M) are Computer Aided Facility Management (CAFM) or other similar systems as Computer Maintenance Management Systems (CMMS), Electronic Document Management Systems (EDMS) and Building Automation Systems (BAS) or Building Management Systems (BMS). These management

[16] https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future

systems are based on alphanumeric data management, capable of uploading data and technical documentation, creating job lists and schedule activities, identifying resources, tools and materials needed to manage the real estate.
Generally, traditional management systems fail in accessing and controlling the information effectively because data coming from different sources is modified several times during the building life cycle without an automated synchronization between servers.
A particular consequence is the inability to efficiently control and optimise the building performance. Moreover, whereas CAFM systems are usually linked with 2D building drawings allowing merely the space management, working with 2D drawings extracted from an updated 3D model would make facility management easier and more efficient. Thus, CAFM systems are ineffective in managing all the information and they lack the ability to integrate the geometrical information along with the technological ones.
The emergence of numerical innovations and open standards generate possibilities to integrate BIM in the Operation and Maintenance information management systems. BIM procedures enable Operation and Maintenance systems to maintain and incorporate information utilizing open standards via the building lifecycle phases. BIM database schemas are not commonly used by O&M staff, primarily due to a lack of understanding of how data is transmitted from BIM models to O&M schemas, which renders the data flow between BIM and O&M processes tediously and time-consuming. Furthermore, from an information management point-of-view, the built environment is virtually isolated within individual lifecycle stages and between stakeholders, with data often stored in enterprise software solutions with poor interoperability resulting in manual and often ad hoc exchange of information (see [4]).

Many research efforts are focused on improving the BIM and O&M integration process., primarily by standardizing the data sharing method and solving interoperability problems between BIM and O&M applications.
There are an unlimited number of information and parameters that can be integrated into a BIM model; however, much of the information typically included in models is useless for everyday O&M operations. Furthermore, considering the level of effort required to input operational parameters into a BIM model, it is critical to strategically identify them. These parameters can vary from project to project depending on specific O&M systems, project type, organizational structure and scope of the model. According to [8], these parameters can be classified into five categories:

- Identification parameters (i.e. category, description, model number, etc.);
- Commercial parameters (i.e. manufacturer, spares identity, etc.);
- Financial parameters (i.e. replacement cost);
- Technical parameters (i.e. height, length, material, etc.);
- Managerial parameters (i.e. reference service life, installation date, maintenance activity frequency, etc.).

Various data standards are available to provide the set of information required in BIM models to ensure the different activities characterizing the operational phase of a building. Each data standard has its strengths and weaknesses in relation of the information needs of O&M systems. The most common of which are listed below:
– **The industry foundation classes (IFC) schema:** Notably, the greatest influx of standardisation occurred between 2010 and 2014 such as ISO 16739:2013 (covering industry foundation classes (IFCs)); PAS 1192:1,-5, (covering data format specification), ISO:29481;1, (covering BIM information manual). While the development of IFC standards has advanced at rapid pace in recent years, there are still some limitations with its use for O&M functions.

– **The NBS BIM Object Standard:** developed by the National Building Specifications (NBS) as data standard for all the BIM-Objects freely available to download from the NBS National BIM Library (National Building Specifications, 2015). The NBS BIM Object Standard, besides including all the COBie parameters, also provides some data concerning assets space management which are: minimum operation space, access space, placement and transportation space, installation space, detection zone space.

– **The Specifiers' Properties information exchange project (SPie):** developed by the buildingSMART alliance, which aims at creating standardized datasets to be first filled out by manufacturers with specific products information, then used by all the actors of the construction process as information source (National Institute of Building Sciences, 2007). The SPie project includes all the COBie parameters;

– **The Product Data Templates (PDTs):** developed by the Chartered Institution of Building Services Engineers (CIBSE) as datasets aiming at identifying all the information required by each party involved in the construction process, thus providing a qualitative/quantitative description of building elements (Chartered Institution on Building Services Engineers, 2015). The PDT, developed by the CISBE, takes into consideration the building use-phase by defining a specific category of parameters named "Operations and Maintenance" in which are included many useful parameters for FM services (i.e. access clearance, frequency, etc.).

- **The Information Delivery Manuals (IDM)**: developed by BuildingSMART and adopted as an ISO standard (ISO 29481:2016). The IDM standard provides a process map-driven methodology that results in a set of information requirements for specific construction related activities by documenting and describing them in a controlled manner. A single IDM is developed for a single activity with the stakeholders mapped as swim lanes within the process map and every point of information exchange between the stakeholders mapped. The IDM methodology aims to serve both industry personnel and software developers using few technical terms.

– **The Construction Operations Building Information Exchange (COBie) schema:** standards published since 2007 in the US and later in 2014 adopted by the UK government as the official data format enabling information management between actors and across phases of the construction process. The COBie schema, specifically developed to satisfy the information needs of the operational phase, includes useful parameters such as Installation Data, Warranty Description, Reference Service Life, etc. Although COBie defines the fundamental data requirements, it is static and needs to be extended by the practitioners based on project's specific needs in the O&M phase.

COBie was first mentioned in this deliverable under Section 3.2.1 Real-Time Usability Testing where it was identified that it can be used for addressing data format compatibility issues before any data is created in a BIM can greatly minimize those issues. COBie schema can be used from the design stage to construction and in post construction as a COBie deliverable. However, in relation to the survey results: BIM passport, model checker, **energy analysis/simulation/calculation** were all mentioned extensively.

In the USA (California) there is a web-based BIM platform that links BIM and Facility management Applications in the cloud. For facilities management purposes their service provides administrator user interface to manage work order teams, with real-time colour coded floor plans and equipment linked to work orders. For which they can attach any type of document to plans, rooms and equipment[17]. The image captured here indicates how COBie can be verified and imported into a relational data structure.

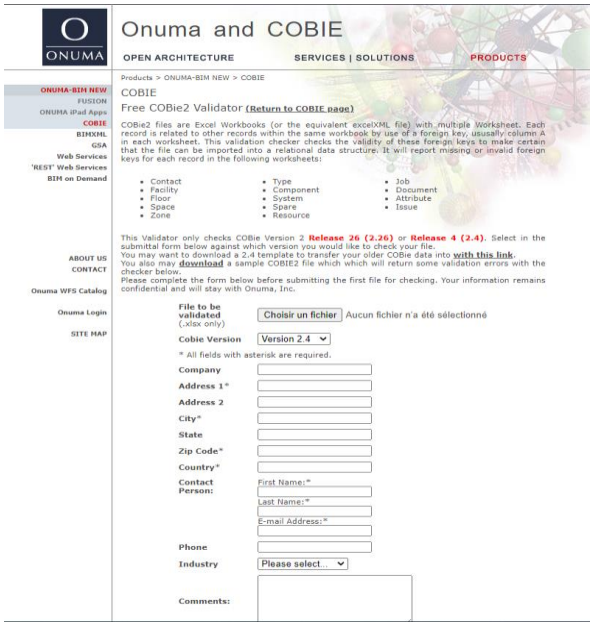

Figure 12 - ONUMA-BIM server Utilising COBie for FM

In addition to these standards some research groups and professional organizations, responsible for O&M, have adopted specifications and information structures proposed by others international standards such as the British Standards Institute (BSI) standards, most notably PAS 1192-3 (see [5]). Today BS EN ISO 19650-3:2020 is the internationalized version of PAS 1192-3:2014.

Although these standards are comprehensive, they still have limitations that hinder their use in O&M, particularly on the aspects of extracting, structuring, and storing information from a BIM model in an O&M tool and vice versa. Several research efforts aim to address these limitations by providing methodologies that support the optimal integration of BIM into O&M systems.

Anyway, there is not yet a consensus on a list of properties strictly necessary for the operation of a building and the maintenance of its equipment. This minimal description could be based on the information described in the "Building Logbook", or in the COBIE Model View Definition (MVD), although this COBIE MVD, which defines the fundamental data requirements, should generally be extended by practitioners according to the specific needs of their project in the O&M phase. As an illustration of this need to customize O&M tools according to the specific needs of each project, we can mention the example of Labeo (editor of the technical asset management software Abyla), which implements mapping files (BIM object <-> business object for exploitation) all different from one customer to another. To conclude, such a "dictionary" of properties required for operation must necessarily be able to evolve (faster than a standard). It is in this context that a Linked Data approach (see the following section on recommendations) is interesting to build an adapted dictionary by relying as much as possible on existing classifications and/or standards, in particular: ISO 12006 (Organization of information about construction works), ISO 25964 (international standard for thesauri and interoperability with other vocabularies), ISO 23386 (Building information modelling and other digital processes used in construction). Many classification systems include properties that meet the standards described in ISO 12006-2. However, they combine them with national guidelines based on cultural, technological, legal and other specificities. Getting closer to the standardisation bodies would facilitate the use of these standards as well as compliance with the rules issued by the W3C.

[17] Facility Management (onuma-bim.com)

Numerous studies and research in the field of building O&M systems are actively working on the development of methods and solutions for easy, bi-directional data exchange with BIM applications.

Therefore, some research results are showing some possible implementation, through integrated platforms, provides two-way connectivity between BIM applications and O&M Systems. Knowing that there are two modes of data exchange between BIM model and O&M systems such as CMMS: “Push mode”, where the BIM model provides updated data to the O&M system, include geometric and material/equipment data. And “Pull mode”, where data is pulled from the O&M system to update the BIM model, examples include historical energy use, maintenance records, hazardous material inventories and occupant survey results.

According to [6] there are several attempts to utilise BIM within the O&M phase. Parn et al (see [7]) developed an Application Program Interface (API) that acts as a plug-in within BIM modelling software and a customer database to integrate O&M data directly within the BIM model. A 3D object (in this case a pyramid) is placed directly in the BIM model within all rooms and other specific locations, with data attached directly to the object via a database link or data attached directly to the BIM object within custom parameters. The end-user can navigate to the objects within the BIM model, click on them and get access to the associated information. While this application does align BIM and O&M information within a visual context, it has several limitations: 1) Information is not associated directly to assets (such as a heating radiator) within the BIM model, so when accessing the data it provides the data for all assets in the room as a whole and not on the individual assets themselves; 2) As all of the data is attached to one BIM object, it makes it complex to search and filter the data, specifically in rooms with multiple complex assets (such as a plant room); 3) while data is stored externally it is accessed via the BIM model, this requires personnel to be trained on operating BIM modelling tools. Motawa et al. (see [9]) investigated how BIM can aid in the development of a knowledge management system for building maintenance. They developed a taxonomy of maintenance processes that aids in the development of Case-Based Reasoning (CBR) for use when developing a knowledge management system. Keywords from the taxonomy are captured directly on BIM objects within the model, which enables a CBR search when making maintenance decisions. While this process captures information directly onto an asset (such as a window), it has shortcomings in classifying them within a hierarchy since it does not address the multiple aspects of assets and how the system can impact O&M requirements.

Effective management and exchange of information, between BIM and specialized maintenance applications, requires not only appropriate platforms but also a paradigm shift in actors from diverse backgrounds taking role in design, construction and commissioning processes.

4.6 Recommendations for BIM data maintenance

4.6.1 BIM update process

The challenge of this new paradigm is to make operational the use of BIM in renovation operations in order to:

- Identify the best renovation scenarios by using geometrical information and properties contained inside BIM model (as for example BIM use for simulation: energy, or LCA simulation)
- Leverage the information used during renovation phases so it can be used for exploitation matters

To structure knowledge of the specific needs in the field of building renovation or maintenance, the BIM Speed D2.2 proposed three ontologies focused on:

- The installation of renovation elements (by focusing on the installation of windows, external thermal insulation composite systems-ETICS panels, and radiators),
- LCA/LCC assessments,
- Building Energy Model (BEM)

CSTB are currently working on Horizon 2020 project BIM2TWIN[18] that aims to build a Digital Building Twin (DBT) platform for construction management that implements lean principles to reduce operational waste of all kinds, shortening schedules, reducing costs, enhancing quality and safety, and reducing carbon footprint. CSTB are creating a model that will enable comparing the as-planned as as-performed processes, as well as the as-designed and as-built building elements in term of quality while monitoring and optimizing impact on worker safety and equipment use. CSTB will utilise existing reference ontologies (state/facts) aligned with standards to create their innovative application ontologies (reasoner to infer). To identify the knowledge relevant to a particular problem CSTB have analysed several reference ontologies for the BIM2TWIN project, of which the following selected two can also influence the BIM SPEED platform, to assist with the above 3 bullet points.

- **IFCOWL** is the semantic web counterpart to the EXPRESS schema definition of the Industry Foundation Classes (IFC) and formulated in Web Ontology Language (OWL). It is automatically generated from the EXPRESS file and has, except for some minor exceptions, the same content but is defined in a different language. IFC itself is an international open-source standard that specifies building and construction-related data. Its focus lies in the representation of geometric and semantic information of structural and spatial building elements but also includes, e.g., specifications regarding construction processes. Through means of IFCOWL, it is possible to make use of the vast number of classes defined in IFC and connect them with information from other domains using semantic web concepts. The main relevant parts of IFC for BIM SPEED is the building site decomposition with storey, space, and building element. IFC standard is widely used in construction industry for building design and it's easy to convert data from IFC to IFCOWL format.
- COBIEOWL is an ontology based on COBIe standard that defines non-geometrical properties of building products. Its primary purpose is transferring information from the planning and construction phase to the operational phase of a building. This can support facility managers and other stakeholders concerned with the operational phase with information about technical devices in buildings, warranty information, and maintenance-related data.

The opportunity to build upon the Logbook data, to source information on the building including material components to be incorporated into the BIM Passport to conduct energy analysis/simulations, while also utilising and extending existing ontologies (**frameworks for representing shareable and reusable knowledge across a domain)** will provide high-quality, linked, and coherent data modelling. Such models coupled with online BIM Viewer and BCF applications will Identify the best renovation scenarios and leverage the information used during renovation phases so it can be used for exploitation matters.

The following figure shows the generally accepted definition of BIM maturity level:

[18] HOME - BIM2TWIN

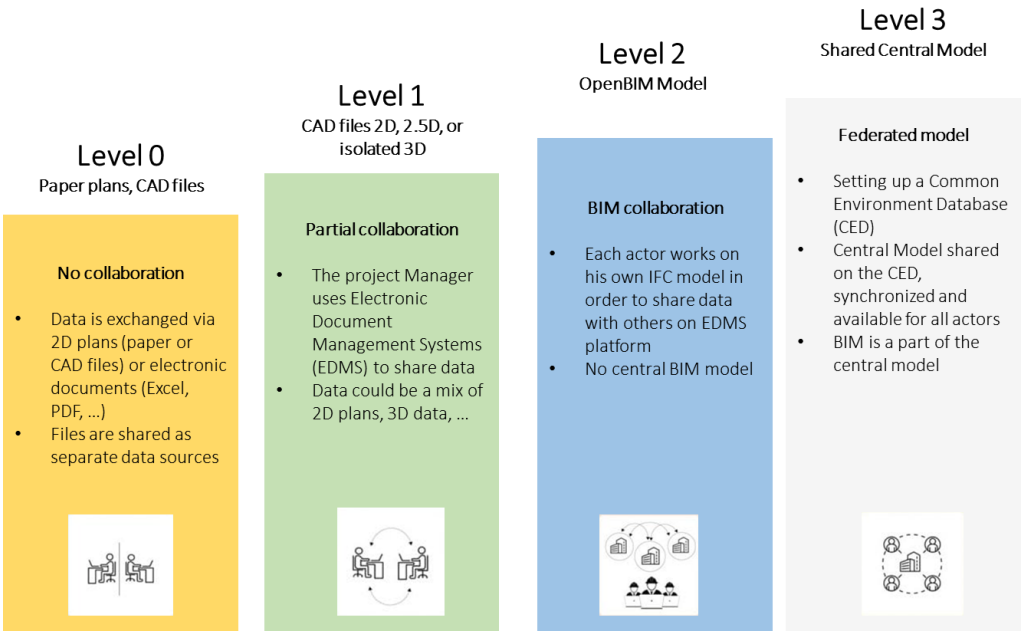

Figure 13 - the Different BIM Maturity Levels

However, the ability of each actor to manage BIM processes and data is essential and must be taken into account. The tool developed within the BIM Speed D2.1 (the Online Tool) address this concern and it would be interesting to ask Software Editors to see how they anticipate the rise of BIM, and more broadly of data sciences, because this will impact their software strategy.

Today, even if some software editors already propose central Building Operating System that can be queried by different types of clients to facilitate the job of software integrators (BIM model, CMMS tool, visualisation tool, mobile solution), this approach is still difficult to implement because it strongly impacts the software editors by leading to the implementation of centralized-data-architectures (file mode vs web services) bringing them to new development efforts. Today, for example, SpinalCOM (software editor), proposes a central Building Operating System that can be queried by different types of clients to facilitate the job of software integrators: BIM model, CMMS tool, visualisation tool, mobile solution.

Indeed, O&M tools generally manage specific sets of properties which could be different from one customer to another which lead them to favour internal data management.

So, to promote user acceptance, a strategy is therefore to set up an operational « level 2 », before gradually increasing to a « level 3 ».

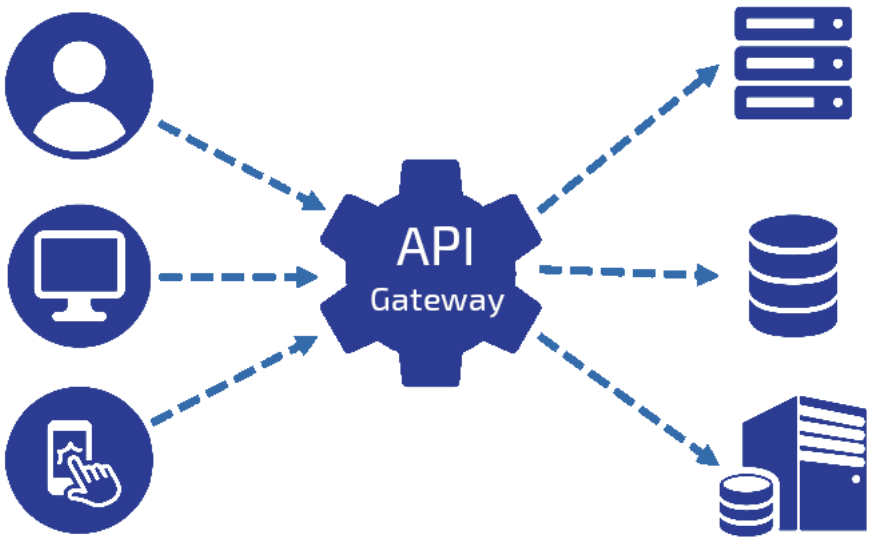

Figure 14 - SpinalCOM API Gateway

In this approach, ontologies developed in the D2.2 are used to enrich the IFC model which becomes the main data source to exchange data for the different business processes targeted (equipment installation, Energy simulation and LCA and LCC assessments). We are clearly in a « push mode » where all semantic data are merged with the geometrical model.

Ontologies developed in the D2.2 could also be used as dictionary to develop semantic checker in the BIM Speed platform to validate IFC model. The checker thus ensures that the BIM model will be usable with management systems softwares (CMMS, O&M, …).

To illustrate this approach, Semantic Design Rules were specified in the W7.3 using a part of the Reno-Inst ontology and IFC files have been produced with the additional property definitions, focusing mainly on thermal comfort, acoustic comfort, and fire safety. These rules have been used to develop a BIM-Speed checker service to validate, or not, the IFC test files.

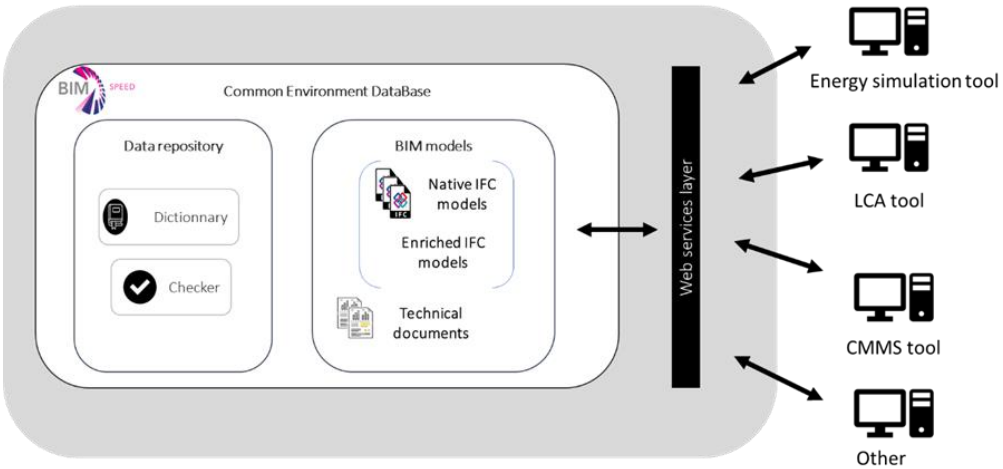

Figure 15 - Proposed BIM SPEED Architecture

4.6.2 Compatibility issues

One of the main issues about IFC is “backward compatibility”. In fact, it covers two different but complementary aspects:

- The backward compatibility of the latest versions of the IFC schema with older versions. BuildingSmart normally ensures this compatibility, but to a certain extent. E.g. ‘*the latest version, IFC 4.1 is recommended for all current developments, which is fully backward compatible with IFC 4.0. Core definitions within IFC 4.1 and 4.0 are backward compatible with IFC 2x3 TC1’.* In practice, it means that some IFC 2x3 entities, not in the core, have been removed in IFC 4.0.
- The compatibility of BIM tools with older versions of IFC, which is usually ensured by vendors but only as long as the version is not too old. For instance, ArchiCAD supports IFC versions from IFC2x3.

To ensure the readability of model data fin the future, it is often recommended to regularly upgrade IFC files to the latest versions of the standard. In practice, it is always better to check different points beforehand:

- Is the BIM design software part of the list given by BuildingSmart of labelled tools for IFC import/export?
- Are the tools that use BIM models (CMMS, etc.) compatible with the latest version?
- Do you just need to read an IFC file (without enriching it)?

If all answers are “yes”, the IFC file can be upgraded to the latest version without any concern. If, at the same time, you want to enrich the IFC file, you will have to check more carefully the compatibility with the whole suite of tools that will use this enriched IFC.

Note that such an upgrade is possible with BIM authoring tools (e.g. an ifc2x3 file loaded in Revit can be saved in ifc2x3 or ifc4 format). Conversely, a file created with a recent version cannot generally be opened with an older version of the software (“forward incompatibility”).

5. Conclusion and future work

The survey conducted as part of this project showed that construction players have a strong expectation for user-friendly BIM platforms, where project information can be collected and structured in a logical way that corresponds to professional practices and project progress, including the ability to trace the history of different changes with their various contributors, and offering a set of basic services (e.g. to track and control workflow, or check the completeness of the BIM model at each stage of the process) as well as business services dedicated to renovation projects.

At the time this survey was conducted, the BIM platform made available to the pilot sites was the launch version, mainly offering a generic CDE environment with still few renovation-oriented BIM services (except for a model checker).

It is therefore not surprising that the survey showed that early users of the platform used it mainly as a file repository and document sharing tool. But the expectations gathered through this survey have been very useful and will help guide future developments. At the time of writing this deliverable, several new services have been integrated into the development platform and will be put into production very soon: a weather data service, a service to link IoT data with BIM, a GIS data collector, a “Material” service (to enrich IFC4 files with material properties), and a LoDlifter service (to enrich IFC files with object properties and values). Others are being integrated, like a tool to predict energy performance (BIM2BEMS) and a tool to assess operational energy costs

using measured data (ECOtool). Eventually, the integration of some other services is to be discussed in the coming months.
Among new functionalities that could be useful for the users, some of them are progressively added on the BIM-SPEED platform. The global interface has been improved, more user friendly, and offering more clear vision on available services and customization. Several additional services were also made available : MEREEN by CSTB, BACN2BIM by Cartiff, GISDataProvider by TUB and CSTB, BIM Server by CYPE, 3DASHtool by Cartiff, RESuite by DEMO consultant, LoDlifter by CSTB.

In this deliverable, we also discuss some areas of study and make some recommendations to keep the BIM up to date and usable during building operation, which includes maintenance and renovation operations. Amongst these recommendations, the integration into the BIM of all the necessary information to be able to undertake a renovation operation in a well-informed way (the so-called BIM PASSPORT, which differs depending on the intended use, for example an energy or structural renovation operation), is a must. Examples of BIM Passports will be provided by some BIM-SPEED demo sites.
On the other hand, the development of a BIM server, co-located with a model server, to keep track of the history of changes requested and made on a BIM, will not be addressed in this project. In the same way, the Linked Data approach proposed to maintain data consistency between a BIM and dedicated O&M tools is outside the scope of the developments planned in this project.

6. References

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APPENDIX 1 – Online Survey (questionnaire)

Objectives: Collect data on how different types of users involved in a building renovation process actually use the cloud platform and services. Does the platform meet their expectations? What are the possible difficulties and brakes? What are the real benefits? How is teamwork effectively supported? What additional functionalities are expected?

A - YOUR IDENTITY

1. What is your organization? (only one answer)

- ○ Company
- ○ Training organization
- ○ Association
- ○ Administration
- ○ Public community
- ○ Research and Technology Organization (RTO)
- ○ Other (open field):

2. What is the size of your organization? (only one answer)

- ○ <10 (VSE)
- ○ 11<250 (SME)
- ○ 251<5,000
- ○ >5,000

3. What IS YOUR business area? (several possible answers and at least one)

- ☐ Promoter
- ☐ Building owner
- ☐ Project manager
- ☐ Architect
- ☐ Engineering Office
- ☐ Main contractor (builder)
- ☐ Subcontractor (crafts)
- ☐ Consultant (crafts)
- ☐ Surveyor
- ☐ Other (free field):

B - YOUR BIM-SPEED PROJECT

4. Where is it located? (free text)

5. What is the building type? (several possible answers and at least one)

☐ Residential

☐ Hotel

☐ Commercial

☐ Offices

☐ Industrial

☐ University

☐ Other (open field):

6. Is the owner of the building public or private? (only one answer)

○ Public

○ Private

7. What is the size of your project (m2)? (only one answer)

○ <500 m2

○ 501<1,000 m2

○ 1,001<2,000 m2

○ 2,001<5,000 m2

○ 5,001<20,000 m2

○ >20,000 m2

8. What is the size of your project (€)? (only one answer)

○ <100,000 €

○ 100,001<500,000 €

○ 500,001<1,000,000 €

○ 1,000,001<2,000,000 €

○ 2,000,001<10,000,000 €

○ >10,000,000 €

C - YOUR BACKGROUND IN BIM

9. Have you ever participated in projects using BIM? (only one answer)

- ○ Never
- ○ Only once
- ○ Several times

10. What expertise/experience does your organization have in working with BIM? (only one answer)

- ○ No experience
- ○ < 1 year
- ○ 1 < 2 years
- ○ 2 < 5 years
- ○ > 5 years

11. Are there staff training sessions related to BIM tools in your organization?

- ○ Not yet
- ○ Yes, on need based
- ○ Yes periodically
- ○ Yes, and every post has a BIM training roadmap

D - YOUR GENERAL APPRECIATION ON THE BIM-SPEED PLATFORM

12. Are you satisfied with the services offered by the BIM-SPEED platform? (only one answer)

- ○ Satisfied
- ○ Partially satisfied
- ○ Not satisfied

Why? (mandatory free field):

13. On a scale of 0 to 10, how would you rate THE ease of use of THE BIM-SPEED PLATFORM? (mandatory answer)

14. Does the BIM-SPEED platform meet your expectations? (mandatory response)

- ○ Yes
- ○ No

Why? (mandatory free field):

E - HOW YOU USE THE BIM-SPEED PLATFORM

15. What kind of DATA do you store on the BIM-SPEED platform? (SEVERAL possible ANSWERS)

Digital models, 2D maps, Images, Documents, Other (free fields)

☐ Documents (Word, Excel, PDF, etc.)

☐ Images

☐ 2D maps

☐ Digital models (IFC files, Revit files, etc.)

☐ Other (open field):

16. What kind of data you were unable to store? (Free text)

17. What are the main teamwork features you use? (SEVERAL possible ANSWERS)

☐ Document sharing

☐ Task scheduling

☐ Calendar

☐ Meeting scheduling

☐ Chat

☐ Videoconferencing

☐ Other (open field):

18. Did you ever use the invitation function to invite a partner to access the platform and connect to your project?

○ Yes

○ No

If No, why?

19. Have you ever used certain basic services integrated into the platform? (SEVERAL possible ANSWERS)

☐ File naming convention

☐ Model checking

20. Have you ever used the eveBIM VIEWER (downloadable from the platform)?

○ Yes

○ No

21. How often do you use the BIM-SPEED platform? (only one answer, mandatory)

- ○ Every day
- ○ 1 to 2 times a week
- ○ 3 to 5 times a week
- ○ Once a month
- ○ Other (free field)

22. What would you say about the BIM-SPEED platform improve the efficiency of your WORK?

- ☐ It speeds up the renovation process

If you tick this case, indicate approximately the percentage gain in time:

- ☐ It reduces the renovation costs
- ☐ It improves the quality of the renovation
- ☐ Other (free text):

23. Which features would you like to change?

What feature would you extend? (free text)

What feature do you lack the most? (free text)

What feature would you like to remove because it is not needed? (free text)

What were the biggest pain points of using the platform? (free text)

F - YOUR EXPECTATIONS

24. Would you like the file directory to be structured with predefined folders when you create a NEW RENOVATION PROJECT?

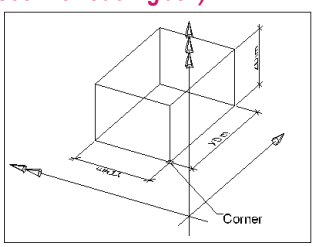
- ○ Yes
- ○ No

If Yes: please suggest how you would like it to be structured (e.g. give a list of folders that you would like to use)

25. Concerning the geometrical information contained in a BIM model for renovation, is a detailed representation needed or is the bounding box ENOUGH (see: ifcBoudingbox)?

Detailed representation needed?

- ○ Yes
- ○ No
- ○ I don't know



26. Are all needed objects/Properties described in the IFC documentation?

- ○ Yes
- ○ No
- ○ I don't know

If No, what specific objects/properties you would like to be described (free field):

27. What are the main types of tools/services you would like to be integrated in the BIM-SPEED platform for performing renovation PROJECTS?

Free field (e.g. energy simulation, product selection…)

28. If you had the option to change 3 features (functionalities, interfaces…), what would they be? WHY? (Optional QUESTION)

29. Have you ever used a competing platform? (mandatory)

- ○ Yes
- ○ No

If Yes: indicate the name of the platform:

30. OTHER(s) comment(s)?

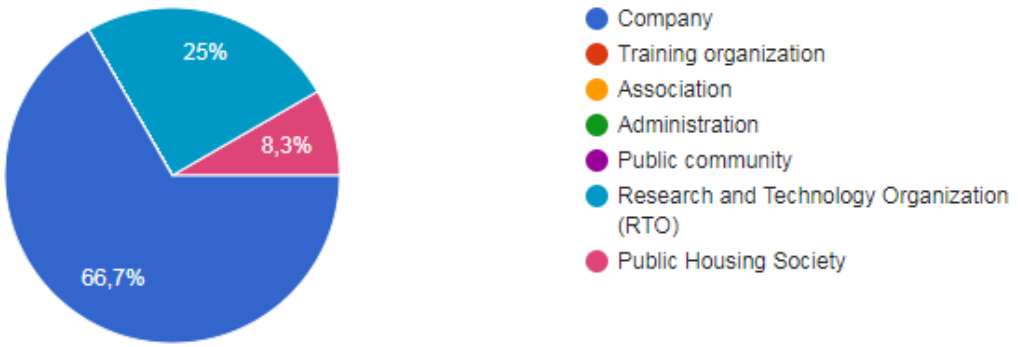
G - ADDITIONAL INFORMATION (OPTIONAL)

Last Name:
First Name:
Organization:
Function and Title:
Phone number:
Email:

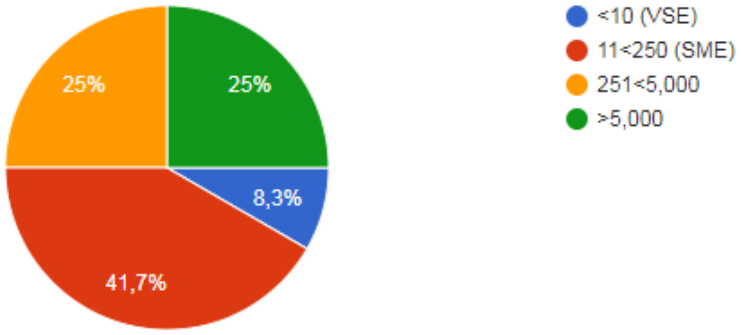
APPENDIX 2 – Detailed survey results

A - YOUR IDENTITY

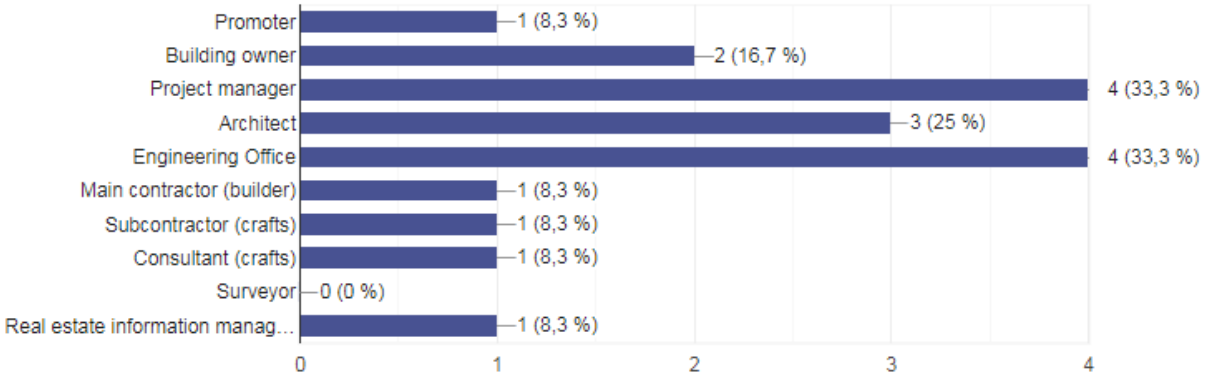
1. What is your organization? (12 answers)



2. What is the size of your organization? (12 answers)



3. What IS YOUR business area? (12 answers)



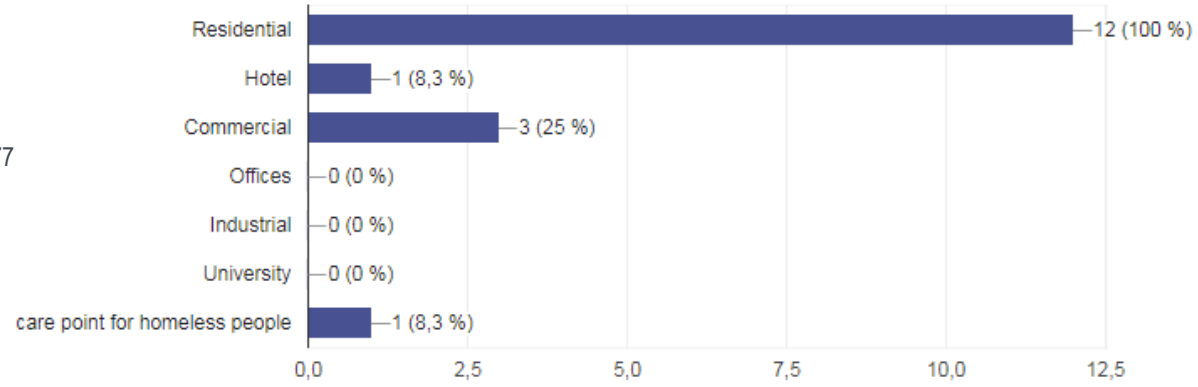
B - YOUR BIM-SPEED PROJECT

4. Where is it located? (12 answers)

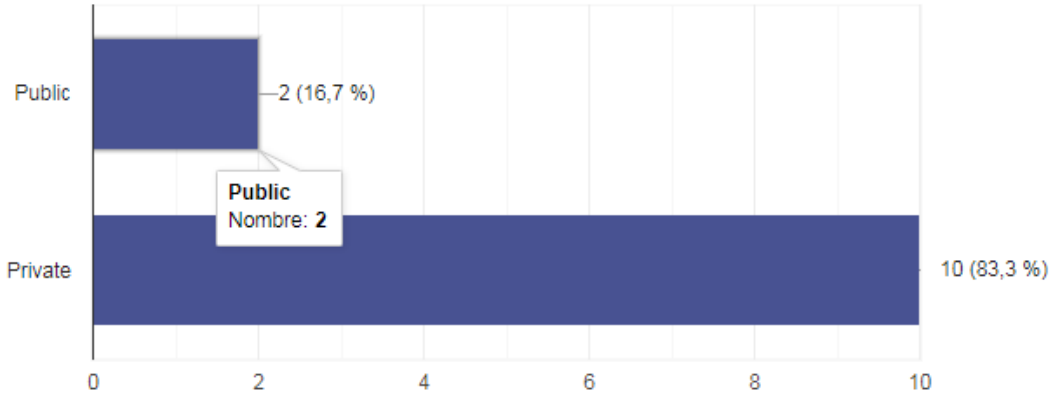
- Frigento - Italy
- Barlad, Romania
- Poland
- The demonstration case is located in Warmond, The Netherlands, owned by STEK (housing corporation).
- Warsaw
- Varna, Bulgaria
- Vitoria-Gasteiz. Basque Country. Spain
- 13 avenue de la République 91300 Massy / France
- Berlin
- Berlin, Germany
- Romania
- Paris Suburb

5. What is the building type? (12 answers)

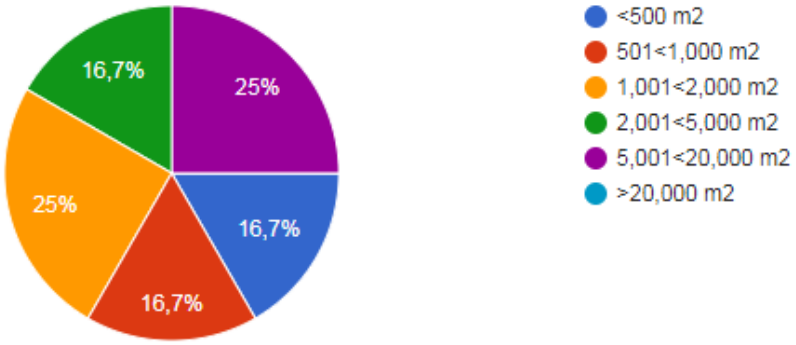
77



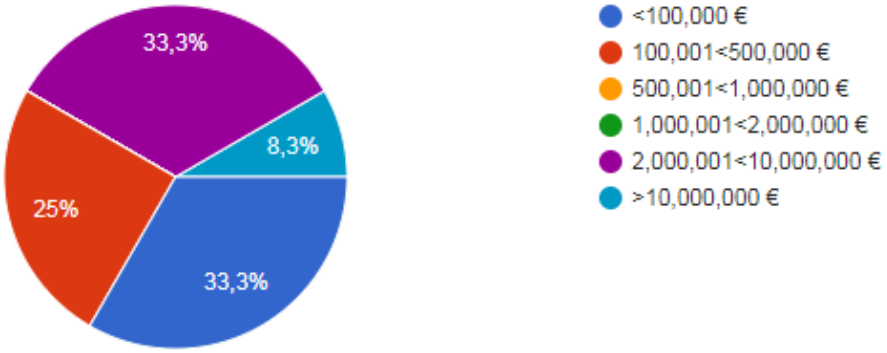
6. Is the owner of the building public or private? (12 answers)



7. *What is the size of your project (m2)? (12 answers)*

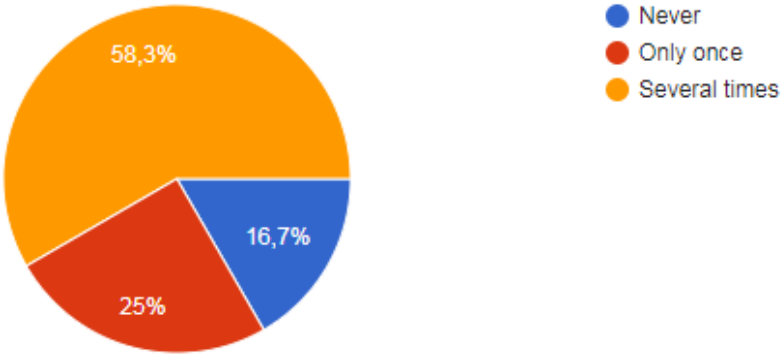


8. *What is the size of your project (€)? (12 answers)*

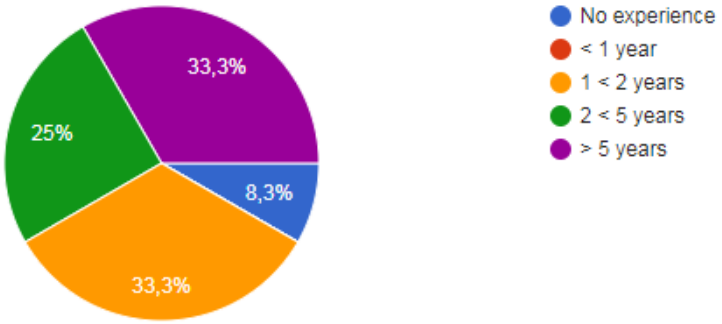


C - YOUR BACKGROUND IN BIM

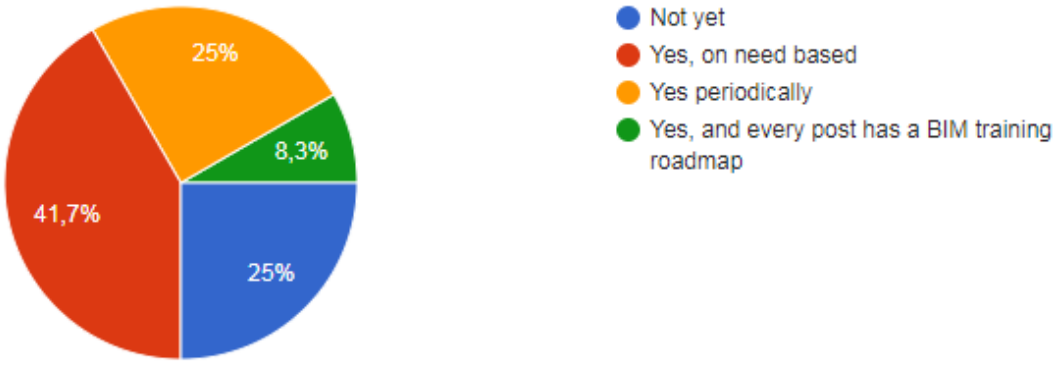
9. *Have you ever participated in projects using BIM? (12 answers)*



10. *What expertise/experience does your organization have in working with BIM? (12 answers)*

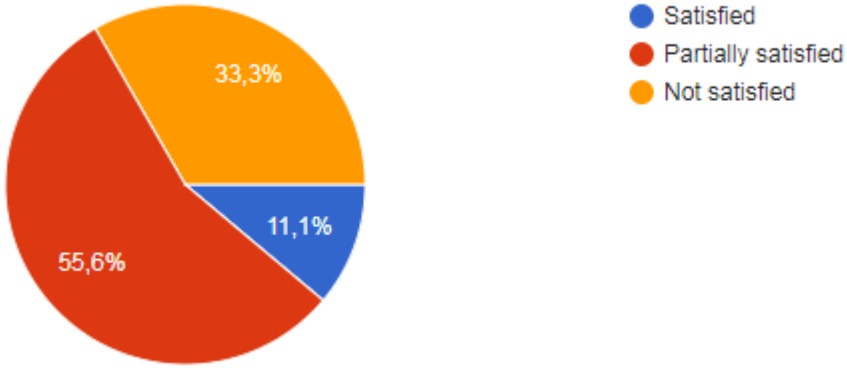


11. Are there staff training sessions related to BIM tools in your organization? (12 answers)



D - YOUR GENERAL APPRECIATION ON THE BIM-SPEED PLATFORM

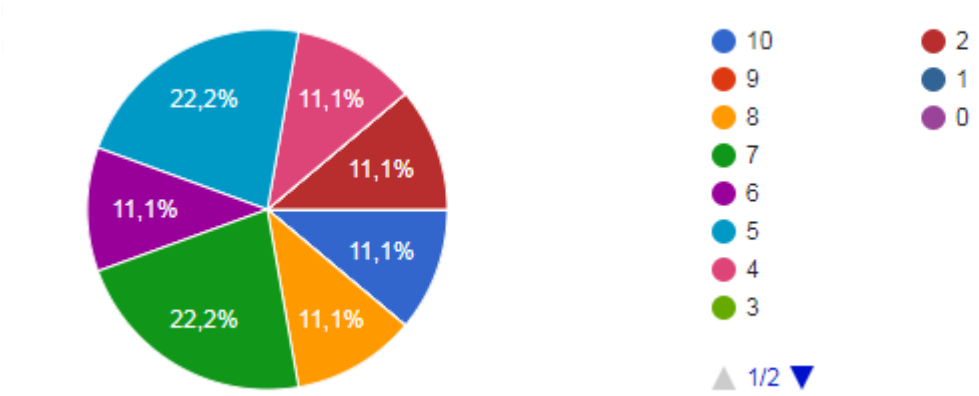
12. Are you satisfied with the services offered by the BIM-SPEED platform? (9 answers)



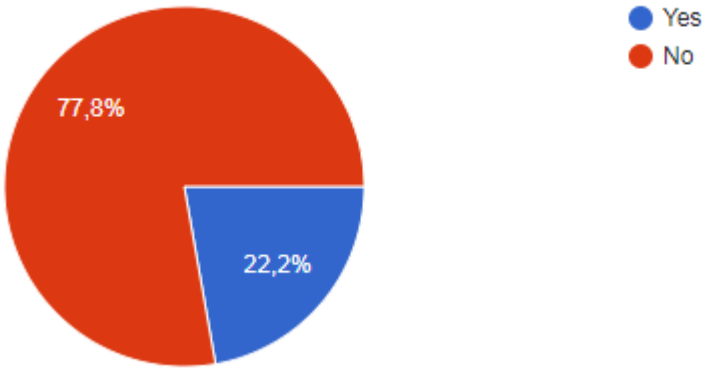
Why? (9 answers)

- Actually, I used only the Kroqui functionalities as repository. I have some trouble opening and viewing IFC models using the tools provided. I would expect a web-viewer that does not require software installation and that allows to link the BIM object with the informations (photos, thermal measures, point cloud) collected during the survey stage.
- Not a big amount of data can be stored. But in rest, looks really to use. Not used to entirely with the interface.
- At this moment it serves as the repository (sharepoint), no tools are attached that can be used.
- The platform currently works only as a repository of documents.
- platform functionality is very limited
- very well organized and frendly to the users
- We should need a clear folder structure common for all demo-sites to provide the information that our stakeholders and the rest of Consortium partners need. In addition it is important to have available the tools needed to apply for different use cases.
- It is basically a file document repos similar to nextcloud ... added functionality is missing.
- After we will implement all the items that we develop in BIM Speed it will be more than satisfactory.

13. *On a scale of 0 to 10, how would you rate THE ease of use of THE BIM-SPEED PLATFORM? (7 answers)*



14. *Does the BIM-SPEED platform meet your expectations? (9 answers)*

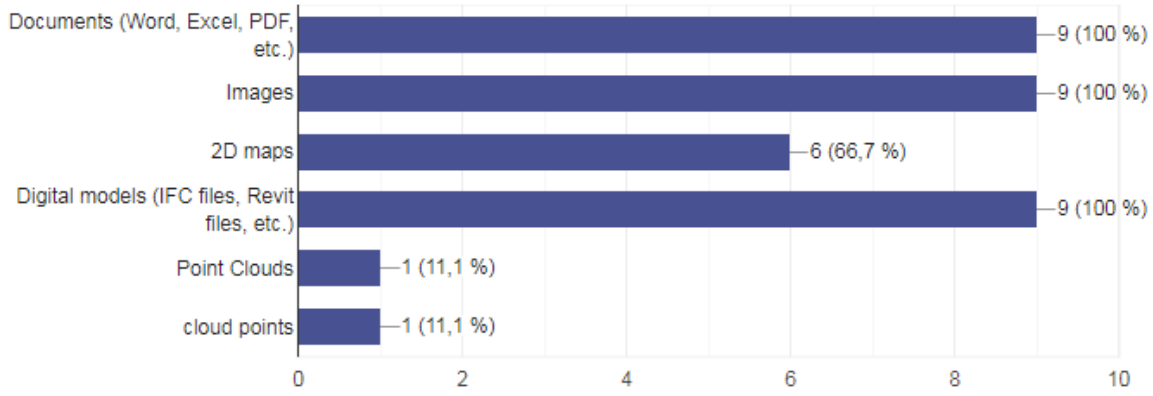


Why? (9 answers)

- See previous answer
- At this point "No" because there are still a lot of things to implement on it. If we succeed with everything, then the answer will be "yes".
- It is not clear what functionalities/servises the platform delivers,
- Currently, it is only being used as a data storage. (by the way, the rating scale of question 14 is not clear, 0 is the most difficult?)
- ex. limited file size, platform functionality is very limited
- well organized
- I understand it is right now under development. So it works only as a repository
- It is basically a file document repository similar to nextcloud ... added functionality is missing.
- Until now the platform behaves good.

E - HOW YOU USE THE BIM-SPEED PLATFORM

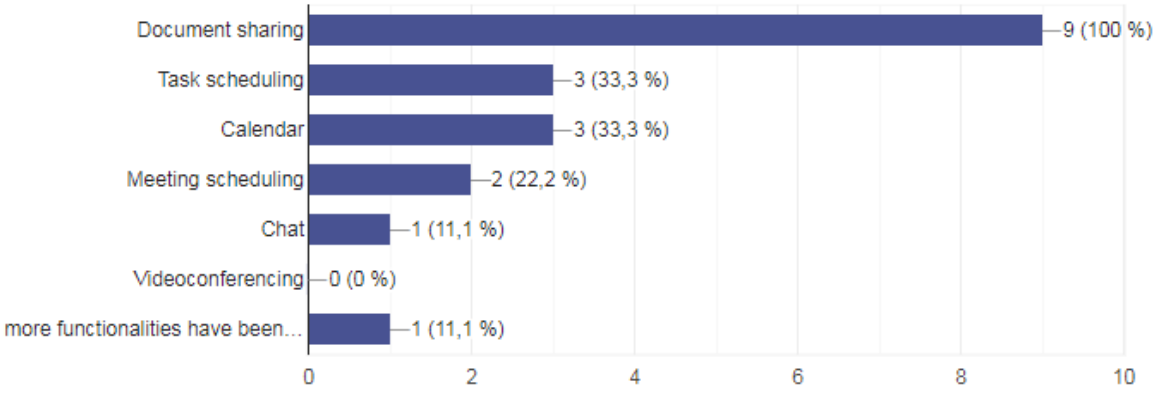
15. What kind of DATA do you store on the BIM-SPEED platform? (9 answers)



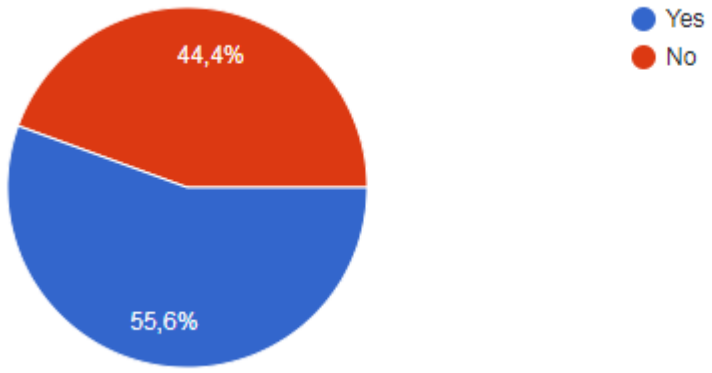
16. What kind of data you were unable to store? (5 answers)

- Point cloud
- cloud point
- POINT CLOUDS
- large files
- did not have too many data

17. What are the main teamwork features you use? (9 answers)



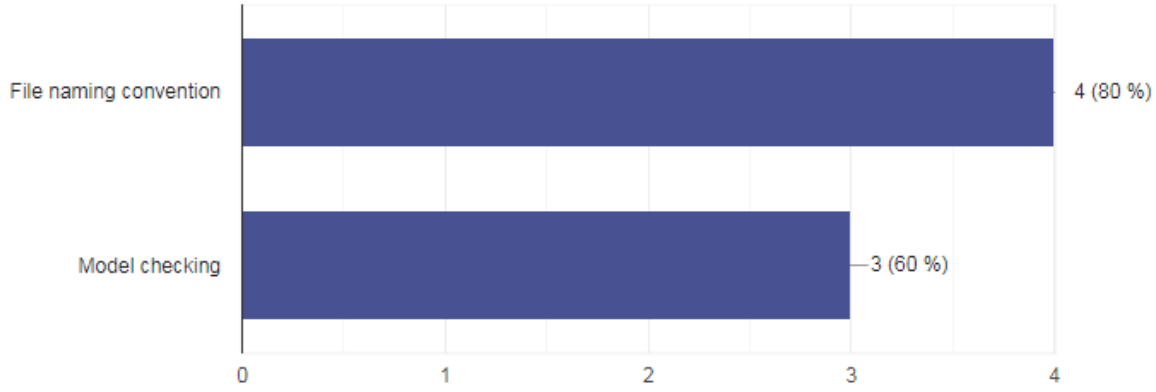
18. *Did you ever use the invitation function to invite a partner to access the platform and connect to your project? (9 answers)*



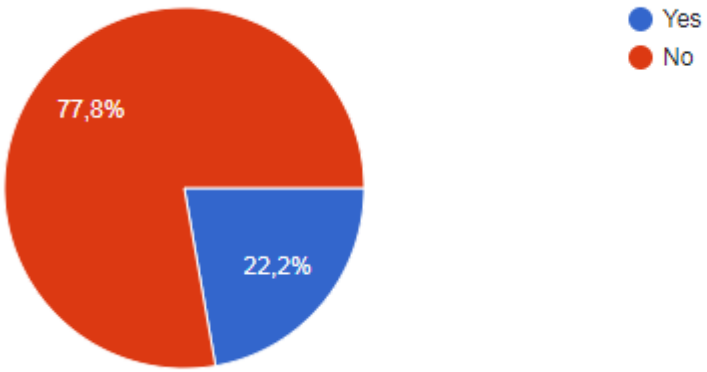
If No, why? (2 answers)

- Not enough functionalities offer in comparison with available on market solutions
- functionality is limited to use it on commercial project, the platform does not meet the investor's requirements

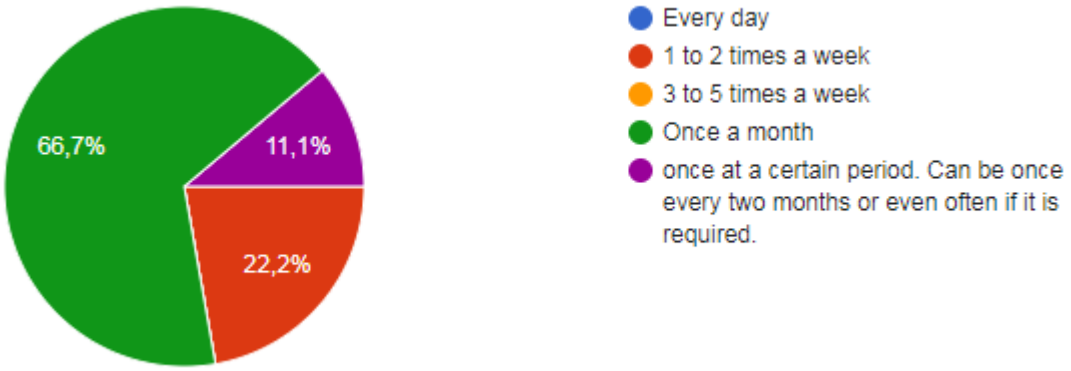
19. *Have you ever used certain basic services integrated into the platform? (5 answers)*



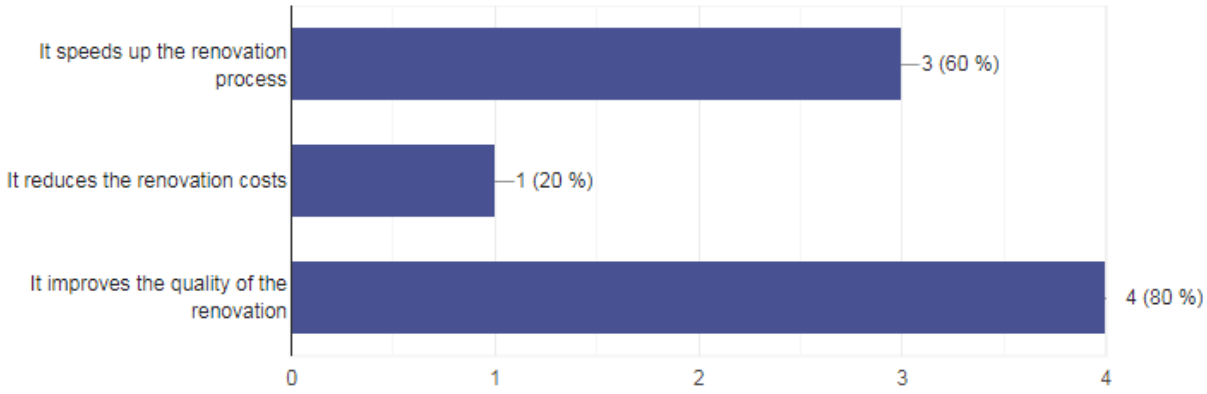
20. *Have you ever used the eveBIM VIEWER (downloadable from the platform)? (9 answers)*



21. How often do you use the BIM-SPEED platform? (9 answers)



22. What would you say about the BIM-SPEED platform improve the efficiency of your WORK? (5 answers)



If you tick the case "It speeds up the renovation process", indicate approximately the percentage gain in time: (5 answers)

- I cannot say right now. It will be done via the demo site.
- the platform is not mature enough to calculate how the renovation process can be speed up
- n/a
- 50%
- 10%

23. Which features would you like to change?

What feature would you extend? (4 answers)

- WEB applications to view and manage BIM model and point cloud (Without downloading softwares)
- functional suggestions have been sent by email
- Is opportunity uploaded archives to be unzipped in the platform?

dedicated model checking, integrations with other applications

What feature do you lack the most? (7 answers)

- IFC - web viewer
- energy calculations, management of the document, checklists, issue tracking, cost analysis, time analysis, soon many constraction sites will have in their Employer's Information Requirements: requirement for Common Data Environment platform.
- functional suggestions have been sent by email
- 1) Unzipping 2) Fast, authomated way to ask access to folders, managed by other partners. We have to write emails.
- viewer
- at this moment none, considering what we intend to bring.

What feature would you like to remove because it is not needed? (2 answers)

- doubling of the functions of Slack channel
- video conference, chat, etc. these are covered through other apps

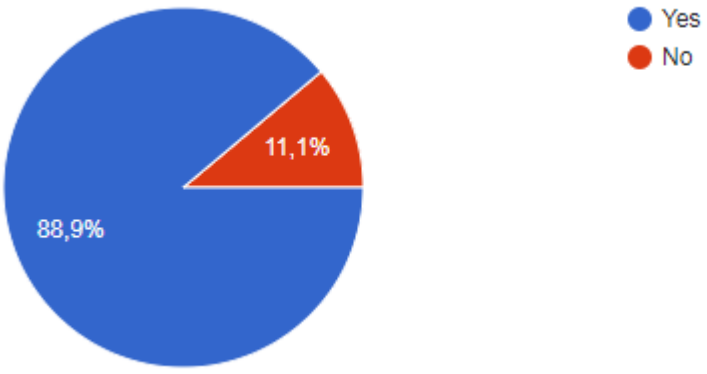
What were the biggest pain points of using the platform? (7 answers)

- Access to the external services
- the platform need to be competetive with other available on market platform
- Integration sandBox
- External Services
- now it is free
- need to vizualize what is in the archives
- Difficult to find the external services apart from those related to naming convention

What feature would you like to remove because it is not needed? (2 answers)
doubling of the functions of Slack channel

F - YOUR EXPECTATIONS

24. Would you like the file directory to be structured with predefined folders when you create a NEW RENOVATION PROJECT? (9 answers)



If Yes: please suggest how you would like it to be structured (e.g. give a list of folders that you would like to use) (5 answers)

- First of all according to international standards: work in progress, shared, published and archive.

1) Survey Folder - General Information, Existing drawings, Geometrical survey (eg. laser scanner or photogrammetric data); Thermal survey (eg. Thermal inspection, thermal measures); HVAC survey ; Site information, etc -

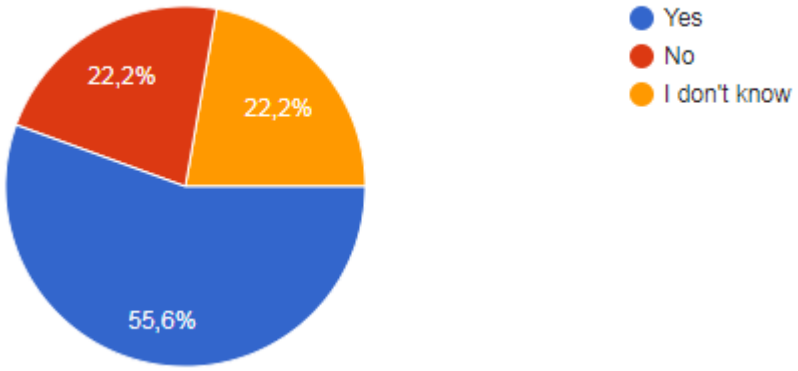
2) As built BIM Model - Containing both IFC file and the native (Bim authoring) file;

3) As built BEM Model ------

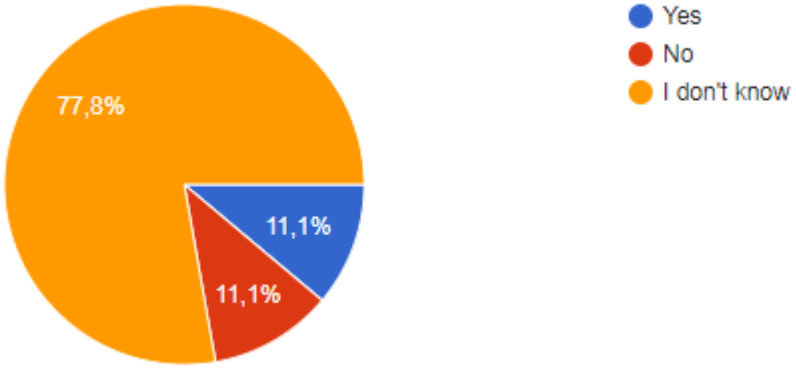
4) Renovation Option

- I would base them on stage of designs and every stage should have some predefine folders such as. Documents received, WIP files, Shared Files, Output (and take into consideration what ISO 19650 suggests). This is a bigger discussion that we should have.
- Divided in Projects, Phases, And specific folder for each phase: Bim model, data acquisition.
- a very simple list of maybe 5-6 top level folders + some dedicated second level that can be extended flexibly.
- A think a list was already given.

25. Concerning the geometrical information contained in a BIM model for renovation, is a detailed representation needed or is the bounding box ENOUGH (see: ifcBoudingbox)? (9 answers)



26. Are all needed objects/Properties described in the IFC documentation? (9 answers)



If No, what specific objects/properties you would like to be described (free field): (1 answer)

- All the information related to the Use Cases

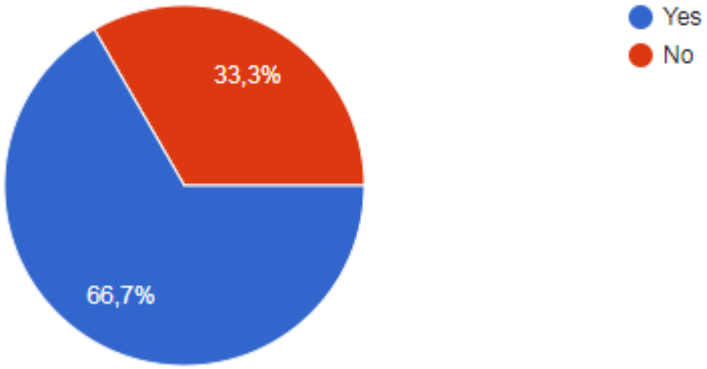
27. ***What are the main types of tools/services you would like to be integrated in the BIM-SPEED platform for performing renovation PROJECTS? (9 answers)***

- Scan to BIM service - BIM passport tool - BIM Object Library - Decision making Tool
- File naming (this one it is, but I do not know on which file naming convention it works), Scan to BIM tool, that makes a LoG 100-200 model, energy simulation, renovation scenarios analysis
- already ansenergy calculations, management of the document, checklists, issue tracking, cost analysis, time analysis,wer
- Energy simulation tool - BIM modeller - BIM based LCC tool - Parametric modeller - automatic quantity takeoff tool
- BEP ducoment creator
- When the AR app for Android will be ready, it should take BIM models from the paltform. It would be good only the BIM data that would be used for the AR demonstrations, to be copied from their original folders and stored in a separate folder.
- Those related for Executive and maintenance phase
- energy simulation, structural analysis
- structure folder, model checker, BIM passport,

28. ***If you had the option to change 3 features (functionalities, interfaces…), what would they be? WHY? (2 answers)***

- May be pre-defining of the folders would be useful
- get rid of the social communication stuff

29. ***Have you ever used a competing platform? 6 answers)***



If Yes: indicate the name of the platform: (4 answers)

- Dalux box, BauApp
- Dalux BOX, Aconex, Thinkprojext, Trimble connect, BIM 360 docs
- C&C (Connect and Construct)
- Bim Server Center by CYPE
- BIM360, BIMServer, CYPE Server,
- BIM360

30. OTHER(s) comment(s)? (0 answer)

G - ADDITIONAL INFORMATION (OPTIONAL)

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