Investigating the Conditions of Emerging Requirements of Advanced Technologies for BIM-SPEED Platform

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***Abstract*—As society is becoming more and more aware of the negative environmental impact of our living environments there is a need for interoperability of a full range of Building Information Modelling (BIM) tools for renovation that will be accommodated on an innovative BIM cloud platform. The use of BIM will be the catalyst for a more intelligent and efficient method of deep renovation for the residential building sector. This paper is based on the deliverable report 'Strategies for user acceptance, collaboration support, and BIM data maintenance' of the BIM-SPEED project, an H2020 research project. This report aimed 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. The methodology is based on two complementary aspects: i) 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 that have been collected and synthesized; and ii) by using end-user expectations regarding BIM content and update during Operation and Maintenance (O&M) of buildings. The result of this paper provides general recommendations for improving such an Integrated BIM Platform to guarantee its usability over time by advancing future versions, such as the services offered, user needs (user friendliness, user interface and ease of use), performances, flexibility, and availability.**

Keywords-BIM; Renovation; Agile Development; Collaboration; Platforms; Usability Testing, O&M.

I. INTRODUCTION

The current trend in the use of digitalization of built assets to support in the deep renovation of buildings has led to the development of many tools based on Building Information Modelling (BIM), both desktop and cloud-based. This paper 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. This platform is part of the Horizon 2020 project BIM-SPEED (harmonized Building Information Speedway for Energy-Efficient Renovation) [1], which aims to improve the performance of building stock by developing a combination of techniques and tools with one central information source at its core: the use of BIM.

The BIM-SPEED platform is part of an ambitious work package '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 European Environmental Bureau renovation projects [2]. For this purpose, there are several points that were analyzed:

- The functionalities or services offered by the platform and how they meet the needs of different end-users' profiles 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.

In order to investigate the conditions of emerging requirements of advanced technologies needed to improve the BIM-SPEED platform, a study was conducted to select the most viable components and what and how to update in practice, explained in Section II of this paper. In Section III is explained the first part of the methodology followed, and the second part focused on the development of an agile platform is explained in Section IV. Some BIM recommendations are included in Section V, and the conclusions and future exploitation of the BIM-SPEED platform are explained in Section VI.

II. EASE OF USE

The following section addresses the selecting of the components for advancement and the use of a desktop study.

A. Selecting the Components for Advancement

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 had a limited set of BIM-based renovation-oriented services) was mainly used as a file repository and document sharing service. In this initial version in which it was at the time of the first survey, the platform did not show significant innovative features compared to many other products available on the market, according to user's answers. However, very valuable information on the expected developments had been collected during the survey, amongst which the most demanded ones were predefined folder structure specific to renovation projects, workflow management, online Industry Foundation Classes (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., Heating, Ventilation, and Air Conditioning (HVAC) system components) during the building operation phase, which allowed to make the link with the second part of this study.

B. The Integrity of the Desk Review

This second part of the study was about the update of BIM during building operation and maintenance, 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 Digital Building 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.

III. METHODOLOGICAL APPROACH (PHASE I)

The methodology followed relied on a two-step approach (Figure 1"). In a first step (1), 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 organization, work progress monitoring, functionalities, and required BIM content for renovation projects. The results of this survey were 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 (2) consists in setting up recommendations for the BIM update and maintenance. This work relied 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.

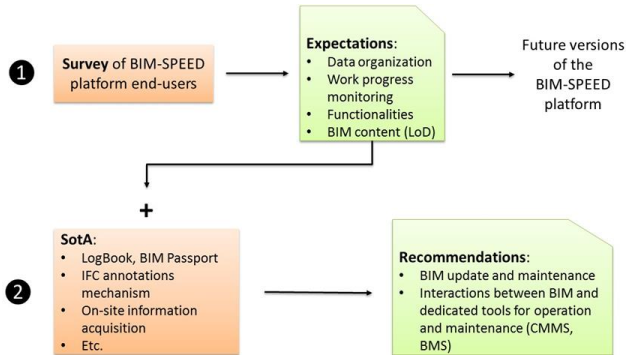

Figure 1. Methodology followed

A. User Survey

An online questionnaire was set up in April 2020 (as the project originally started in November of 2018 with a duration of 48 months). The questionnaire was re-launched in March 2021 for additional answers. The objectives were:

- 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 for the survey: a) the BIM-SPEED partners who are the contacts for the 13 demo projects and b) the registered users of the platform outside the BIM-SPEED consortium. In all, this represented a sample of 41 people. This online questionnaire consisted of some 30 questions organized in several sections such as: identity (Table I), background in BIM, and expectations (Table II).

B. Results

Only a small part of the 41 identified end-users (between 7 and 12, pending the question) of the project had 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.

C. 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 included 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' organizations have plans to develop the use of BIM internally.

TABLE I. YOUR IDENTITY

Structure	***Profile***
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%

TABLE II. BACKGROUND IN BIM

Structure	***Results***
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%

D. Appreciation of the BIM-SPEED Platform

The BIM-SPEED platform questionnaire implemented in this Phase I, used 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, shown in TABLE III. Whereas Phase II outlined the 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.' The BIM-SPEED platform server was in an ALPHA development stage, and in this phase no functionalities of the software are tested, it is a previous stage of a BETA version, something of which respondents were unaware. For that reason, 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.

TABLE III. BIM APPRECIATION

Structure	***Results***
BIM-SPEED Satisfaction	• Satisfied: 11,1% • Partially satisfied: 55,6% • Not satisfied: 11,1%
BIM-SPEED Platform meet your 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%

In summary, the following results provided in TABLE IV. represent comments that contributed constructively to identifying future requirements and deductive comments that enabled the desired features and capabilities to be the target focus of future development

TABLE IV. SUMMARY OF RESULTS

Summary of future requirements	***Summary of key deductive comments***
No predefined folder structure specific to renovations projects.	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 requirement specification will demand Common Data Environment platform".
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 are the main types of tool/services to be integrated into the BIM-SPEED platform: BIM

Summary of future requirements	*Summary of key deductive comments*
	passport, model checker, energy analysis/ simulation/ calculation was all mentioned extensively in the survey. And "file naming, scan to BIM tools – that creates LOD 100-200 model (also referred to as a schematic design stage), and renovation scenarios results."

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, in order to reach this stage, the summary of the results shown in TABLE IV. must be taken into consideration to identify current obstacles.

IV. Agile Platform Development (Phase II)

The generalized 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 [3]. Whereas European H2020 projects recognize 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 (Key Performance Indicators - KPIs, Measurement of Effectiveness (MOE), and Measurement of Suitability (MOS)).

The Agile Platform Development Method had been adapted from the traditional contract/task schedule that is illustrated in a step sequence of events in Figure 2". During this stage of the development, the BIM-SPEED project had been involved in the ALPHA design stage of the platform which had 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 reference to this paper, 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 IV. Step 6 *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.

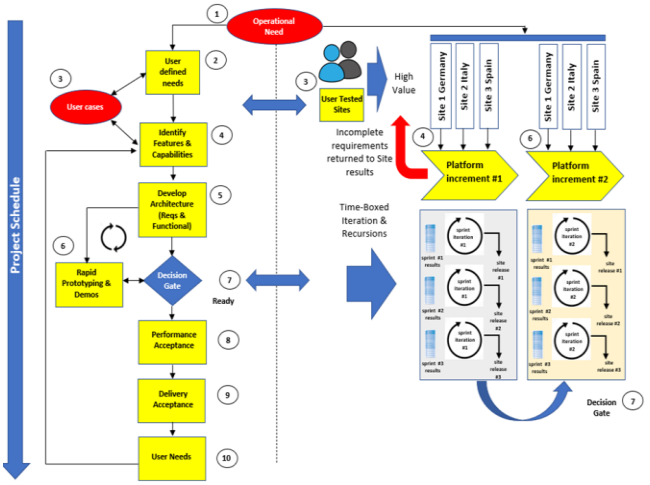

Figure 2. Agile Platform Development Method

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

A. *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, learning material was created 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 [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 Computerized Maintenance Management System (CMMS)/ Integrated Workplace Management System (IWMS) software. Analyzing and addressing these data format compatibility

issues before creating any data in the BIM model can greatly minimize these issues. If both applications support Construction Operations Building Information Exchange (COBie) format, as a non-proprietary data format, you can specify that data from the BIM can be delivered in a COBie-compliant format."

B. Summary of Sprint Iteration

A compilation of the three individual sprints (usability testing) are listed below. These results are based on the analysis of the problems and opportunities arising from the usability test. The following step 5 of Figure 2, *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:

a) *Germany*: the layout of the platform offers useful extensions through the versioning and chat function; very beneficial to publish data (models, reports, versions) which therefore can represent official, trustworthy documents; and the platform is only effectively usable for data storage so far.
b) *Italy*: 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).
c) *Spain*: the main use of the platform has mostly been like a repository to exchange information; BIM model viewer has been implemented which turned out to be helpful.

Evidently the user experience in all three sites recognized 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 recognized as positive applications. Integrating different tools with different data formats streamlined the usability experience. Again, the naming convention was highly recommended.

C. 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, however in the future 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 suggestions addresses the main future services.

V. BIM Recommendations

The Level of Development (LOD) had been defined as a crucial 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, they 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. However, one 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 Digital Building Logbook (DBL) (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).

Alternatively, we also looked at how BIM can be used to provide information to DBL 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.

A. Digital Building Logbook

The 'Digital 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), Life Cycle Assessment (LCA), urban conditions, property, etc. The DBL 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 DBL 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 DBL is already starting to be implemented in countries such as France, Germany, or Belgium, as detailed in the European study BUILDING RENOVATION: Customized roadmaps toward deep renovation and better homes [5].

B. BIM Passport

The automated evaluation of information contained in the DBL 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 (MP) to increase the efficiency and sustainability in the construction sector, promoting circular solutions for building design and operation, as proposed by the HOUSEFUL project [6], which is supported by the MADASTER platform, a cloud platform that allows the generation of Material Passports for buildings [7].

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 DBL regarding the implementation of certain use cases presented (Baseline and Use Cases for BIM-Based renovation projects and KPIs for EEB renovation) [8].

C. BIM Collaboration Format (BCF – IFC Annotations)

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 Informatics 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 [9].

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 process focuses on the support to comments and status of issues across platforms instead of focusing on a single discipline and its own product.

VI. CONCLUSION

The survey conducted as part of the BIM-SPEED project, whose methodology has been explained in this paper, showed that construction stakeholders 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. In these platforms, the ability to trace the history of different changes with their various contributors can be included. In addition, 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) can also be offered, as well as business services dedicated to renovation projects. At the time this survey was conducted, within the BIM-SPEED project, the BIM platform made available to the pilot sites was the launch version, mainly offering a generic Common Data Environment (CDE) 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. However, the expectations gathered through this survey had been very useful and helped guide future developments such as 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).

As a final recommendation, 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 essential.

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