BIM prove

D4.4 – Impact Assessment and Exploitation Interim Report

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Abstract

This deliverable addresses the exploitation, standardization and sustainability of the BIMprove project. Several activities have been implemented during the first 18 months of the project, which are based on the needs identified in the D4.1 earlier. In addition, the standardization plan was updated according to the findings in the standardization workshop and the latest developments in the European technical committee CEN/TC 442 which takes care about BIM.

Keywords

Impact, exploitation, standardization and sustainability

Revisions

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Acronyms and definitions

Acronym	Meaning
IFC	Industry Foundation Classes, the file format for open building information models
BCF	BIM collaboration format, an open standard task-format with strong industry support
API	Application Protocol Interface
AI	Artificial Intelligence
VR	Virtual Reality
AR	Augmented Reality
BIM	Building Information Model(ling)
DT	Digital Twin
GUI	Graphical User Interface
HMD	Head mounted display: "Goggles" for VR/AR/XR
KER	Key Exploitable Result
XR	Extended Reality or Mixed Reality – either VR or AR or something in between
UI	User Interface
UxV	Unmanned Aerial Vehicle (UAV) or Unmanned Ground Vehicle (Robot)
CEN	European Committee for Standardization (French: Comité Européen de Normalisation)
CENELEC	European Committee for Electrotechnical Standardization (French: Comité Européen de Normalisation Électrotechnique)
CWA	CEN Workshop Agreement

BIMprove project

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

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

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

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

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1. Introduction

This report is a mid-project update about status and further plans for exploitation, sustainability, and standardization. If follows up an earlier report (D4.1 BIMprove Impact Master Plan) about the same topics.

An important part of this document it to examine the Key Exploitable Results (KERs) that we are developing. They are of course somewhat similar to the tentative ones from the Grant Agreement (GA), but we know far more about them now. We also present how the KERs relate to the role/simulation-based devices/user interfaces ("BIM@site", etc).

The first part after the introduction (chapter 2) is describing the need that this project tries to contribute to fulfilling - improving safety and efficiency at construction sites in Europe, and in addition some trends related to awareness of the underlying technology that we using. Then in chapter 3 we present the Key Exploitable Results (KERs). They are about what is the core things we are creating in the project that can be seen as having individual value (one of them being the system in total). The word "exploitation" might have some negative ring to it, but in this context we talk about what we are creating that can be taken advantage of - in form of commercialization, further research or standardization. The impact of the project (chapter 4) is about how what we are creating in the project relates to the project goals, including how the KERs contribute to reaching the KPI values set for what the project can contribute to. Standardization (chapter 5) explained activities in the project that is done and being planned for this purpose, and also lists some promising options and venues for this. An update to the standardization plan is then presented (chapter 6). The last part (chapter 7) is about conclusions, Impact assessment, and next steps.

2. The challenge BIMprove helps to solve

The BIMprove project is about developing a system and processes using a set of advanced technologies in order to improve safety and efficiency on the construction site.

2.1. Construction sector and output levels

Division	Group	Class		ISIC Rev. 4
			SECTION F — CONSTRUCTION	
41			Construction of buildings	
	41.1		Development of building projects	
		41.10	Development of building projects	4100*
	41.2		Construction of residential and non-residential buildings	
		41.20	Construction of residential and non-residential buildings	4100*
42			Civil engineering	
	42.1		Construction of roads and railways	
		42.11	Construction of roads and motorways	4210*
		42.12	Construction of railways and underground railways	4210*
		42.13	Construction of bridges and tunnels	4210*
	42.2		Construction of utility projects	
		42.21	Construction of utility projects for fluids	4220*
		42.22	Construction of utility projects for electricity and telecommunications	4220*
	42.9		Construction of other civil engineering projects	
		42.91	Construction of water projects	4290*
		42.99	Construction of other civil engineering projects n.e.c.	4290*
43			Specialised construction activities	
	43.1		Demolition and site preparation	
		43.11	Demolition	4311
		43.12	Site preparation	4312*
		43.13	Test drilling and boring	4312*
	43.2		Electrical, plumbing and other construction installation activities	
		43.21	Electrical installation	4321
		43.22	Plumbing, heat and air conditioning installation	4322
		43.29	Other construction installation	4329
	43.3		Building completion and finishing	
		43.31	Plastering	4330*
		43.32	Joinery installation	4330*
		43.33	Floor and wall covering	4330*
		43.34	Painting and glazing	4330*
		43.39	Other building completion and finishing	4330*
	43.9		Other specialised construction activities	
		43.91	Roofing activities	4390*
		43.99	Other specialised construction activities n.e.c.	4390*

Figure 1 Nace grouping 41, 42 and 43

In the national accounting categories (NACE), the construction sector is to be found at three different categories (buildings, civil, specialized construction).

It is the first of these, division 41 "Construction of Buildings" we will focus on, since that quite purely is within our key scope and it is easy to find statistical data. The other two also contain relevant parts, but at a "division" level we will not look at these. Notice that (as seen in Fig. 1) many activities in division 43 will contribute to the actual construction of the buildings, but with focus on specialized activities.

Key indicator, Construction of buildings (NACE Division 41), EU, 2018

	Value
Main indicators	
Number of enterprises (number)	821 433
Number of persons employed (number)	3 120 348
Turnover (EUR million)	558 562
Purchases of goods and services (EUR million)	431 072
Personnel costs (EUR million)	83 480
Value added (EUR million)	135 548
Gross operating surplus (EUR million)	52 067
Share in non-financial business economy total (%)	
Number of enterprises	3.6
Number of persons employed	2.4
Value added	2.1
Derived indicators	
Apparent labour productivity (EUR thousand per head)	43.0
Average personnel costs (EUR thousand per head)	32.9
Wage-adjusted labour productivity (%)	132.0
Gross operating rate (%)	9.3

Source: Eurostat (online data code: [sbs_na_con_r2)

Figure 2 Key indicators, construction of buildings (NACE Division 41), EU, 2018 - Source: Eurostat

Fig. 2 shows the facts of the size of the constructions sector, and though its size is significant, one might notice that the share of employees in total is lower than expected. Here it is important to notice that this is only within NACE Divisjon 41 all in all it is significantly later (with civil and specialized). Its size varies from country to country, but it is often said that construction in total is about 10% of the Gross Domestic Product of most EU countries.

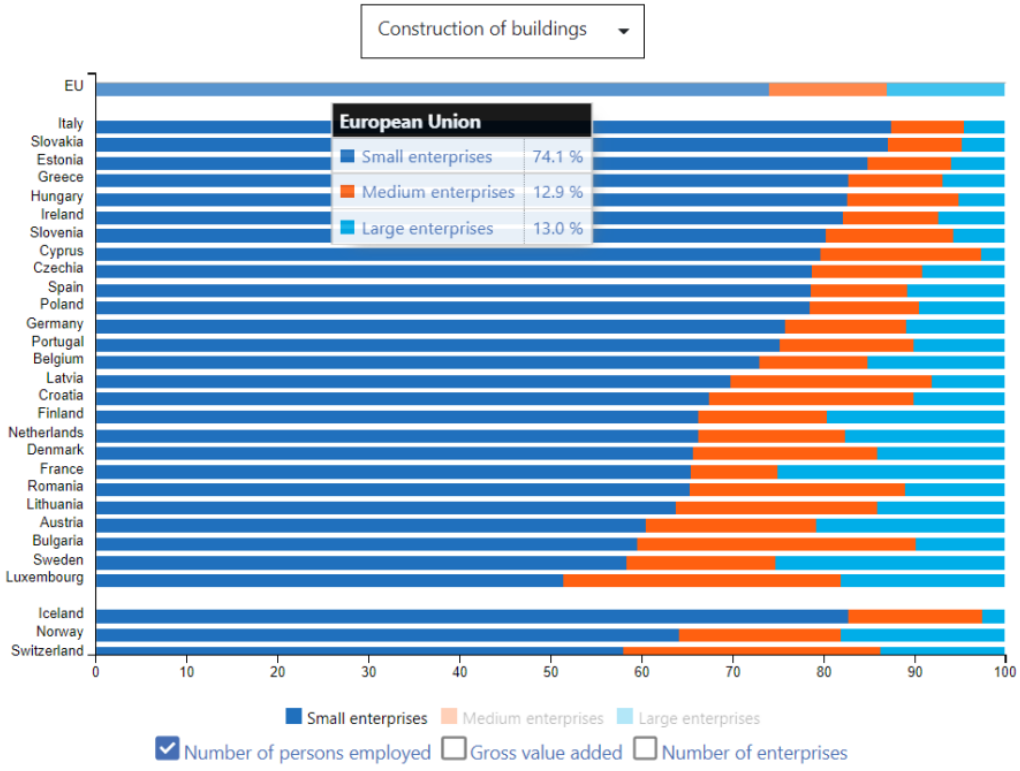

Figure 3 Size distribution of EU companies in the construction of building category i 2018 (by number of persons employed).

Fig. 3 shows the distribution in the EU countries related to how large a share om construction employees work in small, medium and large enterprises. It might be argued that it is more likely that large enterprises are open to using a system like BIMprove, because their size allows them to invest more in systems and equipment that will improve efficiency long term.

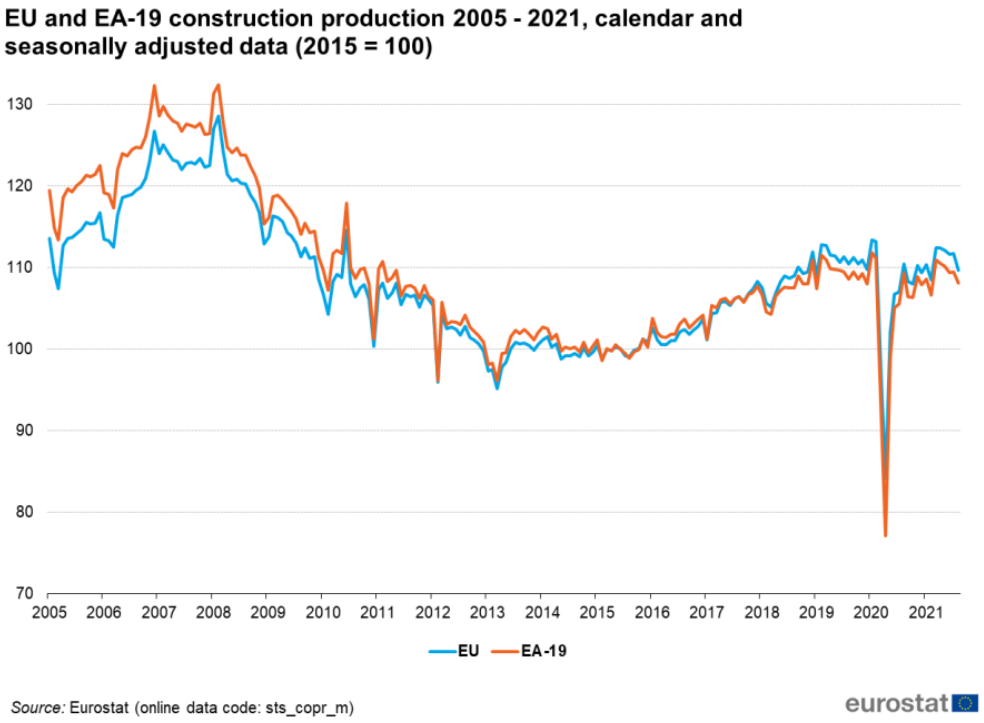

Figure 4 EU and EA-19 construction production 2005-2021 (2015=100). Source Eurostat

Fig. 4 above shows the construction related production output in EU from 2005 to 2021. Notice the increase before the financial crisis in 2008, and then the actual level starting to increase again around 2014. It then got a very heavy reduction in 2020 due to the global COVID-19 pandemic. This shows how very affected by business cycles the industry is. Also notice that the current production output level after the initial COVID-19 breakout is on level with the 2019 number, but significantly lower than it would have been had the trend the last 5 years continued. This volatility has been argued to be one of the major reasons why construction traditionally has very low R&D investments - long term gains can quickly be irrelevant due to drastic changes in the market from one year to the next. This can also be a challenge for the probability of construction companies actually investing in purchasing equipment, systems and changing processes.

2.2. Accidents in the construction industry

One of the goals of the BIMprove project is to use emerging technologies to improve safety on construction sites.

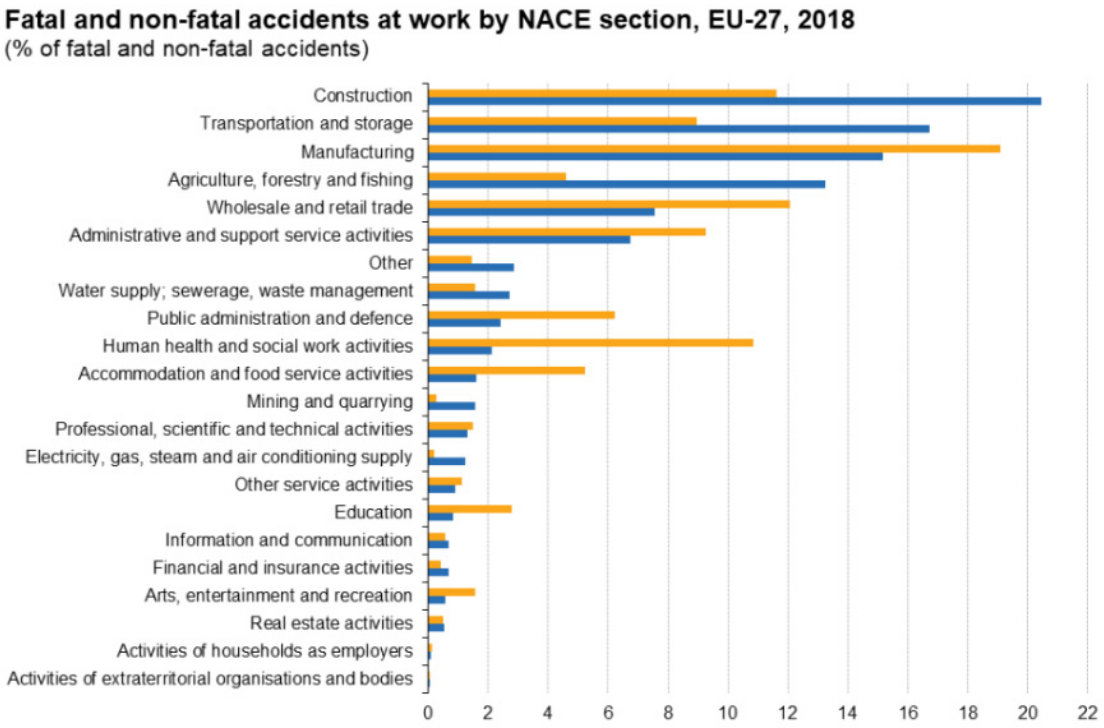

Figure 5 Accidents percentage per sector. Colour code: Blue is fatal, orange is non-fatal. Source: Eurostat

Construction is unfortunately one of the industries with the highest number of serious accidents. As shown in Fig. 5, more than 20% of the fatal worker accidents in 2018 were in Construction. In a sense, that is not surprising because the industry handles a lot of physical work in a quickly changing environment. Heavy machines and big components, high voltage electricity, chemicals and heights are part of the workplace. The teams doing the work have often never worked together before, and they are creating a building that they are usually doing for the first time.

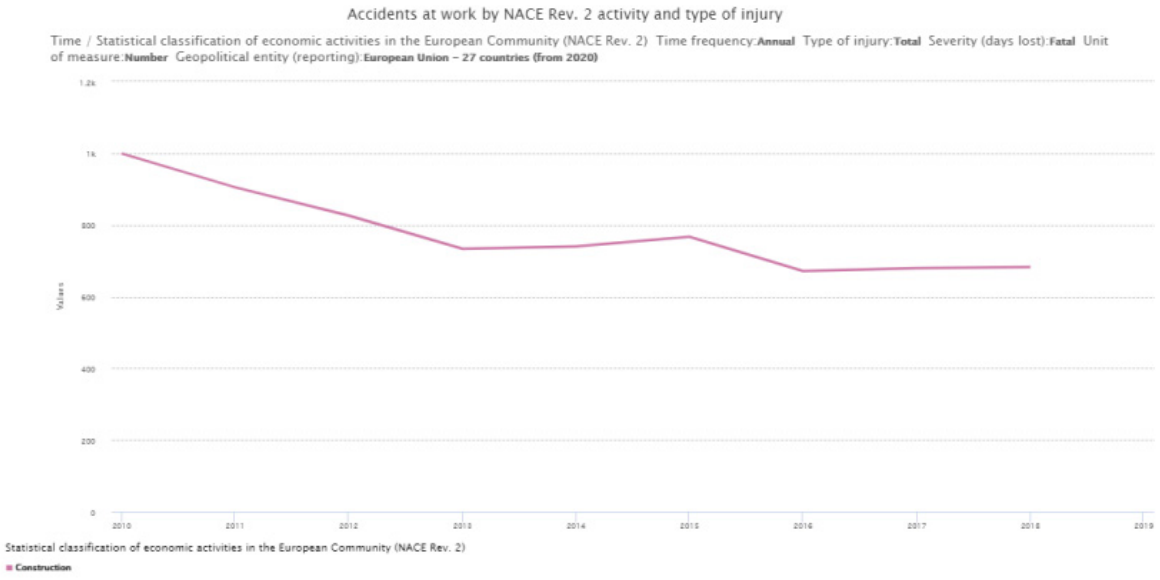

Figure 6 Trend of accidents in construction, 2012 - 2018. Source Eurostat.

A positive thing is that compared with the situation 10 years ago, as shown in Fig. 6 the number of fatal accidents in construction has been reduced by around 30%, according to Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_statistics#Analysis_by_activity

However, the numbers seem to have stabilized and remain higher than those of the other major sectors of the economy (in absolute terms). That is why one of the main objectives of BIMprove is to contribute to the development of new approaches to reduce this risk.

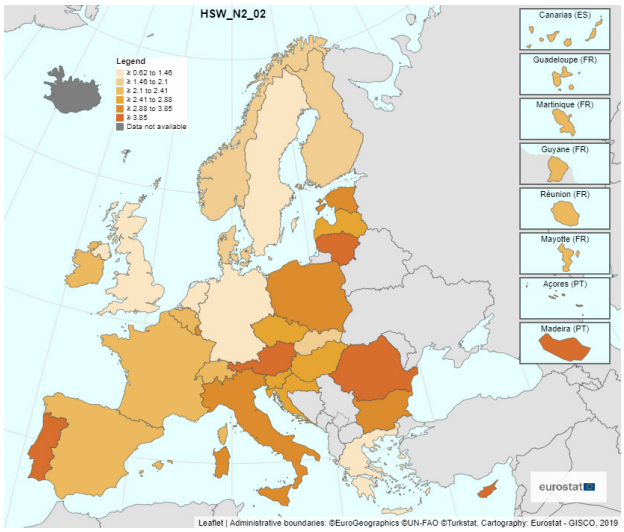

Figure 7a: Fatal accident rate (2010) by country in EU

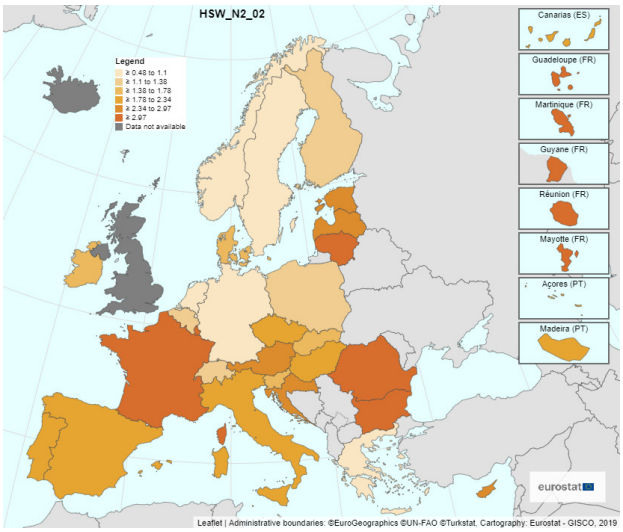

Figure 7b: Fatal accident rate (2019) by country in EU

Figure 7 Fatal accident rates

Fig. 7a shows the map-visualization between European countries regarding the fatal accident rate in 2010, whereas Fig. 7b shows the same for 2019. It is interesting to note that the max accident rate for a country changed for the better - so an important reader guidance is to understand that the colour codes (ref the legend) in 6a and 6b is not the same.

It might be theorized that the highest interest in a system that can improve safety would be in the countries that have the highest rates, because the gain would the biggest. But it could be the opposite, that the countries with the lowest rate are those who prioritize safety the most - and thus would be most interested in such a system.

2.3. Trends in interest in technologies related to BIMprove

BIMprove utilizes many technologies that are relatively new when it comes to use in the construction industry. In this subchapter we investigate the interest (worldwide) as estimated by search trends numbers on Google search. They do not present the absolute number of searches done per term, but rather present a timeline where 100 always is the highest search per time unit in the period the graph shows. The reason this is relevant is that by utilizing technologies that are getting increasing

interest, it is more likely that the BIMprove system will get interest when we present it to the market. The terms we look at the trends for below are "Building Information Modelling", "Digital Twin", "Autonomous Drone/Robot", "Point Cloud" and "Machine learning".

Google trends for searches last 10 years (1st Feb 2012 to 1st Feb 2022).

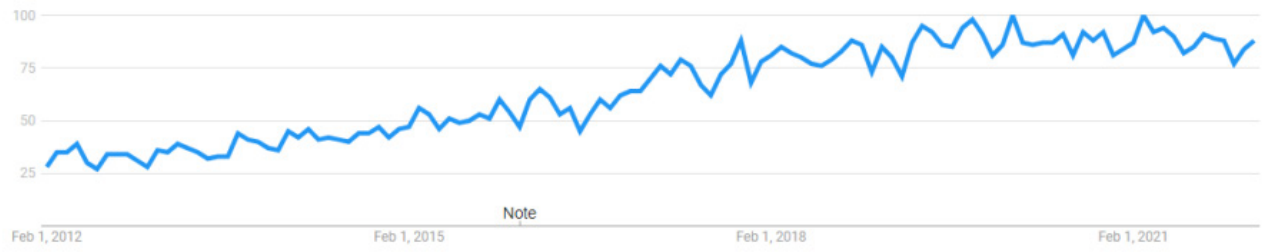

Figure 8 Google Trends search for the term "Building Information Modelling"

As shown by Fig. 8 the trend for the term "Building Information Modelling" had a steady increase until around 2019 or 2020, and then it stabilized. We chose that term instead of "BIM" since the latter gave unrelated search matches.

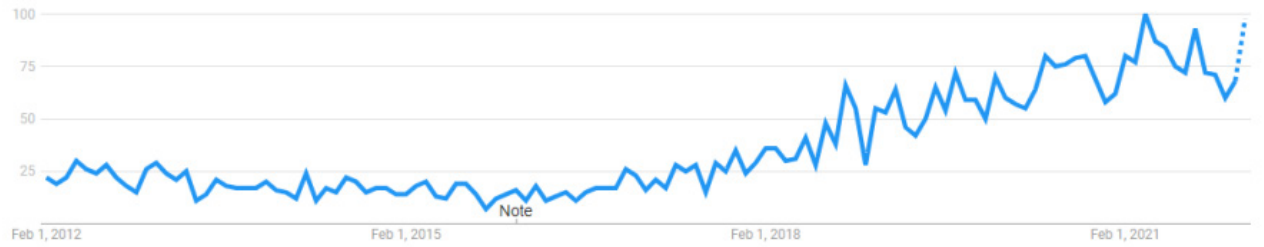

Figure 9 Google Trends search for the term "Digital Twin"

Fig. 9 shows that the interest in the term "Digital Twin" was stable until 2017, and after that it has had a strong increase.

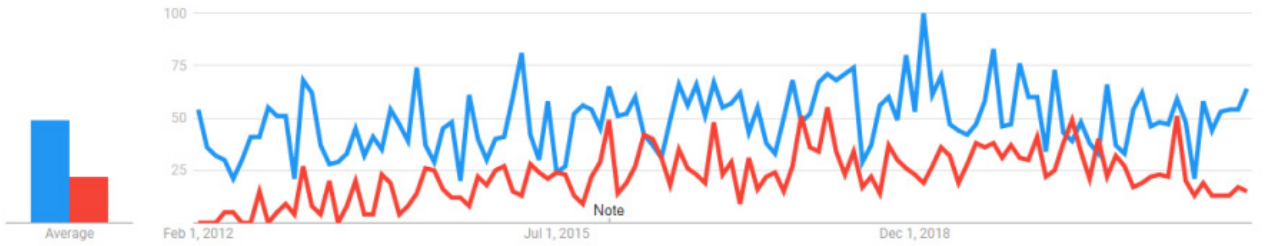

Figure 10 Google Trends search for the term "Autonomous Robot" and "Autonomous Drone"

The search trends for "Autonomous Robot" / "Autonomous Drone" (robot alternative in blue) indicate that the first of them has more awareness, or maybe that the word "drone" in itself indicates some autonomy.

Figure 11 Google Trends search for the term "Point cloud"

The trend for search the term "Point cloud" is shown in Fig. 11. It indicates that the interest has slowly increased over time. At the same time, the cost of equipment to capture point clouds via laser scanning has fallen significantly. This has probably contributed to increased interest and searches. There has also been a long-term improvement in the software generate point clouds from a set of photos ("photogrammetry").

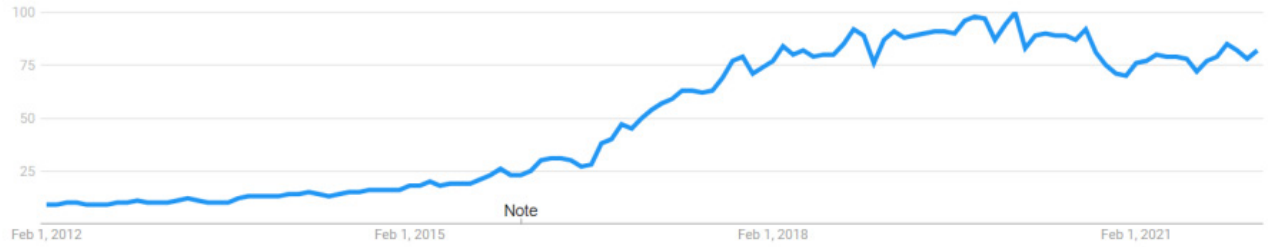

Figure 12 Google trends for the search term "Machine learning"

There has been a strong increase in the search activity for the term "Machine learning", as is shown in Fig. 12.

The search trends above indicate an increasing interest in the key technologies BIMprove is utilizing. We believe that this can be a positive contribution in the market, for further research initiatives and for standardization.

3. The Key Exploitable Results

The Key Exploitable Results are by definition technologies or other knowledge developed in the project that are most relevant for commercialization, standardization or further research.

In this chapter we describe what we see as the KERs of the project. They are all related to those identified in the project definition (grant agreement) but are further specified. The identification of the KERs has been a gradual process, but a key point was a workshop in January 2022 where all consortium members were invited, and which had good participation and engagement.

We will in this report describe the sustainability activities we see as most relevant for each of the KERs, and further investigation will be done later in the project and presented in the report about sustainability of the results at the end of the project (Month 36).

3.1. Introduction to the KERs

In the tables below we introduce the 11 identified KERs, and specify: who are the leading partners, description, asset manifestation, innovation, current market situation, exploitation plan and TRL levels.

KER 1: Defining scan requests using BIM and the schedule

Leading partners: Catenda and SINTEF

Description

This KER depends on several key technologies being worked on in the BIMprove project. The basis is to have a process and tools to enable linking the BIM models and the tasks in the schedule (most detailed version). Then we can know which objects/areas construction tasks are being worked on and when they are supposed to be finished. Based on this one can define a list of objects that should be scanned, including their location (known from the BIM models). The same can be done for safety related objects, like safety fences and no-block fire escapes. This KER can deliver input for KER 2 (mission planning), the specification of output format is in development.

Asset manifestation

Connected tools and processes to link/manage BIM models with schedule tasks, import existing schedule from existing systems (currently native Microsoft project). Support for getting existing schedules built into IFC is planned (for example exported from Synchro). An Interactive web application and API endpoints with support for creating, reading, updating and deleting these links (CRUD) are in development.

Innovation

This enables using BIM and scheduling to request the scan missions. There are some actors who does somewhat similar things (scan based on BIM and schedule), but not as integrated and also not related to safety.

Current market situation

The market consists of construction projects that are using BIM on the construction site, and who want to improve efficiency and safety.

Exploitation plan

Research, commercial development with the intent to improve existing products, can be used as input for standardization related to construction site scheduling using open BIM.

TRL-level current and expected at the end of the project

TRL 6.

KER 2: UxV MISSION PLANNING BASED ON SCAN REQUESTS

Leading partners: Robotnik and ZHAW

Description

Based on the mission request from KER 1, this is a set of tools and processes to plan the exact mission down to all the mission specific details that are needed before starting the actual mission. Both the flying drone and the rolling robot have degrees of autonomy, especially in avoiding collision with objects, but the route they are asked to travel and the scanning positions (robot) and scanning areas (drone) will be defined using this mission planner. There are important differences between the needs for the drone and robot planning, but we are attempting (and might fail since this is not done before as far as we know) to create common tools and processes for both. The fallback is to use mostly separate processes and tools for the drone and the robot.

Asset manifestation

A set of tools and processes to do mission planning based on input from KER 1.

Innovation

A tool to do mission planning for scanning on a construction sites and utilizing information from construction schedules and BIM-models.

Current market situation

An equivalent tool does not exist as far as we know (and one partner is close to this market)

Exploitation plan

Research, Commercial

TRL-level expected at the end of the project

TRL 6.

KER 3: DELTA DETECTION BETWEEN BIM-OBJECTS AND POINT CLOUDS

Leading partners: SINTEF and Catenda

Description

Based on the point clouds generated after the scanning missions have been completed (an important task, but not seen as a KER as existing commercial software is used), the point clouds are sent to the backend via an API endpoint and processed to compare them with the "plan" (the objects from the as-planned BIM ref KER 1). The core is that we have developed tools to compare each of the objects in the BIM with the point cloud observed at the same location (+tolerance). This can segment the points that belong to each object-of-interest and is the basis for reporting to the "decision maker" if the related task is completed, and if the shape and position is of the physical object is correct. BCF (BIM Collaboration Format) will be used to send the results of this process to the Decision Maker. The final decision will be made by a human, who can compare visually in 3D the BIM-object and related point cloud. We plan to colour the "object-related-points" based on distance between point and the BIM-object. To further support human decision making, we are investigating creating a "correspondence metric" indicating how likely it is that the build object is identically formed and positioned as it was planned (the BIM object).

Asset manifestation

Application to compare corresponding parts of the point cloud with the BIM-object and report the results.

Innovation

Integrateable tool to do difference detection.

Current market situation

Applications that compare point clouds with BIM-models do exist, but this is made to be integrated as part of a larger system.

Exploitation plan

Research and commercialization.

TRL-level expected at the end of the project

TRL 6.

KER 4: DRONE / ROBOT MECHATRONICS FOR UAV

Leading partner: ZHAW

Description

The developed drone is more than just a flying platform, it consists of additional sensors for the data capture, namely optical and IR-cameras mounted on a 2DOF gimbal system. The drone is usable both outdoors (with GNSS sensor) and indoor (with tracking camera).

In the BIMprove project we have followed the path of using commercial products when possible, but relying on in-house developments when a certain openness and flexibility cannot be guaranteed with these commercial products. In this way, we have a system at our disposal with which we can react very flexibly to new requirements and can always adapt anew to requirements on the construction site.

Asset manifestation

Physical drone design and microcontroller code.

Innovation

Combining indoor drone navigation with 3D-point cloud generating tools.

Current market situation

In the past 10 years, the use of drones has become established in the construction sector. These are used for pre-sounding of projects, but also during the construction phase for e.g. construction documentation. Volumetric calculation based on image data is also an important use case. However, the scope of application is limited to outdoor areas, as GNSS-based position data is required for accurate and robust flight control.

For indoor use, no technology and no commercial competitor has been able to establish itself yet. Recently, however, there have been new companies promoting their solutions, especially in the American market. These are said to be reliable and technically secure (https://www.emesent.io, https://www.skydio.com)

Exploitation plan

In the near future, the prototypes developed are to be improved as part of applied research projects and their use made safer. Commercialization is then planned in a further development step.

TRL-level expected at the end of the project

TRL 6.

KER 5: MACHINE LEARNING IDENTIFICATION FROM PHOTOS OF SAFETY RELATED BIM OBJECTS

Leading partner: VTT

Description

A machine learning application has been trained to identify security related objects, currently safety nets. The purpose is obviously to use photos from the construction site. This includes the high number of photos taken by the drone, which is primarily used for photogrammetry-based point cloud generation. The application which generates the point cloud as part of that process estimated the camera position / orientation for each photo, and we have created a tool to embed this into the Exif (standardized metadata) information of the jpeg. We are investigating if we can create tools based on this, identify which photos were taken when the camera according to the safety model was looking at a safety object (using camera position/orientation together with the cameras field-of-view and the extent of the safety object in the safety model). Then we can get a subset of photos where a safety object should have been seen and ask the machine learning trained tool with what probability it sees the expected safety object. If the probability is low (for instance we expect to see a safety fence, but the machine says low probability), this will be presented to the Decision Maker as a BCF task.

Asset manifestation

A tool with API endpoints which is trained to recognize relevant objects, and which communicates with the other parts of the system via APIs.

Innovation

The creation of the dataset to be able to train the model to detect these domains specific safety/risk related objects.

Market analysis

Similar commercial general tools exist including from the big cloud providers, but this is suitable for including in the BIMprove workflow and does not need to be exposed to third parties if it is

installed as part of the BIMprove system (relevant since photos can include faces). An important asset is the dataset that is used to train the machine learning model.

Exploitation plan

Research

TRL-level expected at the end of the project

TRL 6.

KER 6: Construction site Digital Twin serialization using open standards

Leading partner: Catenda and SINTEF

Description

The BIMprove system is centred around having a rich digital twin of the construction process and site. A key concept we use is that we want to use open standards as much as practicable possible, so there are very few if any examples of the opposite. We will be able to store the models as IFC, point clouds as e57 or Las, issues as BCF etc. We are investigating if we should propose standardization for how such an open standard based serialization should be done, or if simple recommendations are enough.

Asset manifestation

Export functions/serialization of files, integrated in the backend and the other KERs described in this deliverable.

Innovation

Research, standardization, commercial.

Market analysis

Large use potentially, but not something directly commercialize. Supporting it might give increased willingness to pay for a Digital Twin application.

Exploitation plan

Standardization, Research

TRL-level expected at the end of the project

TRL 6.

KER 7: OPEN BIM REVISION BASED DIFFERENCE DETECTION

Leading partners: SINTEF and Catenda

Description

A large BIM-oriented construction project includes a set of models, typically divided into buildings (if more than one) and domains. Most of these models will be updated through the development of the project, many of them also after the physical construction on site has started. It can be complicated to keep track of what is new from one revision to the next, and we are creating a tool to detect, report and visualize these changes. This includes detecting information changes, geometry changes, deletions, and additions. An important detail is that ideally the GUID of an object should survive between revisions, and this is something we deeply want since we use these GUIDs for the linking between tasks and BIM-objects, BCF-issues and BIM-objects, and more. For that reason, we want to support "fingerprinting" objects, so that we can detect if an object still exists, but with a new guid (a common problem). Changes can be reported as BCF-issues or as a delta-model.

Asset manifestation

Tools to compare two IFC revisions and report the differences as a list or a difference model.

Innovation

BCF-support for the deltas, GUID-fingerprinting.

Market situation

Some open-BIM commercial applications support difference detection, but we want this to work better and in a way that is suitable for being part of an automatic workflow.

Exploitation plan

Research and commercialization.

TRL-level expected at the end of the project

TRL 6.

KER 8: VR FOR THE CONSTRUCTION PHASE

Leading partner: FhG-IAO

Description

A multi-user Virtual Reality system to be installed at the construction site (BIM@SiteOffice) will ease communication about BIM models and scanning results (point clouds) by providing them to users of different expertise and backgrounds in an immersive and intuitive way.

This will help with daily on site decisions. The multi-user-connectivity works through a cloud system so it is location-independent – meaning experts who are not physically available at the construction site can join the VR session. This is possible not only via VR-HMD but also via PC with a normal monitor.

This has a strong connection to other KER listed here, as the VR-system can be used as a general visualisation tool – e.g. visualising scanning results or the links between the schedule and the BIM models. It could also be used as an input tool, e.g. defining trajectories for UxV mission planning.

Asset manifestation

A ready-to-use application where BIM models and point clouds that are part of the BIMprove processes are made available for discussions in VR as quickly and automatically as possible. Multiple instances of this application on different devices can connect and join the same VR "room" through a cloud service.

Innovation

This is another step of actively taking BIM from the design phase into the construction phase of a building project by establishing working with construction digital twins in VR at the construction site. Technological innovation is in the combination of a) the easy usage of OpenBIM- (IFC-) models and point clouds in VR, including cooperation and issue management via BCF; b) multi-user and multi-device functionality; and c) innovative functions like a waypoint-system to easily define 3D-trajectories.

Current market situation

Several applications exist that are capable of using BIM models in VR – some also for openBIM. As stated above, the combination of openBIM (including BCF), point clouds, multi-user and multi-device, and some additional functionality is new.

Exploitation plan

Research and consultancy for industry:

- Give customers from the building industry (planners or construction companies) who use BIM (and point clouds) an easy first access to the usage of VR
- Use as a basis to develop further individual functionality for our customers

Research: Use for research about VR and BIM

TRL-level expected at the end of the project

TRL 6 for general VR functionality, TRL 4-5 for "special functions".

KER 9: AR FOR THE CONSTRUCTION SITE

Leading partner: VTT

Description

Augmented reality can potentially be very useful on the construction site, since a site is a very dynamic environment (things are added and moved every day) and it can show what (according to the schedule) happened in the past and will happen in the future - seen together with today's physical reality exactly where you stand. Together with point clouds from earlier scans, it can also show things that are inside walls. An ambitious, but attractive, thing would be to see if it would be practical to show precisely using AR with high precision where work should be done. A challenge is that the visualization power of today's AR headsets are quite low.

Asset manifestation

Tool to get BIM-geometry from the backend and communicate via BCF.

Innovation

AR solution integrated into a safety and efficiency monitoring system.

Current market situation

Some AR solutions that can be used on the construction site exists.

Exploitation plan

Research, potential commercialization in an AR package.

TRL-level expected at the end of the project

TRL 6 (TRL 5 for micro-positioning).

KER 10: BIM LIGHTWEIGHT / LOW CEREMONY SAFETY MODEL AND ZONE DEFINITION

Leading partners: Catenda and SINTEF

Description

The purpose is to quickly define a simple safety BIM model, without having experience with traditional and complex CAD tools like Revit or ArchiCAD. Typically, one would select a "brush", for instance representing safety-fences, and then use a 2.5D graphical user interface (2D plus

indicating height) to show where this would be located in the BIM coordinate system. Based on this a simple, but correct formatted IFC, safety model would be generated. This can be used for other things too, like quickly defining zones for deliveries to the site etc. The purpose of this is partly visualizing for planning and collaboration, but also to have bounded volumes in BIM-space which can be used as scan targets and also be used for identifying which images should be used for AI photo labelling (ref. KER 4).

Asset manifestation

Application that can import a reference IFC model (typical Architect model) and allows the creation of simple volumetric objects / zones to indicate positions and export this as valid IFC files.

Innovation

It makes it very easy and quick to indicate simple very geometry / volume where things should be located - not considering how they might look in a beautiful rendering.

Current market situation

Some software exists to create BIM-models of safety equipment. A key difference is that our solution is meant to be very easy and quick to use.

Exploitation plan

Research and commercialization.

TRL-level expected at the end of the project

TRL 7.

KER 11: THE BIMPROVE SYSTEM AS A WHOLE, INCLUDING THE SUPPORTING BACKEND

Leading partners: Catenda and SINTEF

Description

The BIMprove system consists of many parts, the most important of which are the KERs described above. In addition to that there are many supporting parts, including the backend (main server part). This can be seen as an exploitable asset and might have larger value than the sum of its parts. Fully realized, the system can contribute significantly to tracking efficiency and safety on construction sites.

Asset manifestation

The backend and all the "satellites" that make up the whole of the system - the other KERs.

Innovation

A comprehensive system for tracking safety and efficiency on the construction site and based on open standards.

Market situation

New offering, but existing applications that partly do similar things exists.

Exploitation plan

Research, standardization, and commercialization.

TRL-level expected at the end of the project

TRL 6.

3.2. User access situations / user interfaces and the KERs

The BIMprove system will be available via different devices. It can be accessed via using a web browser using PCs, tablets or mobiles via web technologies, and via VR and AR devices for each of their uses. To describe these access situations, we use the terms BIM@<somewhere>, indicating in what location (and to a large degree which situation) the system will be accessed and shown in Table 1.

BIM@SiteOffice and **BIM@OffSiteOffice**: PC/tablet/mobile device via web browser, and VR device using a native application (working on a large set of VR hardware)

BIM@Construction: Tablet, mobile device via web, AR on HoloLens 2.

BIM@Emergency: Tablet, mobile device via web for not-superfast communication. This might also include direct-to-sensor alerts (audio or vibration).

BIM@Vehicle: Access in vehicle (when standing still for safety) via web

BIM@Anywhere: Access via web.

Table 1 Connection between user interfaces and the KERs

KER 1	Defining scan requests using BIM and the schedule	BIM@SiteOffice, BIM@OffSiteOffice
KER 2	UxV mission planning based on scan requests	BIM@SiteOffice, BIM@OffSiteOffice

KER 3	Delta detection between BIM-objects and point clouds	BIM@SiteOffice, BIM@OffSiteOffice
KER 4	Drone / robot mechatronics for UAV	BIM@Construction
KER 5	Machine learning identification from photos of safety related BIM objects	BIM@SiteOffice, BIM@OffSiteOffice
KER 6	Construction site Digital Twin serialization using open standards	BIM@SiteOffice, BIM@OffSiteOffice
KER 7	Open BIM revision based difference detection	BIM@SiteOffice, BIM@OffSiteOffice
KER 8	VR for the construction phase	BIM@SiteOffice
KER 9	AR for the construction site	BIM@Construction
KER 10	BIM lightweight / low ceremony safety model and zone definition	BIM@SiteOffice, BIM@OffSiteOffice
KER 11	The BIMprove system as a whole, including the supporting backend	BIM@Construction BIM@Vehicle BIM@Emergency BIM@OffSiteOffice BIM@SiteOffice BIM@Anywhere

4. Impact assessment of the project

The project initially defined a set of KPIs that we have the ambition to reach if the results of the project are developed into a complete set of products and services, and deployed fully and over time at construction sites. It is important to stress that some of the improvements will come over time as learning effects and projects "post-mortem" analysis are done with added insights enabled by the rich and structured data captured by the BIMprove system.

Below (see Table 2) we explain how we think the KERs listed in Chapter 3 in this report relate to reaching the goals (at headline level).

It should be noted that the actual measurement of the KPIs can only be evaluated when we are in the pilot phase - and then in light of the system being in an early prototype version. In the next 18 months we will define KPIs to measure how the KERs contributes to the objectives of the project, and for each KER what is suitable and related KPIs. Work on this has started and include insights from the consortium partners who were gathered in a workshop that took place in January 2022.

Table 2 Expected impacts mentioned in the work programme

Better scheduling forecast by 20%
KPIs (contribution to overall cost savings in brackets): • BIMprove digital thread enabling 100% digital workflow with AI based scheduling tools, (4 to 6%) • Automated daily resource rescheduling based on real-time tracking of building progress / errors / resource availability / weather forecast etc. (1 to 2%) • 50% better subcontractors scheduling (5 to 7%) • 80% overall workforce capacity utilization (4 to 6%) • 30% to 50% less material stockpiling (depending on the size of the construction site), (2 to 4%) • 40% better meeting of critical milestones and deadlines (1 to 3%) resulting in 17 to 28% better scheduling forecast by automated / semi-automated building progress monitoring via Digital Twin compared to static planning
⇒ The linking and tracking of progress, correctness, and safety on the construction site together with decision support based on schedules, scanning and BIM can contribute to significantly better scheduling quality, especially when learning effects are taken into account.

Proposals for a future standardisation for Digital Twins at a European scale
KPIs: • Early adoption and use of existing standards in AECO Industry Foundation Classes IFC (ISO 16739-1:2018) and Model View Definition (MVD) • Development of Reference Architecture Model for AEC industries • Initializing open standardization activities • Publishing a white paper on Reference Architecture Model for AEC industries
⇒ We are in progress of doing the above, including activities explained in the standardization chapter in this report.
Better allocation of resources and optimization of equipment usage
KPIs: • 80% overall workforce capacity utilization, including the reduction of personnel over-allocation • 30 to 50% less stockpiling • 80% overall capacity utilization of key components at buildings sites (cranes, big machinery) • 60% overall equipment utilization • 1-day maximum on-site downtime for hand tools before repair or exchange
⇒ This is related to tracking site-activities and using data available in the BIMprove system to find bottlenecks that hinders efficiency and lowers capacity utilization.
Reduced number of accidents on construction sites
KPIs: • 80% fewer accidents with direct body injuries through BIMprove early warning system • 50% fewer accidents with material or machinery damage • Detecting and firefighting on site within 5 minutes after occurrence

⇒ Reducing accidents can be done by identifying safety relevant zones, scanning to document and control that safety measures are in place, and also using position-based warnings. Fire prevention can be supported before actual fires happen by preventive thermal scanning, and firefighting on site can be supported by training using virtual simulations.

Reduction of costs on constructions projects by 20%

KPIs (contribution to overall cost savings in brackets):

- 80% overall workforce capacity utilization, incl. reduction of personnel overallocation, (3 to 4%)
- 50% optimized equipment utilization and reduction of machine overallocation, (2 to 3%)
- 50% reduction of reworking (4 to 5%)
- 50% reduction of stock cost, contributing 1 to 2%)
- Automated / semi-automated building progress monitoring (2 to 3%)
- Automated BIMprove digital tool thread (3 to 4%)
- Automated / semi-automated Quality assessment (2 to 3%)
- Enhancing safety on building sites (1 to 2%) resulting in an overall potential of cost reduction on building sites from 18 to 26%

⇒ A major factor for construction site efficiency, and thus costs, is to make sure that progress and quality is monitored very systematically. This is supported by BIMprove using processes including linking schedules, BIM, and scanning by autonomous robots, drones and image analysis using a trained AI. By tracking this and using the rich set of data for statistical and qualitative analysis, further improvements can be done over time. Reducing accidents can also be important for costs, as accidents are costly and delays progress. Site activities can also be stopped if safety is not in line with external requirements, which is also affecting the costs.

5. Standardization potential

Standards provide people and organizations with a basis for mutual understanding, and are used as tools to facilitate communication, measurement, commerce, and manufacturing. Research projects that wish to take advantage of standardization ask themselves how they can contribute to standardization and how their developments could be smoothly integrated in the standardization landscape, as pointed out in D4.1 BIMprove Impact Master Plan.

Need for new standards or needs for the adjustment of existing standards were collected mainly through a standardization workshop.

One standardization potential was provided long before the workshop via mail: The potential "BIM – Requirements (and recommendations) for real-time data acquisition on construction sides" was not part of the workshop but integrated in the evaluation.

The evaluation of all potential ideas with the most important indicators is integrated into this deliverable as Table 4 in Appendix 4.

5.1. Standardization ideas identified through the standardization workshop

In this section, the most promising ideas will be presented in detail. In preparation for possible standardization activities, questions from the standardization application and the CEN/CENELEC workshop application were answered. The answers reflect the nature of the standardization workshop and are therefore in bullet form.

5.1.1. Processes regarding scheduling

Overview

Title	BIM -> monitoring and scheduling		
ID	7	**Score (Workshop vote)**	4
Topic	Digital Twin	**already existing**	no
Standard Type	process	**project specific**	no
feasibility	high	**Priority on taking forward**	high
project knowledge	yes	**High benefit for project**	yes
Existing Standards	IFC (to be improved)	**Effort**	medium
Partner who would work in an activity.	CATENDA, AFG, HRS	**Chance of success**	medium to high

Description

Use BIMprove to take a deeper look into how to connect the plan and schedules with the objects in BIM. The next step should be progress monitoring of the executed work on the site. This is a point that occurs in a lot of projects but connecting the timeline to BIM in an efficient way is something that hasn't been solved yet.

Suggested action

Elaborate idea further to approach BuildingSMART with the suggestion for an update of the IFC standard

Further details

1. Which activity (work package, deliverable, solution) forms the basis for this proposal?
    - Scheduling mechanism in IFC
    - WP2 and WP3
    - part of it already exists in a deliverable
    - located between high level planning and day to day planning
    - related to tasks, BIM objects, should e.g. include costs
2. Which challenge should be tackled by developing a CWA?
    - There are two approaches
        - put everything in the large IFC file (you have to do this today)
        - link IFC to another -> you don't need to change the big IFC file every time the schedule changes
    - The second approach is the most favoured and would require an update of the IFC standard
    - Further points of the discussion:
        - may lead to a referencing problem, in case a reference isn't found
        - chronology, 1st date, end date, how many spots? maybe dynamically, maybe link to external tool
        - stored in IFC, not independent from the objects
        - To make something that hopefully would fit for most construction projects today and relates to BIM
        - shouldn't be too complex
        - relates to information flow
        - processes regarding scheduling -> BIM -> monitoring
        - many different processes exists
        - lot of different practices
3. What are the future benefits of the CWA(s)?

- IFC offers no sufficient standalone scheduling, it could be better used if referencing from one file to another will be allowed
- easy updatable schedule
- open scheduling format, which may be used
- simulation could be divided: one person thinks about years another person thinks about months
- pushing the idea to the limit means that one IFC file is nearly empty, just containing the relationship and dates of the objects in the large IFC file, referencing to
- time stamps on BIM data
- transferability of schedule
- interoperable tools
- improved learning effect
- comparison of different sites, benchmarking i.e.
- anonymous benchmarking

4. Why is this also important for other stakeholders?
   - easy access to a consistent schedule at any time
   - simulation of scheduling possible without the 3D metrics, (can be merged afterwards)
   - easy updatable schedule
5. How strongly is a common basis needed?
   - From the BIMprove perspective this would be very useful, scheduling would be much easier
   - for construction companies also very useful
   - The approach general -> detail is very useful

5.1.2. Point cloud vs BIM

Overview

Title	Process: Point-Cloud -> compare with BIM		
ID	3	**Score (Workshop vote)**	3
Topic	BIM	**already existing**	no
Standard Type	process	**project specific**	no
feasibility	to be evaluated	**Priority on taking forward**	high
project knowledge	yes	**High benefit for project**	yes

Existing Standards	Point cloud and BIM are defined, no 'scan to bim' standard found, no 'compare with BIM' standard found	**Effort**	to be evaluated
Partner who would work in an activity.	VIAS, FhG-IAO	**Chance of success**	to be evaluated

Description

How can we go from a point cloud to a BIM object?

How do you get from a point cloud scan to a BIM object and to a correct BIM model of what has been scanned on the construction site?

It is also possible to standardize the interface in case the actual idea is something that should be rather protected as IPR than standardized.

Suggested action

Elaborate idea further in view of a possible CWA

Further Detail

1. Which activity (work package, deliverable, solution) forms the basis for this proposal?
   - BIMprove will develop a process to come from a point cloud to a stage where it could be compared with the BIM model
   - What was measured vs. what was planned
   - Catenda is currently involved in a task (together with SINTEF) doing point cloud vs BIM (aka scan vs plan)
2. Which challenge should be tackled by developing a CWA?
   - undefined process -> uniform process
   - Requirements for point cloud
   - Requirements for BIM model (maybe defined elsewhere, maybe need for adjustment)
   - Sync between scan and surveyors
3. What are the future benefits of the CWA(s)?
4. Why is this also important for other stakeholders?
   - process development not necessary
   - transferability
   - For example: different workers are working on the building site which would all profit from an automated risk detection
5. How strongly is a common basis needed?

- It would help the building industry very much

6. What is explicitly not part of the CWA(s)?
   - Definitions for the BIM model or point clouds as such
7. Market environment - What is already on the market and how does the envisaged CWA(s) differ from it?
   - more information should be do added, there are programs that made a 3d from point cloud as MDTP
   - several companies offer "scan to BIM"
   - Scan to BIM scans existing buildings, works good for simple buildings
   - This scan should be done at a building site
   - BIM model already exists
   - Comparison needed
   - Processes to update a BIM model by surveyors
8. Legal environment - Directives and relevant European legislation
9. Scope: What is the CWA about?
   - Definition of process from a point cloud to the comparison with an existing BIM model
   - Requirement to the BIM model and the point cloud (or scanners)
10. Scope: Who is the target group of this CWA?
    - BIM software companies
    - Surveyors
    - Building industry
11. Proposers of the CWA - Who from the project could be the initiator and who the main contributors? Who else should be involved (project internal and external) and who has already agreed to take part in the CWA development?
    - To be clarified
12. Possible elements of the CWA - How could the CWA look like (e.g. table of contents)? Which elements need to be included?
    - Definition of process from a point cloud to the comparison with an existing bim model
    - Requirement to the BIM model and the point cloud (or scanners)

5.1.3. Coordinate systems

Overview

Title	same Coordinate Systems for all applications		

ID	8	**Score (Workshop vote)**	3
Topic	BIM	**already existing**	no
Standard Type	common tests	**project specific**	no
feasibility	medium	**Priority on taking forward**	high
project knowledge	yes	**High benefit for project**	yes
Existing Standards	ISO/TR 23262:2021 GIS (geospatial) / BIM interoperability ISO 19111 Geographic information — Referencing by coordinates ISO/TS 19166:2021 Geographic information — BIM to GIS conceptual mapping (B2GM) https://www.buildingsmart.org/standards/bsi-standards/standards-library/ -> User Guide for Geo-referencing in IFC	**Effort**	to be evaluated
Partner who would work in an activity.	HRS, ZHAW	**Chance of success**	high

Description

There are many coordinate systems:

- BIM CS
- global CS
- robot CS
- drone CS
- CS per floor
- CS of surveyors

→ clear definitions needed, transforms, during scanning: assign each scan to specific CS

Suggested action

Elaborate idea further in view of a possible CWA

Further Details

1. Which activity (work package, deliverable, solution) forms the basis for this proposal?
   - Coordinate models, WP2 and WP 3, not focussed in a deliverable yet
2. Which challenge should be tackled by developing a CWA?

- there are many coordinate systems: BIM CS, global CS, robot CS, drone CS, CS per floor, CS of surveyors -> clear definitions needed, transforms, during scanning: assign each scan to specific CS
- calibration - you find 50 crosshairs per floor on a site - they need to be identified by i.e. a QR Code
- global definition of crosshair identification
- proper naming of different CS
- proper definition of the coordinate systems (including units) I.e. a fixed point for a construction site
- define if stick to site, stick to GPS coordinates
- 4 values or 6 values?
- is z always up?

3. What are the future benefits of the CWA(s)?
   - Different measurements and data from different stakeholders at a building site are easy integrateable
4. Why is this also important for other stakeholders?
   - data from different partners could be used
   - it is important to be able to merge the data
   - some software providers might fear to lose a lock-in
5. How strongly is a common basis needed?
   - 7 votes for very high, 1 vote for medium
6. What is explicitly not part of the CWA(s)?
   - not about reinventing the existing standards
7. Market environment - What is already on the market and how does the envisaged CWA(s) differ from it?
   - recommendations from the BIM perspective (Norway), Norwegian municipalities
8. Legal environment - Directives and relevant European legislation (not answered today)
9. Scope: What is the CWA about?
   - defines how current CS are defined (or defines them itself) and defines how different systems could be transformed into each other
   - defines a common system for the definition of crosshairs to calibrate the coordinate systems
10. Scope: Who is the target group of this CWA?
    - everyone in BIM
    - construction companies

- software providers for BIM visualization
- planner engineers (architects, civil engineers, …)
- "Geo-data captures", surveyors, UXV operators
- software providers dealing with BIM, GIS, and "on site superlocal" machines/devices/systems

11. Proposers of the CWA - Who from the project could be the initiator and who the main contributors? Who else should be involved (project internal and external) and who has already agreed to take part in the CWA development?
    - Initiator: ZHAW
    - partners who are interested in the idea (additional poll necessary)
12. Possible elements of the CWA - How could the CWA look like (e.g. table of contents)? Which elements need to be included?

5.1.4. Common Ontology for Digital Twin

Overview

Title	Terms and Definitions in Building Digital Twins. Common ontology/semantic modelling		
ID	11	**Score (Workshop vote)**	2
Topic	Digital Twin	**already existing**	currently in preparation by an initiative of H2020 Projects
Standard Type	common language	**project specific**	no
feasibility	to be evaluated	**Priority on taking forward**	high
project knowledge	to be evaluated	**High benefit for project**	yes
Existing Standards	-	**Effort**	to be evaluated
Partner who would work in an activity.	HRS, SINTEF	**Chance of success**	to be evaluated

Description

A conference in Luxembourg in October 2021 showed that there are many different ideas for digital twins in many European projects and how to implement them in BIM and construction etc.

Suggested action

Participate in initiative

Further information

Activity was launched in a workshop on Thursday, 14 October 2021: "linking EU H2020 projects on digitization in the construction and maintenance industry: Linked Data and ontologies for BIM and Building Digital Twins", organized by Eduard Loscos, President, Building Digital Twin Association.

5.1.5. Guidelines / Methodology for use of XR with BIM

Overview

Title	Guidelines/ Methodology for use of XR with BIM		
ID	18	**Score (Workshop vote)**	1
Topic	AR/VR	**already existing**	-
Standard Type	common language	**project specific**	no
feasibility	to be evaluated	**Priority on taking forward**	high
project knowledge	yes	**High benefit for project**	yes
Existing Standards	Fraunhofer guideline	**Effort**	low
Partner who would work in an activity.	FhG-IAO	**Chance of success**	to be evaluated

Description

One partner is putting effort into constantly convincing people to work with virtual and augmented reality. Having guidelines or a methodology of how to use these technologies with BIM would help point out advantages of these technologies.

Suggested action

Support the partners in the establishment of a guideline which can be shared with BuildingSMART and the DIN committees relevant for BIM.

Further information

Example: define paths for drones and robots, especially for drones 3-dimensional paths need to be defined. This could be done with VR. To give guidelines or structure a methodology for the use of XR together with BIM would help.

5.1.6. Requirements for real-time data acquisition

Overview

Title	BIM - Requirements for real-time data acquisition on construction sides		
ID	21	**Score (Workshop vote)**	not part of workshop
Topic	Digital Twin	**already existing**	-
Standard Type	requirements	**project specific**	no
feasibility	to be evaluated	**Priority on taking forward**	high
project knowledge	yes	**High benefit for project**	high
Existing Standards	-	**Effort**	medium
Partner who would work in an activity.	Catenda	**Chance of success**	to be evaluated

Description

This standardization potential fits one of the core activities of the project - to have a digital twin of the building asset, which is updated on a short timescale.

Content

1. Legal requirements (Drone license, GDPR…)
    - Artificial Intelligence
    - AR/VR
    - Unmanned Aerial Vehicles (UAVs)
    - wearable technology
2. Environmental requirements (Weather conditions, Light conditions…)
    - Artificial Intelligence
    - AR/VR
    - Unmanned Aerial Vehicles (UAVs)
    - wearable technology

3. Hardware requirements
    - Artificial Intelligence
    - AR/VR
    - Unmanned Aerial Vehicles (UAVs)
    - wearable technology
4. Software requirements
    - Artificial Intelligence
    - AR/VR
    - Unmanned Aerial Vehicles (UAVs)
    - wearable technology

5.2. Next steps for standardization potential

Further information and assessments regarding the standardization ideas of the project partners will be collected in the upcoming months.

Furthermore, the sister projects of BIMprove will be informed about our planned standardization activities. This could be done in one of the joint meetings of the sister projects.

A coordination with the Technical Committee (TC) 442 will be done, where it is to be clarified whether one of the proposals mentioned before will be considered for a future EN standard. In this option, project partners would collaborate with the respective TC through a liaison.

Alternatively, one of the ideas within the project could lead to the creation of a CEN Workshop Agreement (CWA).

As a final step, a decision will be made regarding the topics which will be followed further on. This includes decisions on the kind of activities like for example approaching a certain consortium, handing in a NWIP at CEN or ISO or applying for a CEN-CENELEC workshop to create a CWA.

The standardization plan will be updated according to the developments at CEN/TC 442 BIM and internal BIMprove decisions.

6. Standardization Plan – update

The following section updates the given proposals/suggestions in D4.1, section STANDARDIZATION PLAN.

6.1. Formation of Liaisons with Committees

Like already pointed out in D4.1, on national (German) level DIN has established an observer status with the German committee NA 005-13 FBR "BIM - Building Information Modeling" in order to receive information about ongoing BIM activities on European (CEN/TC 442) and international (ISO/TC 59/SC 13) level.

In addition, a request for a Liaison with TC 442 BIM will be handed in, to be able to actively contribute to a proposed Digital Twin Working group.

Collaboration with ISO/TC 59/SC13 is not necessary at the moment and will be further evaluated in the course of the project.

6.2. Initiation of New Standards

There was no direct need identified to initiate a new full standard in one of the respective committees. The possible creation of the working group for digital twin in CEN/TC 442 will be monitored throughout the project.

If the WG will be approved, DIN will approach the CEN/TC and discuss about the envisaged standardization activities of BIMprove and eventually other Horizon projects. In case, ideas might be suitable for any WG of the TC, DIN will support the partners in handing in a NWIP, otherwise the creation of other documents will be considered.

6.3. Development of New Specifications or Agreements

6.3.1. CWA Process

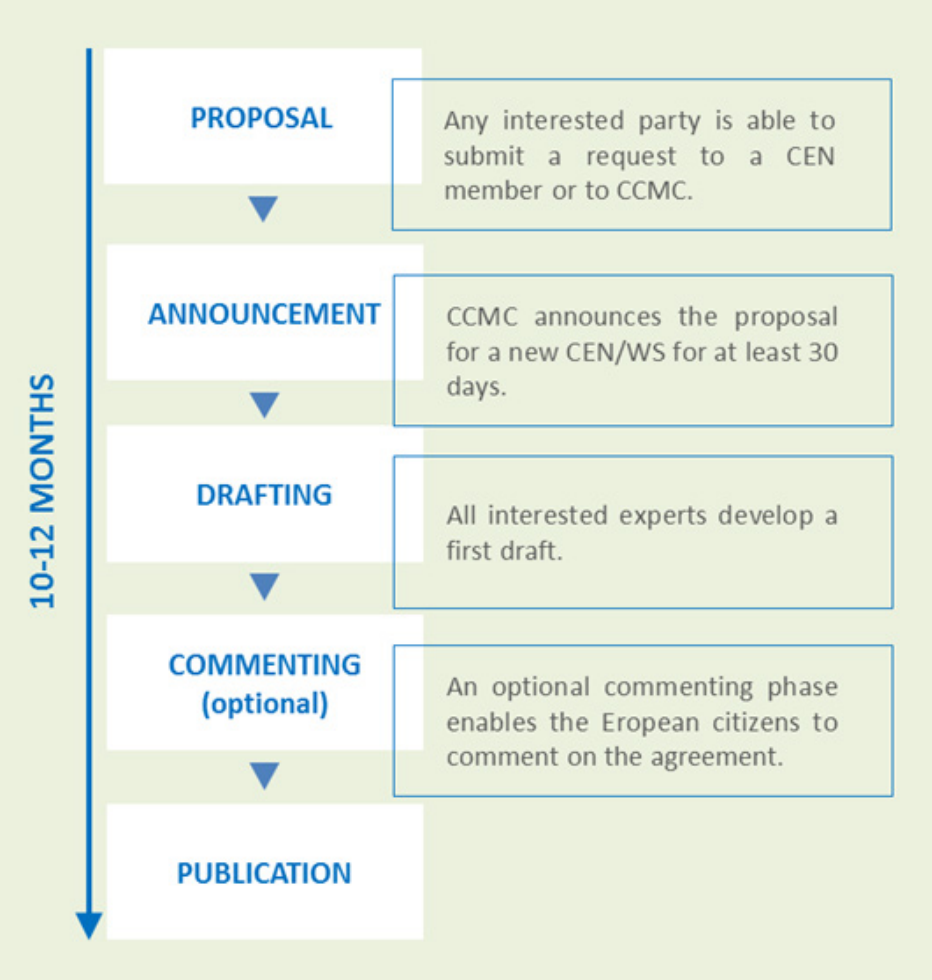

Figure 13 Development of a CWA (own work)[1]

Compared with the development of EN or ISO standards which take 2-3 years, the development of CEN Workshop Agreements (CWAs) follows streamlined processes which make them a perfect tool for innovations. The development time can be shortened to 10 to 12 months. Such an Agreement can be used as a first step to a full standard and can be handed in as a standards proposal (NWIP).

The CWA development starts with a request of an interested party to a national standardization body (NSB) as a member of CEN or to the CEN/CENELEC Management Centre (CCMC). The proposer needs to prepare a draft project plan, which describes the objective of the CEN workshop. This can be prepared with the help of an NSB. Subsequently, the CCMC announces the proposal for a new

[1] S. Nissen, C. Grunewald, HARMONI (768755) D4.1, 2018, https://www.aspire2050.eu/harmoni, file accessed 18.02.2022

CEN workshop for information and transparency reasons in order to inform the European experts and the public about the planned installation of a temporary CEN Workshop. Comments on the draft project plan can be made and shall be considered in the further development of the document.

During the kick-off meeting of the CEN Workshop, the proposed project plan is approved, the workshop formally launched and the participants who want to work on the CWA become registered. The workshop participants develop draft CWA(s) according to the project plan. The chairperson decides when an agreement is reached amongst the workshop participants on the final text of the CWA. Subsequently, the optional commenting phase begins. It is open to everyone for at least 60 days. The comments are considered by the workshop members. Afterwards the workshop secretariat submits the approved CWA to the CCMC. CWAs do not have the status of a European Standard and there is no obligation for the national standards bodies to adopt them as national standards. They are checked after 3 years and have a total lifetime of 6 years. The CWA can be understood as a pre-normative test-document. The European companies can work with it and if it is found to be positive, it will be likely used as basis for a new European EN standard. Since a CWA is created in a rather short time, it is an ideal tool for innovations and research projects.

6.3.2. Recommendations

The creation of a CEN Workshop Agreement (CWA) would be the ideal standardization activity after coordination with the respective technical committees on ISO and CEN level. If there are not enough resources for the creation of a standard, BIMprove could provide a provisional document which can be used as a basis for the later development of a European or worldwide standard. If suitable, DIN will take the necessary steps to apply for a CEN-CENELEC Workshop to create a CWA on the respective topic.

6.4. Collaboration with other Projects

We are currently in regular discussion with Austrian Standards International, who are partners in ASHVIN.

BIMprove already participated in a workshop about Linked Data and ontologies for BIM and Building Digital Twins on 14 October 2021, which was organized by Eduard Loscos, President, Building Digital Twin Association. Eduard Loscos is the proposed chair for the proposed digital twin WG of CEN/TC 442.

In connection with the planned standardization activities in BIMprove, we will ask for other interested parties in other projects. This will allow us to get a broader and more valuable consent in case a CWA will be developed. In addition, an early exchange on challenges where a mutual understanding

is needed, prevents the projects from double work. Projects with which we will exchange information about possible standardization topics are:

StandICT, CBIM, BIM2TWIN, ASHVIN, COGITO.

6.5. Improvement of existing standards

BIMprove will approach the respective consortia to hand in a suggestion for the improvement of the IFC standard. The suggestion will be most likely handed in via Catenda who is already a member of the consortium, responsible for IFC.

DIN will support BIMprove in compiling all necessary information and the creation of the suggestion to maximize the chance of its approval.

6.6. Contribution to Standards Under Development

BIMprove participated in a workshop in connection with ISO/IEC AWI 30172 of ISO/IEC JTC 1/SC 41 Internet of things and digital twin. A representative will be invited to present BIMprove in one of the next meetings of the German mirror committee to keep contact. BIMprove might be considered as one of the use cases which will be integrated in the future ISO/IEC standard for digital twin use cases.

In addition, we provide an update of the table which contains standards under development. Some of the standards have been released in the meantime and some new standardization projects have been launched.

The participants will be asked if they would like to contribute to a standard under development e.g. through a liaison (see Table 4). Using this path, BIMprove could actively provide their latest findings to the standardization community.

6.7. Standardization conclusions

The topics of BIM and digital twin are both very current and important. In standardization, basic standards for these topics are still very new, and standards based on them are still being developed. These are good conditions for European research projects such as BIMprove to contribute their findings and experience to the development of standards on these topics. An example of the topicality of the issues is an application of the CEN/TC 442 working group for 'digital twin', which is currently still ongoing. BIMprove is in a relatively good environment and will be able to contribute to existing and emerging standards. The solutions to be developed, the technical competence and the standardization needs of the project partners also contribute to this. In terms of timing, BIMprove's standardization efforts fit well with current developments and will continue to be synchronized with them.

7. Summary of Impact assessment, and next steps (updated exploitation plan)

We plan to present the impact assessment for the month 36 deliverables (D4.6 and D4.7), which are follow-ups of the present deliverable. We will work further with the KPIs from section 2 of the Grant agreement. Before that we will define what these KER-related KPIs should be and how we plan to measure them. In relation to that we will define to compare the numbers to be able to evaluate them. The original exploitation plan is available as deliverable D4.1. The table below (Table 3) details the progress plan with activities and milestones that was presented there. The month 18 to month 36 list of key activities has not been changed since the last deliverable.

Table 3 Updated exploitation plan

	2020				2021												2022												2023							
Month (1-12)	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Running month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Overall project dissemination, communication and exploitation strategies	x	x	x																																	
Deliverable 4.1			O																																	
Assesment of project footprint in terms of KPIs				x	x	x	x	x	x	x	x																									
Assesments of explotiable assets in period 1						x	x	x	x	x	x	x	x	x																						
Contributions to standardization						x	x	x	x	x	x	x	x	x																						
Overview of expected business models								x	x	x	x	x	x	x	x	x	x	x																		
Overview of sustainability measures								x	x	x	x	x	x	x	x	x	x	x																		
Deliverable 4.4																		O																		
Evaluation of the impact created by the project																			x	x	x	x	x	x	x	x	x	x	x	x	x					
Key Exploitable assets define																			x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Report contrubutions to SDOs																							x	x	x	x	x	x	x	x	x	x				
Market readiness assessment																							x	x	x	x	x	x	x	x	x	x	x	x	x	
Knowledge and protection managemnt plan																										x	x	x	x	x	x	x	x	x	x	
Deliverable 4.6																																				O
Exploitable results for further work																			x	x	x	x	x	x	x	x	x	x	x	x	x					
Exploitable results for further research																			x	x	x	x	x	x	x	x	x	x	x	x	x					
Exploitable results for further innovations																			x	x	x	x	x	x	x	x	x	x	x	x	x					
List of peer reviewed publications, source code repositories, open research data																							x	x	x	x	x	x	x	x	x	x	x	x	x	
List of educational material, standardization and open source contributions																							x	x	x	x	x	x	x	x	x	x	x	x		
Deliverable 4.7																																				O

Appendix 1 Results of D4.4 workshop - related to KERS, KPIs and market

Link to board: BIMprove D4.4 Workshop, Online Whiteboard for Visual Collaboration

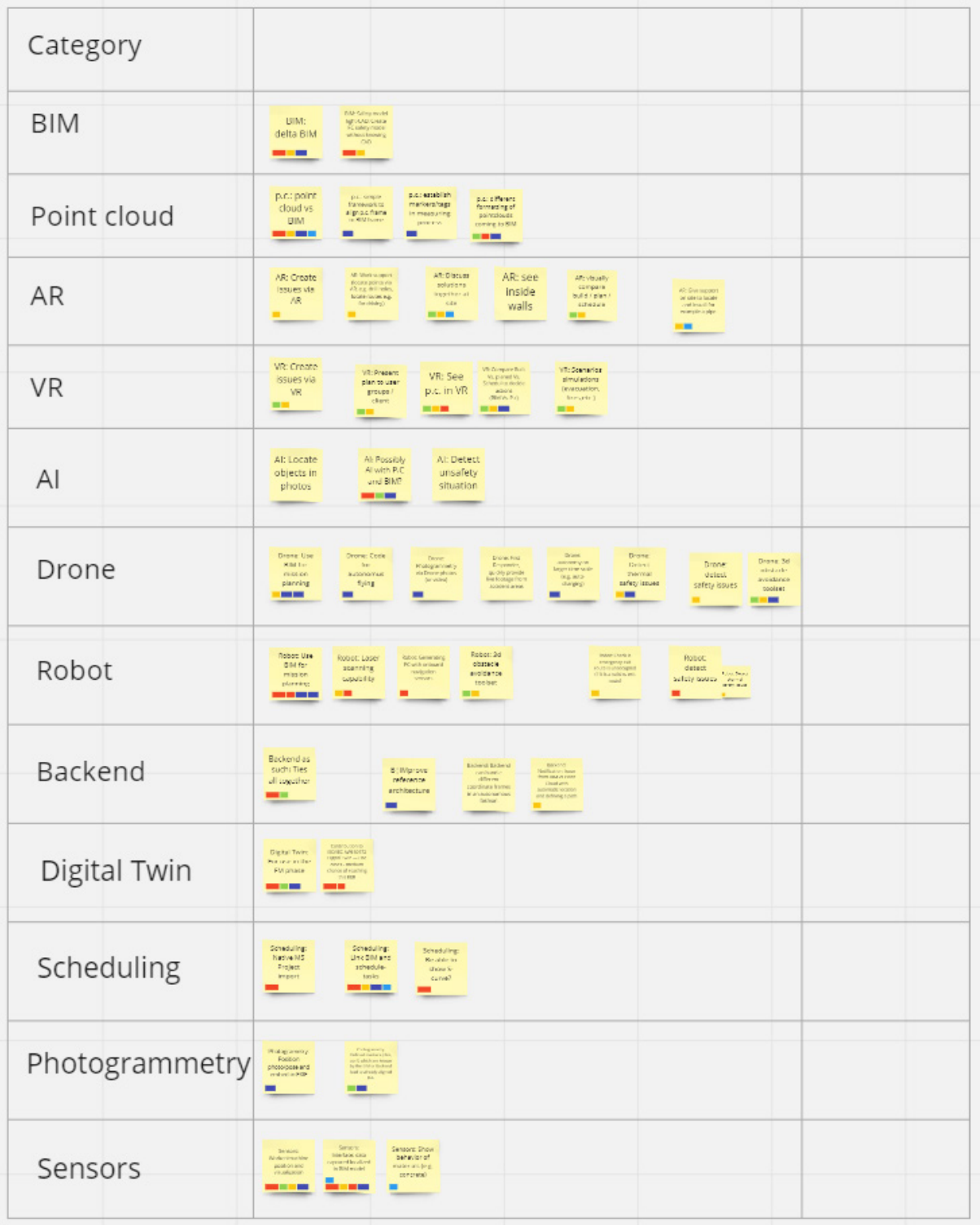

Figure 14 From the workshops (text on labels is not meant to be readable, from identification phase of most important KERs and who might want to exploit what).

Appendix 2 Standardization Workshop

Purpose

The aim of a standardization workshop is to find potential topics for new standards, which originate from the experience and the daily tasks and challenges of the project partners. As the Horizon calls address new and relevant topics in emerging fields, the chance is high that the project partners experience needs for additional standards or adjustment of existing standards in their project work.

Standards should be utilized as enablers, which lay a common ground on which new advancements in new technologies can build upon. In some cases, disruptive technologies may experience missing support in existing standards that leads to a need for the adjustment of those standards.

Workshop Concept

Welcome and round of introduction (very brief)

45 min

- What do you expect from today's meeting?
- What area are you working at?
- What are your current challenges?
- Whiteboard training (How to create sticky notes)

Presentation

20 min

- Short revision: Main facts about standardization
- Aim for today

Familiarize with the software tool "Conceptboard"

10 min

- Short training of the functions, used in the workshop
- Including small "ice breaker"

"Warming up": live polls

10 min

- Questions to learn about the standardization experience and needs of the participants
- Introduces the voting tool which is used in the later ranking session

Identification of challenges - what should be standardized?

20 min

- Main purpose of the workshop
- The participants place sticky notes with their ideas on the board
- For inspiration, standard types and project topics form a matrix where the notes can be placed

Break

15 min

Short Presentation of the potentials

30 min

- The participants explain each of their standardization needs or ideas
- The audience can form an opinion on the importance of the idea
- The explanations will be noted in the minutes for further analysis and support

Evaluation and Ranking

15 min

- Each of the participant has three votes to spread among the ideas

Further development of the top ideas

30 min

- The top ideas will be presented
- Groups with interested participants are formed
- Depending on the size of the workshop, the participants are either separated into breakout session or work together in the planetary
- Questions which belong to standards application are answered in a common discussions by the participants
- Notes are taken directly on the board

Summary and Feedback

10 min

- Short summary of the work done
- Next steps (analysis of results, action points)
- Feedback

Results

Most participants (5) worked with Conceptboard before.

The participants are familiar with standards and one participant already participates in standardization. Two Participants brought a standardization idea with them.

Most important benefits are interoperability, compatibility, quality and compliance with regulations.

In the creative phase of the workshop, 20 ideas were discussed, which are shown on the board in Appendix 3.

Appendix 3 Minutes of Standardization Workshop

Minutes of meeting

Standardization Workshop

WebEx, online

12. January 2022, 09:00-12:30 CET

INITIATED BY	**WRITTEN BY**		
DIN (Christian Grunewald, Yusuf Yilmaz)	Gundula Haber	**PRESENT**	**ABSENT**

Agenda

Time	**Topic**
09.00 – 09.10	Welcome and introduction
09.10 – 09.40	Round of introduction - What do you expect from today's meeting? - What area are you working at? Give a short overview of what you are working on and what your current challenges are.
09.40 – 10.05	Short revision: Main facts about standardization
10.05 – 10.10	Aim for today
10.10 – 10.30	Familiarize with the software tool "Conceptboard" https://app.conceptboard.com/board/h7m3-y0b3-t15m-6ier-g027
10.30 – 10.50	Identification of challenges - what should be standardized?
10.50 – 11:05	Break
11.05 – 11.35	Short Presentation of the potentials
11.35 – 12.00	Evaluation and Ranking
12.00 – 12.20	Further development of the top ideas
12.20 – 12.30	Summary

Minutes of meeting

Presentations can be found on Confluence

Mr. Grunewald welcomes the participants and opens the BIMprove – Standardization workshop. He first shows the agenda and gives an overview about today's workshop.

The participants introduce themselves and describe their expectations for today, their work area, and the challenges they currently face in their field.

Mr. Grunewald then gives a short presentation about the fundamentals of standardization explaining that standardization is the activity of establishing, with regards to actual or potential problems, provisions for common and repeatable use, aimed at the optimum degree of order in a given context. He then explains the characteristics of the different standardization deliverables: the standard, the consortium standard and especially the workshop agreement, which is a document agreed upon by the group of developers, which is designed to meet an immediate need and form the basis for future standardization activities. Mr. Grunewald also illustrates the different options of participating in the standardization process. Option 1 is the participation in ongoing standardization activities and option 2 is the development of a new workshop agreement. The aim for today is to collect ideas through the identification of standardization potentials/needs for the development of a new workshop agreement in the field of the BIMprove project.

Then the interactive part of the workshop using Conceptboard begins. https://app.conceptboard.com/board/h7m3-y0b3-t15m-6ier-g027

1. **Familiarize with Conceptboard**

To familiarize with the software Conceptboard Mr. Grunewald explains the basic functions and asks the participants to create sticky notes, with their name and organization. The participants then choose their avatar and write their name below it. Subsequently, they are asked to respond to five statements and questions regarding their level of experience with standardization and their idea for standardization in BIMprove.

1. I worked with Conceptboard or similar before, **most participants vote yes (5)**
2. How familiar are you with standardization?

6 participants use standards,

0 participants are interested but didn't call their standardization body yet,

1 Participant already participated in standardization,

0 participant is currently active in standardization

0 participants have never looked into any standard

1 participant has never heard of standards

3. I can imagine something under these types of standards: description of interfaces

(3 yes, 4 a little bit), requirements for products or services (4 yes, 4 a little bit), processes (3 yes, 5 a little bit), test methods (4 yes, 4 a little bit), terms and definitions (7 yes, 1 a little bit).

4. Today, I brought a standardization idea with me. YES: 2 votes NO: 4 votes

5. Which benefits of standards and standardization are important for BIMprove ?

Benefit	**very important**	**medium**	**not important**
Trust in new technology	3	5	
Trust in Cybersecurity	4	3	1
Interoperability	8		
Safety	3	4	1
Compatibility	7	1	
Compliance with regulations	6	2	
Market acceptance	3	4	
Quality	6	2	

2. Identify challenges - what should be standardized?

To identify challenges within the BIMprove project that could be solved by the development of a standard a matrix was prepared. The participants are asked to think about what can be standardized within BIMprove and write down their idea, keeping in mind the following 4 questions:

1. Is there a methodology, process or result within your BIMprove task, work package or subproject you would recommend to someone outside the project to work with?

2. Are you facing problems within the communication? Do your colleagues understand you when you are explaining your work? Would a Terminology standard help?

3. Do you discuss the quality of the results in your field with your colleagues? Could a standard set minimum requirements?

4. Is there anything within BIMprove you needed to agree on with other partners e.g. related to interoperability or compatibility? Could this become a standard outside of BIMprove?

The ideas for standardization within BIMprove are to be placed at the suitable spot in the matrix regarding the topic and type of standard.

Topics:

BIM

Digital Twin

GIS - Geographic Information Systems

Robotics

Drones/UAV - Unmanned aviation vehicles

AR/VR - Augmented/Virtual Reality

other topics

Types of standards:

Common interfaces

Trust, Common requirements: service or product, process

Common tests

Common language

Terminology

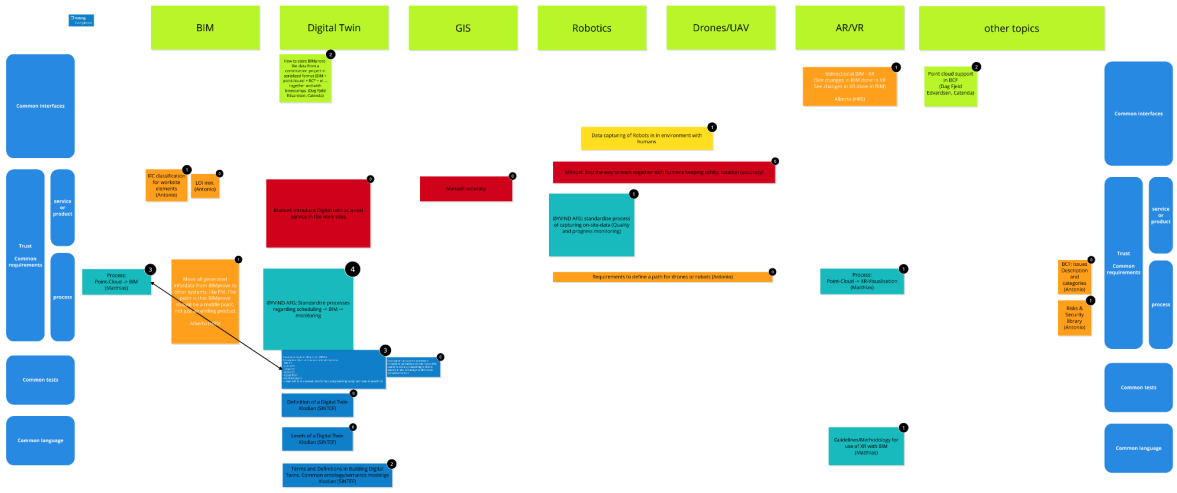

Image of the Matrix with the ideas (please zoom in to read the text or visit the board)

The participants explain their ideas in more detail.

ID	Field	Idea	Description
1	BIM	IFC classification for worksite elements	Classification only exists for building elements, however it would be good to also have classification for other things such as storage area and elements, security elements
2	BIM	LOI min	Level of Information - define which information is required
3	BIM	Process: Point-Cloud -> BIM	How can we go from a point cloud to a BIM object? How do you get from a point cloud scan to a BIM object and to a correct BIM model of

ID	Field	Idea	Description
			what has been scanned on the construction site? Christian: It is also possible to standardize the interface in case the actual idea is something that should be rather protected as IPR than standardized.
4	BIM	Move all generated info/data from BIMprove to other systems, like FM. The point is that BIMprove should be a middle point, not just an ending product.	Each construction project consists of 3 stages: design, construction and operation. How can we pack all the information united in BIMprove (models, documents, images, point cloud etc.) and move it from the construction stage to the next stage (operation, facility management) and how can people working on that next stage import all information to manage the building?
5	Digital Twin	How to store BIMprove like data from a construction project in serialised format (BIM + point cloud + BCF + etc together and with timestamps	defining interfaces to ensure compatibility When it comes to all the information gathered in BIMprove we will have a lot of data mostly in open formats but what is not defined is how the data is stored and can later be opened by other people.
6	Digital Twin	introduce Digital twin as a real service in the work sites	point of view: construction site There seems to be a lot of talk about creating a digital twin so the next step would be to try to introduce the digital twin as a real service in the work sites and try to find a way of bringing the digital twin into reality.
7	Digital Twin	standardize processes regarding scheduling -> BIM -> monitoring	Use BIMprove to take a deeper look into how to connect the plan and schedules with the objects in BIM. The next step should be progress monitoring of the executed work on the site. This is a point that occurs in a lot of projects but connecting the timeline to BIM in an efficient way is something that hasn't been solved yet.
8	Digital Twin	Coordinate Systems Description: there are many coordinate systems: - BIM CS - global CS - robot CS - drone CS - CS per floor	Surveyors use markers (crosshairs) as markers on site: it would be useful to add a QR-based tag to that to identify it later and assign to BIM-model QR-based markers This might fit Matthias' note about point cloud and data processing from captured data to the BIM.

ID	Field	Idea	Description
		- CS of surveyors -> clear definitions needed, transforms, during scanning: assign each scan to specific CS	There were many discussions about coordinate systems but they haven't come to an end yet. There are various coordinate systems in BIM; on the construction site, onboard coordinate systems for robots, each sensor for measuring positions has its own coordinate system and the issue we are facing is how to capture the data and bring it in line with the BIM models. On the other hand there is a lot of position information on the site itself; the surveyors have their markers but that is not really connected to the BIM. So if every marker the survey identifies would have its own QR code or just a number it would help to align these coordinate systems to each other. Standardization might be a tool to define coordinate systems, define QR-Codes, etc. to bring these systems together.
9	Digital Twin	Definition of a digital twin	standardize what is a digital twin
10	Digital Twin	Levels of a digital twin	standardize what are the different levels of development and adoption of a digital twin that can be implemented for different life cycle phases
11	Digital Twin	Terms and Definitions in Building Digital Twins. Common ontology/semantic modelling	A conference in Luxembourg in October showed that there are many different ideas for digital twins in many European projects and how to implement them in BIM and construction etc.
12	GIS	Accuracy	GIS is one of the great challenges for improving the accuracy of where the elements are located. It might be related to Rupert's note. In order to have a good digital twin it is mandatory to have a good geopositioning system for different elements.
13	Robotics / Drones	find the way to work together with humans keeping safety, location (accuracy)	Define rules for how the workers can act with drones and robots with the help of digital twins.
14	Robotics	standardize process of capturing on-site-data (Quality and progress monitoring)	BIMprove project will help to identify the process regarding the capture of on-site-data without interrupting the processes on site.

ID	Field	Idea	Description
15	Robotics / Drones	Requirements to define a path for drones or robots	define some rules, requirements or standards for persons who define the paths for the drones or robots
16	AR / VR	bidirectional BIM - XR (See changes in BIM done in XR See changes in XR done in BIM)	This point is about how to move all the information (graphic information, data interfaces) between digital twins and extended environments in both directions.
17	AR / VR	Process: Point-Cloud -> XR-Visualization	Alberto's idea is very important. Other issues we are facing are: Do we need to reduce point cloud data to have quick performance in XR? How do we do it? The process of getting scan point cloud data into AR/VR environments.
18	AR/VR	Guidelines/ Methodology for use of XR with BIM	One of the main issues faced at Fraunhofer: constantly trying to convince people to work with virtual and augmented reality. having guidelines or a methodology of how to use these technologies with BIM would help point out advantages of these technologies. Example: define paths for drones and robots, especially for drones 3-dimensional paths need to be defined. This could be done with VR To give guidelines or structure a methodology for the use of XR together with BIM would help.
19	other	Point cloud support in BCF	BCF is mostly used together with BIM but there is not really a support for it.
20	other	BCF: Issues Description and categories	important to define categories, so that issues of the same kind could be merged or summarized
21	other	Risks & Security library	A research project created a library with all the risks and security issues, which could happen in a building project (Klodian knows which project) The risks could be an inspiration for BIMprove.

3. Evaluation and Ranking

The participants are asked to think about which ideas are the most important ones for them and vote for their favorite ideas. Each participant has 3 votes.

The ranking shows that the following ideas are considered to be the most important ones:

1. **4 votes:** Standardize processes regarding scheduling -> BIM -> monitoring
2. **3 votes:** Process: Point cloud → BIM / Coordinate systems
3. **2 votes:** Point cloud support in BCF
4. **2 votes:** Terms and definitions in Building Digital Twins. Common ontology/semantic modelings
5. **2 votes:** How to store BIMprove-like data from a construction project in serialised format (BIM + point cloud + BCF + et ... together and with timestamps)

4. Develop your ideas further

The participants are now asked to choose their avatar and place it next to the one of theses most important ideas that they would like to participate in developing further. The participants have assigned themselves to the 3 ideas as follows:

1. Standardize processes regarding scheduling -> BIM -> monitoring
   →DAG + OYVIND + ALBERTO + ANTONIO
2. Process: Point cloud → BIM / Coordinate systems
   →MATTHIAS + MANUEL + ALBERTO + RUPRECHT + ANTONIO
3. Point cloud support in BCF (Dag)
   →RUPRECHT + DAG + MATTHIAS
4. Terms and definitions in Building Digital Twins. Common ontology/semantic modelings
   →ANTONIO + KLODIAN

Mr. Grunewald explains the next actions, which will be that the ideas considered as most important will be discussed further by small subgroups considering the following questions regarding the background of the idea. These questions have to be answered before filing an application for a new standardization activity/a new workshop agreement.

1. Which activity (work package, deliverable, solution) forms the basis for this proposal?
2. Which challenge should be tackled by developing a CWA?

3. What are the future benefits of the CWA(s)?
4. Why is this also important for other stakeholders?
5. How strongly is a common basis needed?
6. What is explicitly not part of the CWA(s)?
7. Market environment - What is already on the market and how does the envisaged CWA(s) differ from it?
8. Legal environment - Directives and relevant European legislation
9. Scope: What is the CWA about?
10. Scope: Who is the target group of this CWA?
11. Proposers of the CWA - Who from the project could be the initiator and who the main contributors? Who else should be involved (project internal and external) and who has already agreed to take part in the CWA development?
12. Possible elements of the CWA - How could the CWA look like (e.g. table of contents)? Which elements need to be included?

First, the participants focus on idea **No 2.** and answer the questions by placing sticky notes in the respective spot in the Conceptboard.

1. Which activity (work package, deliverable, solution) forms the basis for this proposal?
    - **Coordinate models, WP2 and WP 3, not focussed in a deliverable yet**
2. Which challenge should be tackled by developing a CWA?
    - **there are many coordinate systems: BIM CS, global CS, robot CS, drone CS, CS per floor, CS of surveyors -> clear definitions needed, transforms, during scanning: assign each scan to specific CS**
    - **calibration - you find 50 crosshairs per floor on a site - they need to be identified by i.e. a QR Code**
    - **global definition of crosshair identification**
    - **proper naming of different CS**
    - **proper definition of the coordinate systems (including units) I.e. a fixed point for a construction site**
    - **define if stick to site, stick to GPS coordinates**

- **4 values or 6 values?**
- **is z always up?**

3. What are the future benefits of the CWA(s)?
    - **Different measurements and data from different stakeholders at a building site are easy integratable**
4. Why is this also important for other stakeholders?
    - **data from different partners could be used**
    - **it is important to be able to merge the data**
    - **some software providers might fear to lose a lock-in**
5. How strongly is a common basis needed?
    - **7 votes for very high, 1 vote for medium**
6. What is explicitly not part of the CWA(s)?
    - **not about reinventing the existing standards**
7. Market environment - What is already on the market and how does the envisaged CWA(s) differ from it?
    - **recommendations from the BIM perspective (Norway, Dag knows), Norwegian municipalities**
8. Legal environment - Directives and relevant European legislation **(not answered today)**
9. Scope: What is the CWA about?
    - **defines how current CS are defined (or defines them itself) and defines how different systems could be transformed into each other**
    - **defines a common system for the definition of crosshairs to calibrate the coordinate systems**
10. Scope: Who is the target group of this CWA?
    - **everyone in BIM**
    - **construction companies**
    - **software providers for BIM visualisation**
    - **planner engineers (architects, civil engineers, …)**
    - **“Geo-data captures”, surveyors, UXV operators**

- **software providers dealing with BIM, GIS, and "on site superlocal" machines/devices/systems**

11. Proposers of the CWA - Who from the project could be the initiator and who the main contributors? Who else should be involved (project internal and external) and who has already agreed to take part in the CWA development?
    - **Initiator: Ruprecht**
    - **partners who are interested in the idea (additional poll necessary)**
12. Possible elements of the CWA - How could the CWA look like (e.g. table of contents)? Which elements need to be included?

Subsequently, the participants are asked to take a closer look at idea No 1 and answer the questions.

1. Which activity (work package, deliverable, solution) forms the basis for this proposal?
    - **WP2 and WP3**
    - **part of it already exists in a deliverable**
    - **located between high level planning and day to day planning**
    - **related to tasks, BIM objects, should e.g. include costs**
2. Which challenge should be tackled by developing a CWA?
    - **To make something that hopefully would fit for most construction projects today and relates to BIM**
    - **shouldn't be too complex**
    - **relates to information flow**
    - **processes regarding scheduling -> BIM -> monitoring**
    - **many different processes exists**
    - **lot of different practices**
3. What are the future benefits of the CWA(s)?
    - **time stamps on BIM data**
    - **transferability of schedule**
    - **interoperable tools**
    - **improved learning effect**

- **comparison of different sites, benchmarking**
- **i.e. anonymous benchmarking**

As the time for today's workshop has run out, the discussion of the other questions will be postponed to another meeting at a later date.

Mr. Grunewald thanks the participants for their contributions and the ideas they provided and asks for feedback on the workshop.

The participants give feedback and state that they are happy with the workshop and the outcome.

- good preparation, very structured
- good tool
- good discussions
- good starting point for developing a standard
- great ideas/topics
- helpful to get insight into standardization work

Mr. Grunewald thanks the participants again for the fruitful discussions and closes the workshop.

Appendix 4 Evaluation of results

Table contains the evaluation of the results with the most important indicators.

The standardization potentials which were mainly expressed in the workshop are presented in a clearly structured way in Table 4. The workshop score results in a vote during the workshop, where each partner was allowed to give three votes to different ideas. The best idea was voted with 4 votes. In the Table, it is indicated if a standard already exists and if a high benefit for BIMprove is suspected. The actions necessary to follow up the idea of standardisation are indicated and the priority on taking forward is shown. The indicators were collected by DIN in discussion with the project partners.

Table 4 Evaluation of results

ID	Title	Score (Work-shop vote)	standard already existing	High benefit for project	Suggested action	Priority on taking forward
7	standardise processes regarding scheduling -> BIM -> monitoring	4	yes / to be improved	yes	elaborate idea further to approach BuildingSMART with the suggestion for an update of the IFC standard	high
3	Process: Point-Cloud -> BIM	3	no	yes	elaborate idea further in view of a possible CWA	high
8	Coordinate Systems Description: there are many coordinate systems: • BIM CS • global CS • robot CS • drone CS • CS per floor • CS of surveyors -> clear definitions needed, transforms, during scanning: assign each scan to specific CS	3	no	yes	elaborate idea further in view of a possible CWA	high

21	Requirements for real-time data acquisition on construction sides	not in WS	no	yes	elaborate idea further in view of a possible CWA	high
11	Terms and Definitions in Building Digital Twins. Common ontology/semantic modelling	2	currently in preparation by an initiative of H2020 Projects	yes	participate in initiative	high
18	Guidelines/ Methodology for use of XR with BIM	1	-	yes	support the partners in the establishment of a guideline which can be shared with BuildingSMART and the DIN committees relevant for BIM	high
10	Levels of a digital twin	0	in preparation		create a liaison with CEN/TC 442, monitor development in digital twin standards	high
19	Point cloud support in BCF	2	extension		support partners to get in touch with BCF	medium
9	Definition of a digital twin	0	partly		Create a liaison with CEN/TC 442, monitor development in digital twin standards	medium
20	BCF: Issues Description and categories	0	extension		support partners to get in touch with BCF	medium
5	How to store BIMprove like data from a construction project in serialised format (BIM + point cloud + BCF + etc together and with timestamps	2	not clear			low

1	IFC classification for worksite elements	1	extension		support partners to get in touch with BuildingSMART	low
4	Move all generated info/data from BIMprove to other systems, like FM. The point is that BIMprove should be a middle point, not just an ending product.	1	no		establish contact with DIN building management, as this is actually being realized with the freshly refurbished DIN building	low
14	standardise process of capturing on-site-data (Quality and progress monitoring)	1	no			low
16	bidirectional BIM - XR (See changes in BIM done in XR See changes in XR done in BIM)	1	no			low
17	Process: Point-Cloud -> XR-Visualisation	1	not clear			low
21	Risks & Security library	1	-		encourage partners to make use of the risk definitions	low
2	LOI min	0	yes			low
6	introduce Digital twin as a real service in the work sites	0	-			low
12	Accuracy	0	yes			low
13	find the way to work together with humans keeping safety, location (accuracy)	0	no			low

15	Requirements to define a path for drones or robots	0	no			low

Appendix 5 List of standards under development

As already introduced in D4.1, the standards are labelled with stage codes indicating the progress of work. The stages are presented in Table 5 and Fig. 15. Depending on the liaison category, liaison organizations have the opportunity to comment on different drafts of standards under development in stages from 00 Preliminary to 40 Enquiry.

Table 5 Stage codes

Stage	ISO	CEN/CENELEC	Action	Chance for successful technical contribution
00.xx	PNWIP	PWIP	Liaison with WG	high
10.xx	NWIP	WIP	Liaison with WG	high
20.xx	WD	WD	Liaison with WG	high
30.xx	CD	WD	Convince national experts to provide comment or Liaison with WG	medium
40.xx	DIS	prEN	Public comment	low
50.xx	FDIS	FprEN	-	very low/ stored for next revision

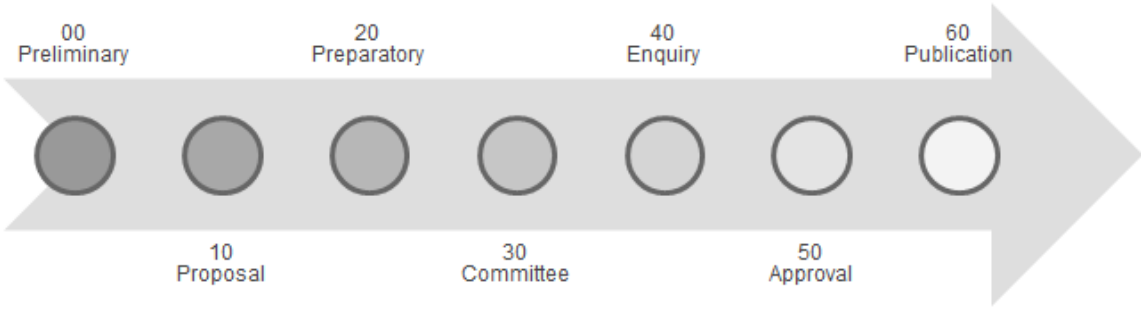

Figure 15 Stage codes (ISO_codes)

On European level DIN has access to active CEN and CENELEC Work Items via the CEN-CENELEC Projex database. European standards currently under development in CEN/TC 442 are summarized in Table 6. Further activities and ongoing work will be continuously monitored and provided to the project partners by DIN.

Table 6 European standards under development in CEN/TC 442

Document identifier	Title	Status (contribution possible if 00.xx – 40.xx or 90.92)	Remarks
WI 00442029	Building Information Modelling – Level of information need – Part 3: Data Schema	00.60	BIM, data exchange
WI 00442030	Building Information Modelling – Level of information need – Part 2: Guidance for application	00.60	BIM, data exchange
WI 00442032	Common Data Environments (CDE) for BIM projects – Open data exchange between platforms of different vendors via an open CDE API	00.60	BIM, data exchange
WI 00442037	Professions and competence related to the Building Information Management	00.60.0000	Information management
WI 00442038	Guidance on how to implement EN ISO 19650-1, -2, -3 and -5 in Europe	00.60.0000	BIM, Information management
WI 00442011	Digital information exchange - Definition of activities and transactions – use cases of built assets within a framework of steps of maturity and activities	00.98.0009	Data exchange
WI 00442039	Guidance, Framework and Implementation of Common Data Environment (CDE) workflow and solution, in accordance with EN ISO 19650	00.98.0009	Common Data Environment (CDE)
WI 00442027	BIM in infrastructure – standardization need and recommendations	10.99	BIM, strategy, infrastructure

WI 00442031	Framework and Implementation of Common Data Environment Solutions, in accordance with EN ISO 19650	10.99	BIM, information management
WI 00442027	BIM in infrastructure – standardization need and recommendations	10.99.0000	BIM infrastructure
WI 00442036	ISO 19650-6: Organization and digitization of information about buildings and civil engineering works, including building information modelling – Information management using building information modelling – Part 6: Health and Safety	10.99.0000	Information management
WI 00442035	Building information modelling (BIM) - Data templates for construction objects used in the life cycle of built assets - Data templates based on European standards and technical specifications	20.60.0979	Data templates
WI 00442014	Information container for data drop (ICDD)	30.97.0009	Information container for data drop (ICDD)
WI 00442018	Building information modelling - Information structure based on EN ISO 16739 1 to exchange data templates and data sheets for construction objects - Part 1: Data templates and configured construction objects	30.99.0979	BIM, Data exchange
prEN 17549-1	Building Information Modelling (BIM) – Information structure based on EN ISO 16739-1:2018 to exchange data templates and data sheets for construction objects –	30.99.0979	BIM, information management

	Part 1: Data templates and configured construction objects		
WI 00442033	Building information modelling – Exchange structure for product data templates and product data sheets based on ISO 16739-1 – Part 2: Requirements and configurable products	40.60	BIM, information management
prEN ISO 19650-4	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4 : Information exchange	40.60	BIM, information management
WI 00442028	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 4: Information exchange (ISO/DIS 19650-4:2021)	40.60.0000	Information management, Data exchange
WI 00442034	Building information models - Information delivery manual - Part 3: Data schema and code (ISO/DIS 29481-3:2021)	40.60.0000	BIM, Information management
WI 00442008	Building information modelling (BIM) - Data templates for construction objects used in the life cycle of any built asset - Data templates based on harmonised technical specifications under the Construction Products Regulation (CPR)	40.98.0009	Data exchange, Construction Products Regulation (CPR)

prEN 17473	Building information modelling (BIM) – Data templates for construction objects used in the life cycle of any built asset – Data templates based on harmonised technical specifications under the Construction Products Regulation (CPR)	40.98.0009	BIM, data structures, Industry Foundation Classes (IFC)
WI 00442019	Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information (ISO/DIS 12006-3:2021)	45.99.0979	Information management
WI 00442021	Building Information Modelling (BIM) - Semantic Modelling and Linking (SML)	45.99.0979	BIM, Semantic Modelling and Linking (SML)
prEN 17632	Semantic Modelling and Linking Standard (SMLS) for data integration in the built environment	45.99.0979	BIM, information management
prEN ISO 12006-3	Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information	45.99.0979	BIM, information management, Digital Twins, standardised static Digital Twins, buildingSMART Data Dictionary (bSDD)
WI 00442023 EN/ISO 29481-1	Guideline on how to understand and utilize EN/ISO 29481 Building information models – Information delivery manual – Part 1: Methodology and format and Part 2: Interaction framework	60.60	BIM, information management
WI 00442024 EN ISO19650-1 and -2	Guideline for the implementation of BIM Execution Plans (BEP) and Exchange Information Requirements (EIR) on European level based on EN ISO 19650-1 and -2	60.60	BIM, information management

FprEN 17412-1	Building Information Modelling – Level of Information Need – Part 1: Concepts and principles	60.60	BIM, data exchange
FprEN ISO 21597-2	Information container for data drop – Exchange specification – Part 2: Dynamic semantics	60.60	BIM, data exchange Digital Twins, Semantic enrichment, organization and integration of heterogeneous Digital Twin data, Multimodal multi-models and Information Container for Data Drop (ICDD)

On international level DIN has access to active ISO and IEC Work Items via the ISO Projects database. International standards currently under development in ISO/TC 59/SC13 are summarized in Table 7. Further activities and ongoing work will be continuously monitored and provided to the project partners by DIN.

Table 7 International standards under development in ISO/TC 59/SC13

Document identifier	Title	Status (contribution possible if 00.xx – 40.xx or 90.92)	Remarks
ISO/PWI 12006-2	Building construction — Organization of information about construction works — Part 2: Framework for classification	00.00	Information management
ISO/NP 16739-1	Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries — Part 1: Data schema	10.20	Industry Foundation Classes (IFC), Data exchange
ISO/AWI 19650-6	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using	20.00	Information management, BIM

	building information modelling — Part 6: Health and Safety		
ISO/AWI TR 16214	Geospatial and BIM review of vocabularies	20.00	GIS
ISO/DIS 12911 previously ISO/TS 12911:2012	Framework for building information modelling (BIM) guidance	40.20.	BIM, information management
ISO/DIS 19650-4	Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4: Information exchange	40.60	BIM, Information management
ISO/DIS 7817	Building information modelling — Level of information need — Concepts and principles	40.60	BIM, Information management
ISO/WD 29481-3	Building information modelling – Information delivery manual – Part 3: Data schema and classification	40.60	BIM, information management
ISO 16739-1:2018	Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries — Part 1: Data schema	90.92	Industry Foundation Classes (IFC), Data exchange
ISO/FDIS 12006-3 (previously ISO 12006-3:2007)	Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information	50.00	BIM, information management Digital Twins, standardised static Digital Twins, buildingSMART Data Dictionary (bSDD)
ISO/FDIS 22057	Enabling use of Environmental Product Declarations (EPD) at	50.20	BIM

	construction works level using building information modelling (BIM)		
ISO 21597-2:2020	Information container for linked document delivery – Exchange specification – Part 2: Link types	60.60	Digital Twins, Semantic enrichment, organization and integration of heterogeneous Digital Twin data, Multimodal multi-models and Information Container for Data Drop (ICDD)
ISO/TR 23262:2021	GIS (Geospatial) / BIM interoperability	60.60	BIM, data exchange, GIS
ISO 16757-2:2016	Data structures for electronic product catalogues for building services — Part 2: Geometry	90.20	Data structures