Ref. Ares(2021)997318 - 04/02/2021

DigiPLACE
TOWARDS A EUROPEAN DIGITAL PLATFORM FOR CONSTRUCTION

D5.2 – Architecture guidelines

This project has received funding from European Union's H2020 research and innovation programme under grant agreement N. 856943

Programmes	H2020
Call for Proposal	H2020-DT-2018-2 / DT-ICT-13-2019 / CNECT/A/12
Project Title	*Digital Platform for Construction in Europe*
Acronym	DigiPLACE
Project Grant Agreement	856943

D5.2 – Architecture guidelines

Work Package	WP5
Lead Partner	CSTB
Contributing Partner(s)	POLIMI, ECTP, LIST, VTT, TNO, TECNALIA, BBRI, CPE, INDRA, bSI, UL, ENCORD, BAM, MIT
Dissemination Level	Public
Type	Report
Due date	31/01/2021
Date	29/01/2021
Version	1.0 Final

DOCUMENT HISTORY

Version	Date	Comments	Main Authors
0.1	09/11/2020	Template and outline	N. Naville, M. Bourdeau (CSTB)
0.2	11/01/2021	Partners inputs and draft	N. Naville, N. Pastorelly (CSTB), S. Kubicki, C. Boje (LIST), B. Ingelaere (BBRI), E. Schulze (CPE), C. Mirarchi, A. Pavan (POLIMI), W. Van Woudengerg (BAM), J.A. Chica Paez (Tecnalia), B. Luitent, C. Montalvo Corral (TNO), C. Castaing (EFCA), T. Beach (Cardiff University), R. P. Hevia Aranguren (INDRA)
0.3	27/01/2020	Review comments	S. Kazi (VTT), L. Van Berlo (bSI), T. Beach (Cardiff University), S. Angotti (MEEM), W. Van Woudenberg (BAM)
1	29/01/2020	Final version	N. Naville, N. Pastorelly (CSTB), C. Mirarchi (POLIMi)

Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

DigiPLACE action has received funding from the European Union under grant agreement number 856943.

EXECUTIVE SUMMARY

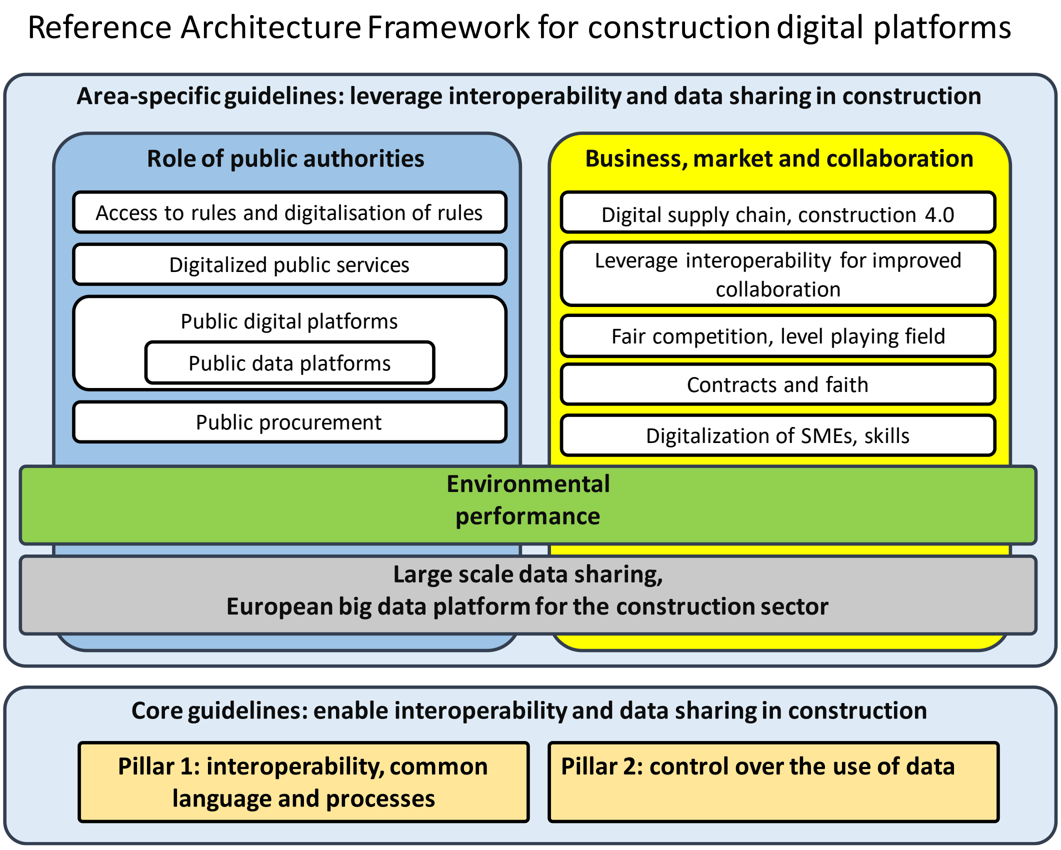
This deliverable provides a set of architecture guidelines, aiming to define a Reference Architecture Framework for interoperable digital construction platforms in Europe.

Considering the complexity of the digitalisation of the construction sector, the first objective of this framework is to **replace existing references and initiatives into a comprehensive and structured vision**, in order to highlight their interconnections, and to improve the **common understanding of the ongoing evolutions**. Involved partners share the will to educate themselves and others on the **disrupting potential of digital platforms for the sector**: what platforms are, how they technically operate and enable new business models.

Beyond this, a second objective is to identify **the gaps in this current landscape**, and the actions to be carried out to fill them, in order to facilitate and **orchestrate the development of platforms based on a common vision**, and considering in particular the will to **create a level playing field for both European construction stakeholders and digital services providers**.

The role of the different standardisation works in addressing the challenges of digitalisation is highlighted, and a **mapping of the main references** is provided. Further proposed guidelines aim to **bridge the gap between standards and implementation**, by describing how public or private stakeholders can implement these standards to support identified objectives.

The figure below synthetizes the structure of the framework.



Main guidelines can be summarized as follows:

CORE GUIDELINES

Pillar 1: interoperability, common language and processes

Guidelines are focused primarily on the use of open standards. **Semantic interoperability** stands out as a cornerstone for the development of interoperable digital platforms. Proper implementation of EN ISO 23386 (properties and data dictionaries) and 23387 (product data templates) is key in the path towards **interoperable product data**. A need appears for the development of a European data dictionary, or network of dictionaries, in a standardised approach and with an appropriate governance.

Room for convergence and harmonization is observed in the field of **Asset lifecycle information management**, supported by the emerging **building digital twin methodology**. Ongoing works towards a Semantic Modelling and Linking standard are presented as a means to improve data interoperability along the lifecycle, relying on a network of ontologies around a shared core structure. Further discussions appear necessary on the way to implement this vision, building on existing practices and initiatives.

Information management processes are of utmost importance for **digitally enabled collaboration**, with the **recently published ISO 19650** constituting a major advance.

Pillar 2: control over the use of data

Enabling collaboration and data sharing also supposes to ensure a control over the use of data. The proposed guidelines relate to **data security, data ownership** (for both personal data and business data), **data sovereignty**, **data qualification and trust, and data accessibility and sustainability**. A link is proposed with the ongoing GAIA-X initiative, which addresses many of the above, although not directly targeting the construction sector as a primary application.

GUIDELINES FOR THE IDENTIFIED AREAS OF APPLICATION

Environmental performance

Guidelines cover several topics and use cases identified in D5.1: **integration of existing environmental reporting frameworks** such as the LEVELs framework, **Lice Cycle Assessment and energy performance calculations**, **circular economy and digital deconstruction**. Ongoing ISO works on Environmental Product Declaration for BIM are presented as a move to **bridge the knowledge gap between the worlds BIM and Environmental data**, paving the way for increased benefits from the use of digital tools to support environmental performance.

Large scale data sharing, European Big data platform for the construction sector

Several of the core guidelines of this framework are necessary conditions to enable big data and artificial intelligence approaches (e.g. access to the data, use of open standards, semantic interoperability). Scenarios for large scale data sharing in the construction sector are analysed, for both public and private data.

Business, market and collaboration

The actual development of digitally enabled collaboration based on the above standards raises implementation issues. Guidelines are proposed to address them, especially highlighting the need to simplify the definition of exchange requirements, and more generally the setup of common data environments, based for example on pre-defined templates and shared use cases classifications.

Perspectives for the digitalisation of the supply chain are analysed. They are supported among others by the development of product libraries and catalogues based on the core guidelines of the framework, and their integration into BIM processes. Other guidelines relate to the need of integration with ERP and CRM tools, the contractual aspects of digitalisation, and the issue of skills.

Public authorities and their role in the development of construction digital platforms

The multiple involvement of public authorities in the development of construction digital platforms is highlighted.

Improving the access to construction rules, and progressively harmonizing the way they are formulated, will be of important value for the construction sector, enabling e.g. machine readability and the development of compliance checking tools.

Benefits are expected from the digitalisation of processes related to public authorities, such as building permitting, for which guidelines are provided.

Finally, a special focus is given to the possible perimeter and architecture of public digital platforms. The creation of **publicly supported open platforms for BIM and other digital services** is analysed, with several identified benefits, among which the promotion of **a level playing field**: guarantee market access for new entrants independently from proprietary platforms, foster competition, avoid market capture by some players, ensure a fair distribution of value across the value chain, reinforce the ecosystem of European digital AEC services, or ensure the respect of European principles in terms of data security, data sovereignty or data ownership.

Public digital platforms could also integrate other services, including access to digitalized public services (e.g. building permit), access to construction rules and standards, access to public data, the above-mentioned European big data platform, educational content ant tools, sharing of best practices and innovation, connection with public procurement platforms, or with other public platforms (e.g. LEVELs).

A new European platform could provide common services (e.g. access to intentional standards, sharing of digitalisation best practices, big data platform), connected to a network of national platforms for the services that need to remain at national level (e.g. digitalised building permit, access to national rules).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 Introduction

1.1 Introducing DigiPLACE Reference Architecture Framework

1.1.1 Scope

The scope of this Reference Architecture Framework is to provide *a comprehensive set of common guidelines for building and deploying **interoperable digital platforms for the construction sector** across Europe.*

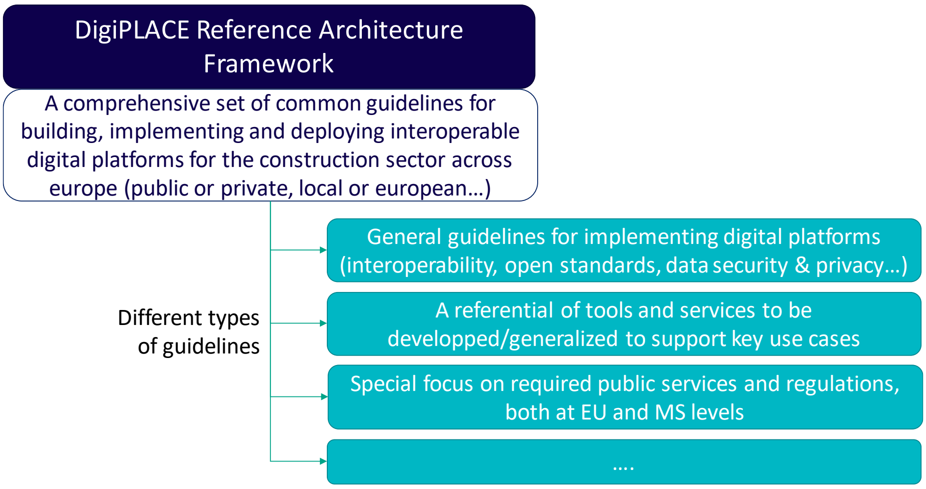


Figure 1: scope of DigiPLACE Reference Architecture Framework

Digital platforms do already emerge in the construction sector, as highlighted by the analysis of the current level of digitalization performed in WP3. They often rely on proprietary approaches, and are provided primarily by software vendors, who are key players of the digital transformation. On the other hand, public authorities have an important role to play in this transformation. Furthermore, many subjects call for harmonization and mutualization at EU level, in a **single market** perspective.

The present framework applies to both private and public initiatives. It identifies the common guidelines they should follow, and the role each one can play to create an integrated digital environment supporting the underlying objectives.

1.1.2 Purpose

Numerous initiatives already exist to support the digitalization of the sector and improve interoperability and collaboration: standardisation works, associations, public platforms, other public supports. Others specifically address some of the identified objectives (e.g. the LEVELs framework for environmental reporting). Taken together, these initiatives cover many of the issues at stake.

Considering the complexity of the subject, the first objective is to replace these existing references into a comprehensive and structured vision, in order to highlight their interconnections, and to improve the **common understanding** of the ongoing evolutions. Involved partners share the will to **educate**

themselves and others on the disrupting potential of digital platforms for the sector: what platforms are, how they technically operate and enable new business models…

Beyond this, the objective is also to identify the gaps in this current landscape, and the actions to be carried out to fill them, in order to facilitate and **orchestrate the development of platforms based on a common vision**, and considering in particular the will to create a **level playing field** for both construction stakeholders and digital services providers, with an adapted **governance.**

1.1.3 Articulation with other DigiPLACE outputs

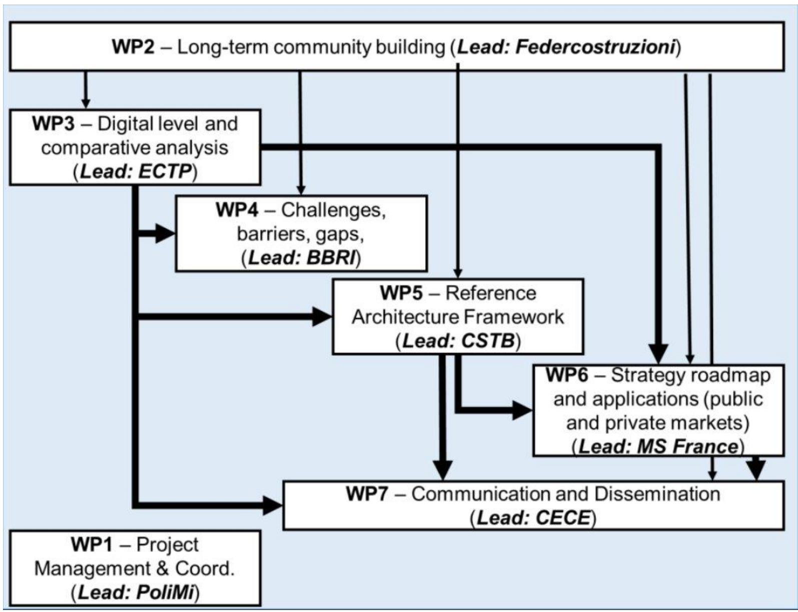


Figure 2: DigiPLACE work structure

This Reference Architecture Framework constitutes a central output of the DigiPLACE project. Nevertheless, it should be considered together with the other outputs of the project. As illustrated by Figure 3, these outputs are complementary as they provide:

- A shared prospective vision of the digital transformation of the construction sector, considering underlying objectives, and based on the identification of key use cases (D5.1 – platform specifications)
- The required architecture to support this vision (the present D5.2 - architecture guidelines)
- A strategy roadmap, aimed at progressively implementing this vision, starting from the current situation (D6.3 - strategy roadmap)

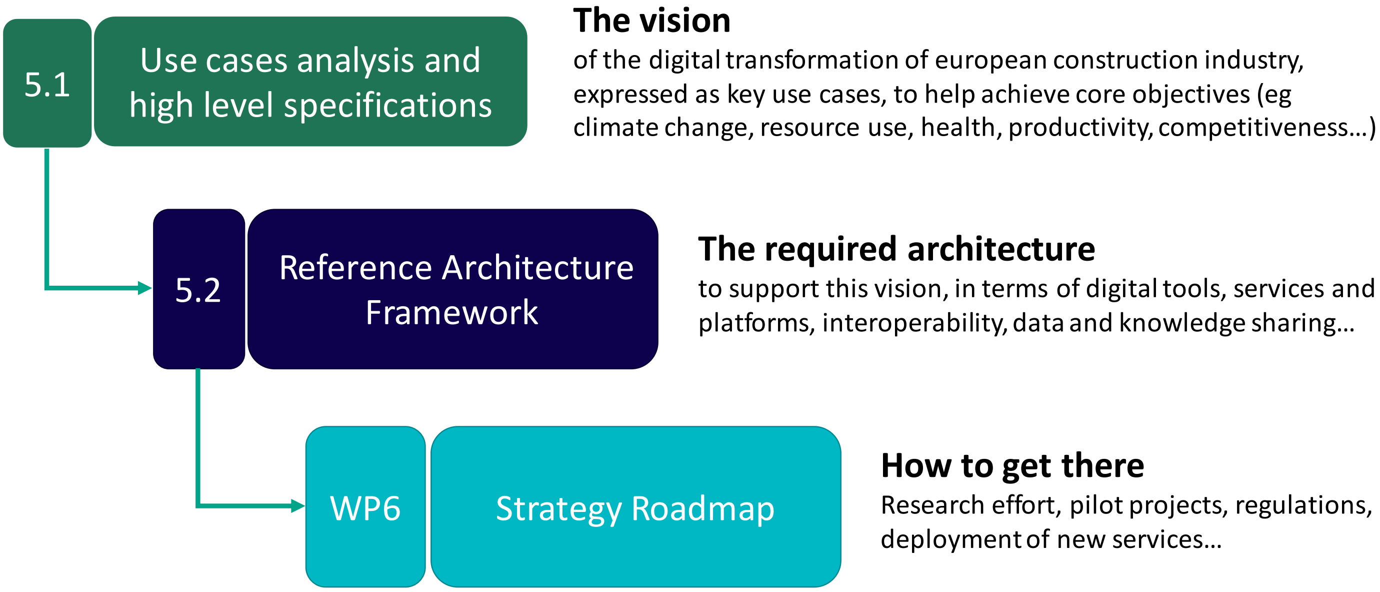


Figure 3: articulation between DigiPLACE main outputs

1.2 A framework supporting a shared prospective vision

1.2.1 Underlying objectives

Chapter 1 of D5.1 “platform specifications” has synthetized the underlying objectives of the project, based on the strategic objectives stemming from different sources: European Commission, member states, and general market analysis as provided by previous works of the project and by external studies.

Without repeating here this comprehensive review, it is important to remind that the present Architecture Framework is designed to support these underlying objectives. Below are reminded the expected impacts of the DigiPLACE project as defined in the Call, and endorsed by the project partners:

1. Increase **productivity and sustainability** of European Construction Industry
2. Facilitate the diffusion of a **common language for better interoperability** in the construction sector
3. Pave the way for the development of **smart cities** and **smart infrastructures technologies**
4. Strengthen the role of **EU in Global Construction Ecosystem**
5. Accelerate an efficient **collaboration between public authorities and industry**
6. Validate in usability, **risk, security assessment and sustainability**
7. Maintain and extend an active **eco-system** of relevant stakeholders, **including start-ups and SMEs**
8. Promote the diffusion of **knowledge** and facilitate the introduction of **digital practices**
9. Contribute from European key players to actively engage with the platform building Process
10. Efficiently share **information** across the programme stakeholders for horizontal issues of common Interests

11. Facilitate the **Digital Transformation of the Construction sector**

Sustainability appears as a major underlying objective, and a special attention has been given to aligning with the ambitions of the EU Green Deal and the EU renovation wave, and more generally supporting the environmental transition of the construction sector. Chapter 5 below of this document is the result of dedicated discussions throughout the project.

1.2.2 Key use cases

Furthermore, the list of key use cases identified in D5.1 "platform specifications" (section 2.7) intends to synthetize in a concrete way the expectations associated with the development of digital platforms. This framework has been designed in order to cover all the identified topics and enable these key use cases. The four application areas of the framework (chapters 5, 6, 7 and 8) match the areas emerging from this identification of key use cases.

1.3 Methodology

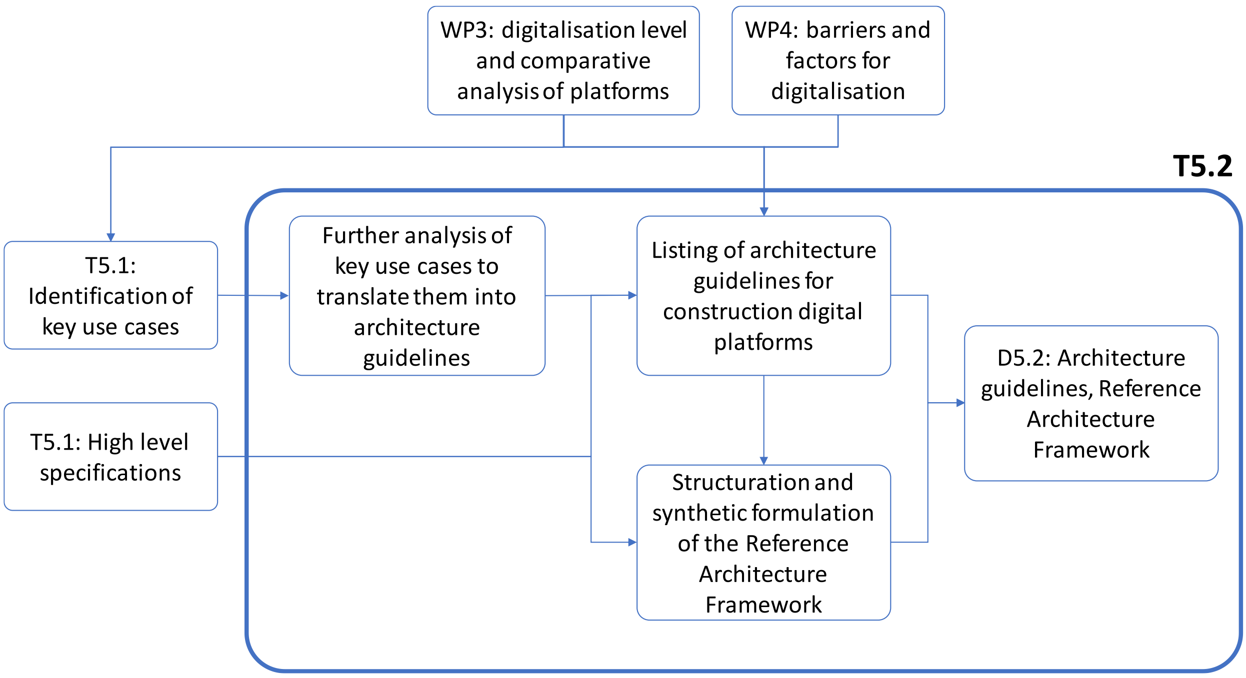


Figure 4: methodology used to carry out task 5.2 of the project

Figure 4 illustrates the methodology used to carry out task 5.2 of the project. A further analysis of key use cases was performed by 5 parallel working groups, in order to identify related requirements. A consolidated list of architecture guidelines was then obtained by adding those deriving from the results of WP3 and WP4. Finally, the work focused on gathering these architecture guidelines into a structured framework, as presented in this document.

1.4 Structure of the deliverable

After this introduction (chapter 1), chapter 2 provides the synthesis and overall structure of the framework, described through schemas. It can be used by the reader as a "map" of the subsequent chapters which detail the guidelines.

As detailed in chapter 2, the framework is comprised of:

- Core guidelines (chapters 3 and 4)
- Further guidelines regrouped in four areas of application (chapters 5, 6, 7 and 8)

2 Reference Architecture Framework for construction digital platforms in Europe: synthesis

2.1 Structure of the Reference Architecture Framework

Figure 5 synthetizes the overall structure of the Reference Architecture Framework. It is comprised of:

- Core guidelines, divided into two pillars:
    - Pillar 1: interoperability, common language and processes
    - Pillar 2: control over the use of data
- Further guidelines regrouped into four areas of application:
    - Environmental performance
    - Large scale data sharing, European big data platform for the construction sector
    - Business, market and collaboration
    - Public authorities and their role in the development of construction digital platforms

Figure 6 provides a zoom on the structure of the core guidelines. These apply to all digital platforms and all four areas of application.

The four areas are not independent from each other, and there is some overlap between them. As illustrated in Figure 5, environmental performance and large-scale data sharing can be considered as transversal to the two other vertical areas.

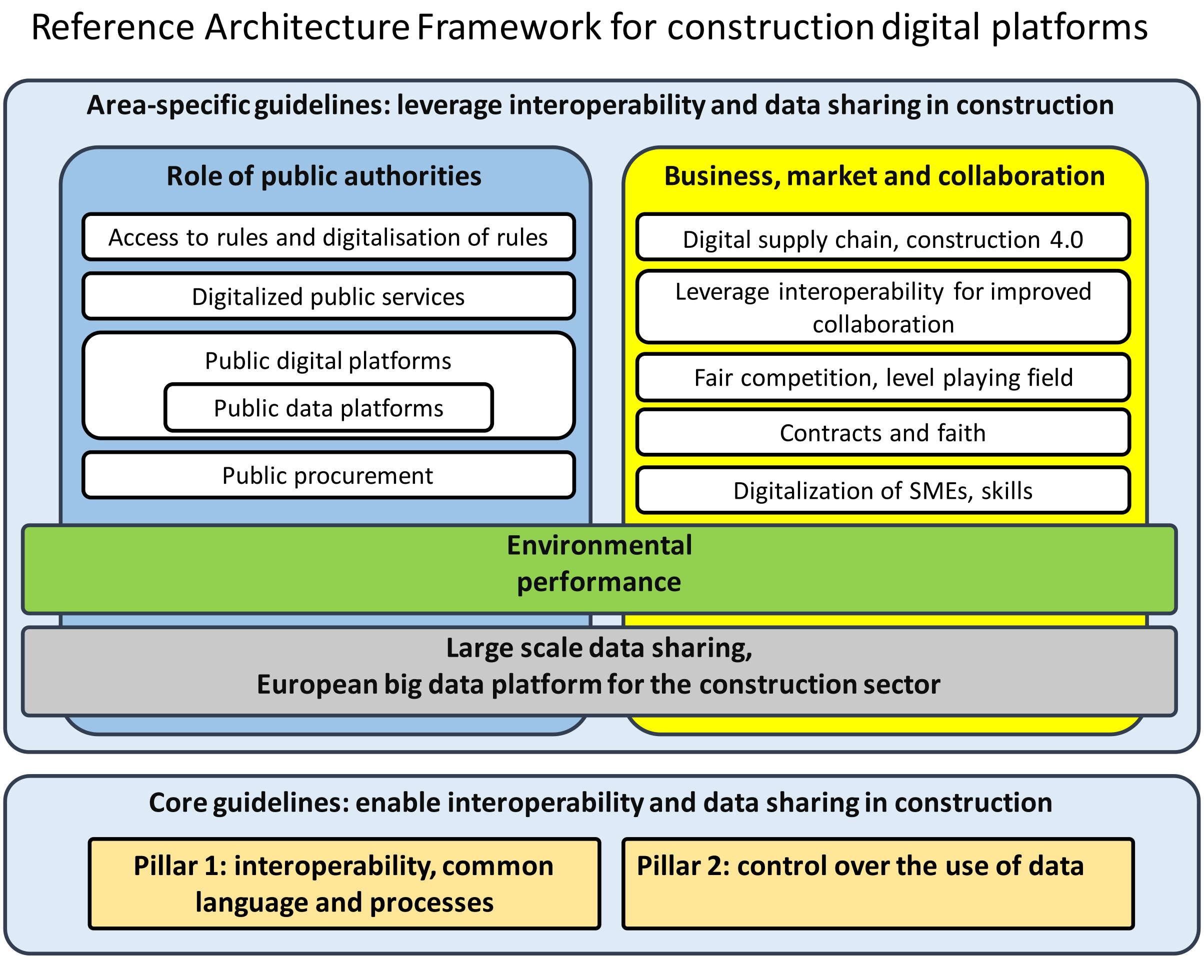


Figure 5: Structure of the Reference Architecture Framework

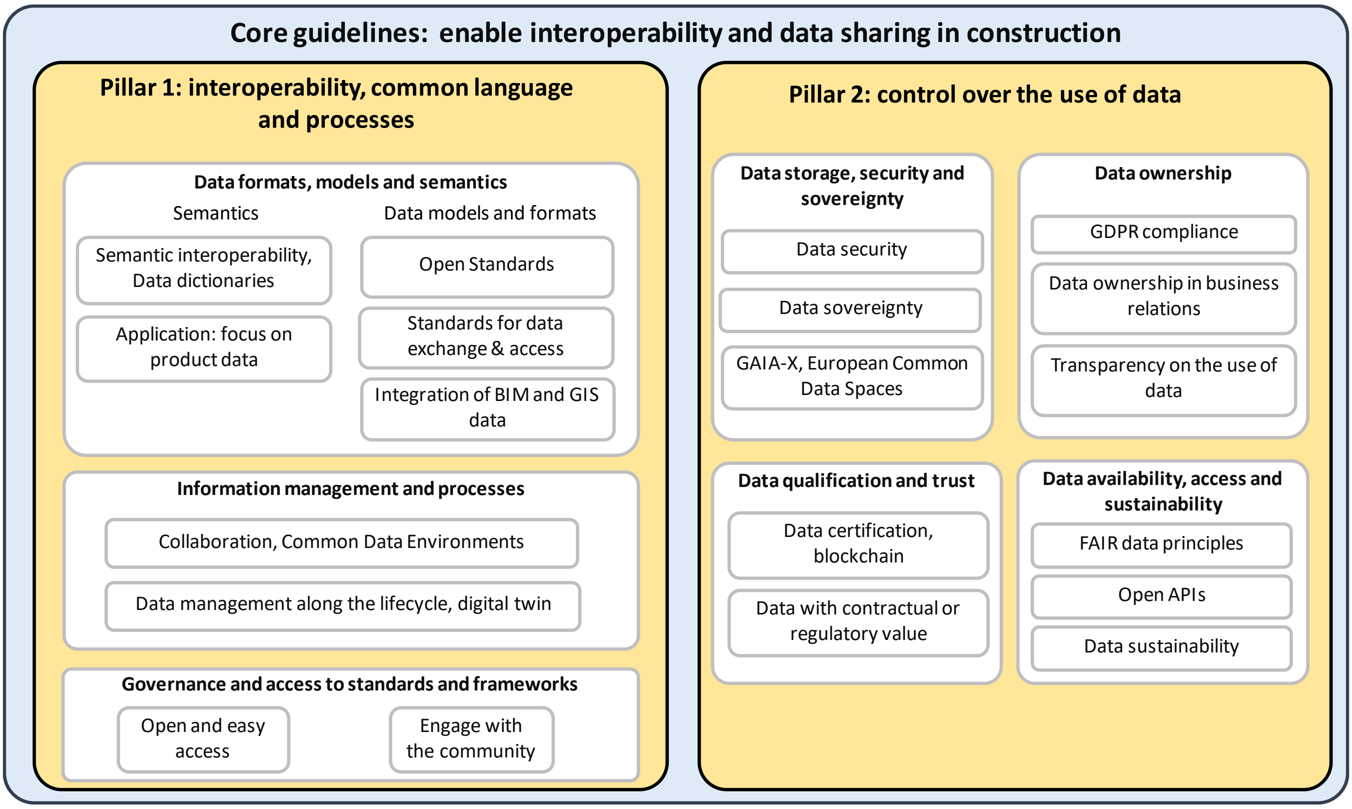


Figure 6: zoom on the core guidelines of the Reference Architecture Framework

2.2 Public vs private platforms, regulations, standards: positioning of the Reference Architecture Framework

2.2.1 Role of public authorities

As already stated in the introduction, the scope of this framework includes both private platforms and public initiatives. It identifies the common guidelines they should follow, and the role each one can play in creating an integrated digital environment.

The role of public authorities is developed in chapter 7.6 below of this document. They are involved in multiple ways:

- They set up the **regulatory framework** for both construction and digital services
- They manage the related **public services**, which can be digitalised
- As part of their **policies**, they support measures to improve e.g. the performance of the building stock and the security and health of inhabitants, for which digitalisation can be a key enabler
- They own **public data** that should be made available to construction stakeholders
- They build, own and manage **public assets,** relying on **public procurement,** which can be an important driver for digitalisation. In addition, data relating to public assets is often strategical, with cyber-security issues (e.g. railway networks, airports…)

- In relation with all previous points, they can set up **public digital platforms (or support public/private initiatives),** either to provide new services, or as part of the digitalisation of existing ones. A special focus is given to the possible perimeter and architecture of such platforms (section 8.3 below).

Figure 7 illustrates this multiple involvement of public authorities in the development of digital platforms, and highlights several important points that need to be considered:

- Ensure the coordination and complementarity between public and private digital services and infrastructures
- For the different aspects of public initiatives, ensure the coordination and complementarity between EU and member state level

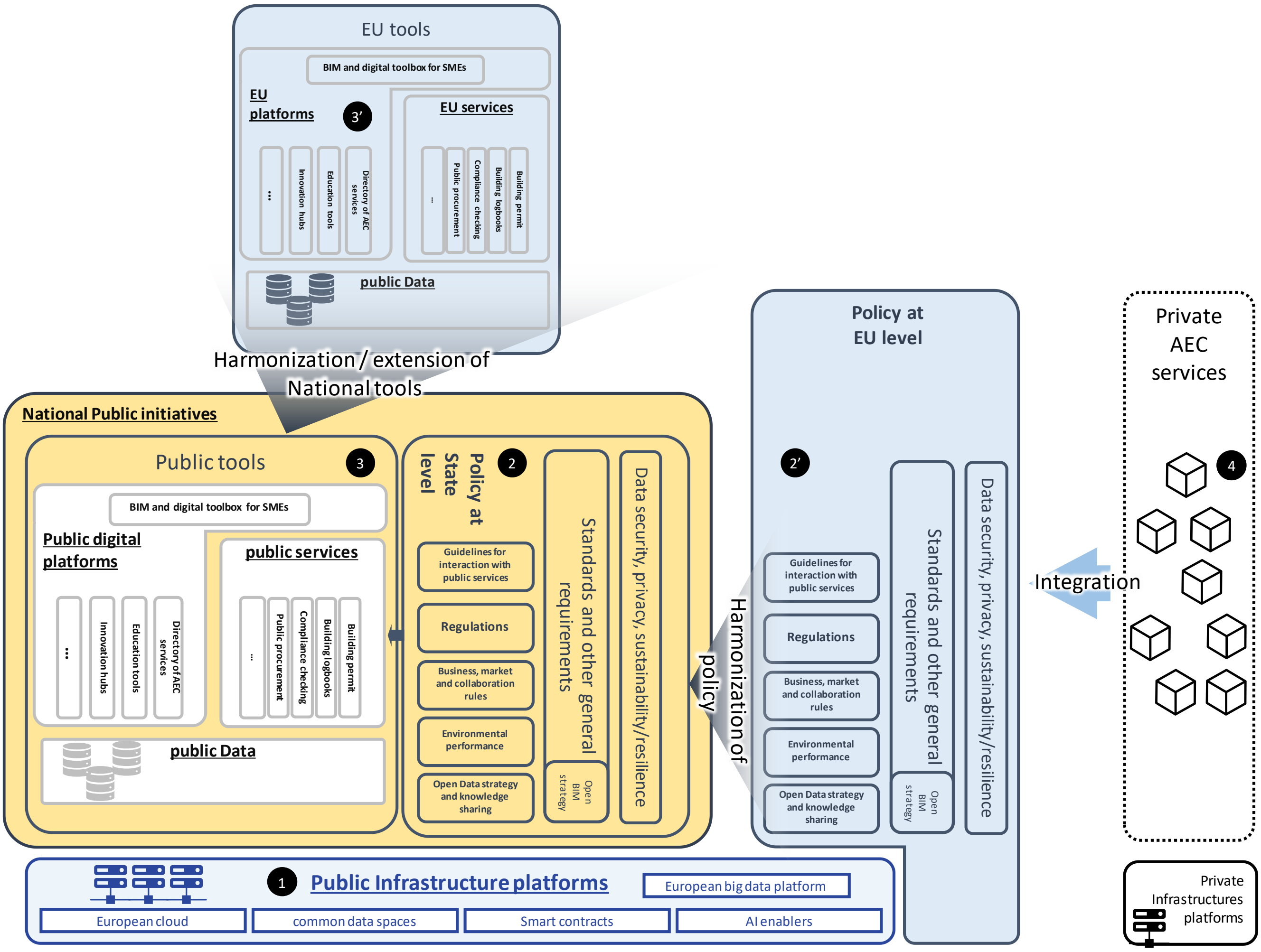


Figure 7: Public authorities, private platforms and the reference architecture framework

2.2.2 Regulations

The present framework is not intended to provide a comprehensive list of existing regulations applying to the construction industry, and even less to replace these regulations. It is consistent with the current regulatory context, while considering its main ongoing evolutions.

As it represents a **prospective vision,** it also includes guidelines about possible future evolutions of this regulatory framework, e.g. to improve the potential of digitalisation by harmonizing the concepts used in construction regulations, to tend towards e.g. improved understanding of the different National frameworks, or machine readability of the rules. The digitalisation of regulations is a key success factor for the digitalisation of construction, in terms of digital continuity and real gain of productivity.

The importance of considering construction regulations when defining the framework has been emphasized during the project. The concepts and rules they define determine in large part the way information should be structured. Thus, they constitute the base reference for designing digital tools and processes.

The relevant regulations are referred to when addressing the different topics of the framework, within the subsequent sections of this document.

Several categories of regulations are referred to:

- Regulations applying to construction, which comprise product and equipment scale, building-scale or urban-scale regulations: Construction Product Regulation, Low Volt Directive, Machinery Directive, REACH, Electromagnetic Compatibility Directive, EPBD Directive, urban planning rules...
- Regulations related to data and digital services: GDPR, INSPIRE directive… The projects of Digital Services act and Digital Market act[1] will add to this regulatory framework. The analysis of their provisions concluded that there is no direct interaction with the scope of the present framework
- Other general regulations with implications for the construction sector, such as the EU directive on public procurement

[1] https://ec.europa.eu/digital-single-market/en/digital-services-act-package

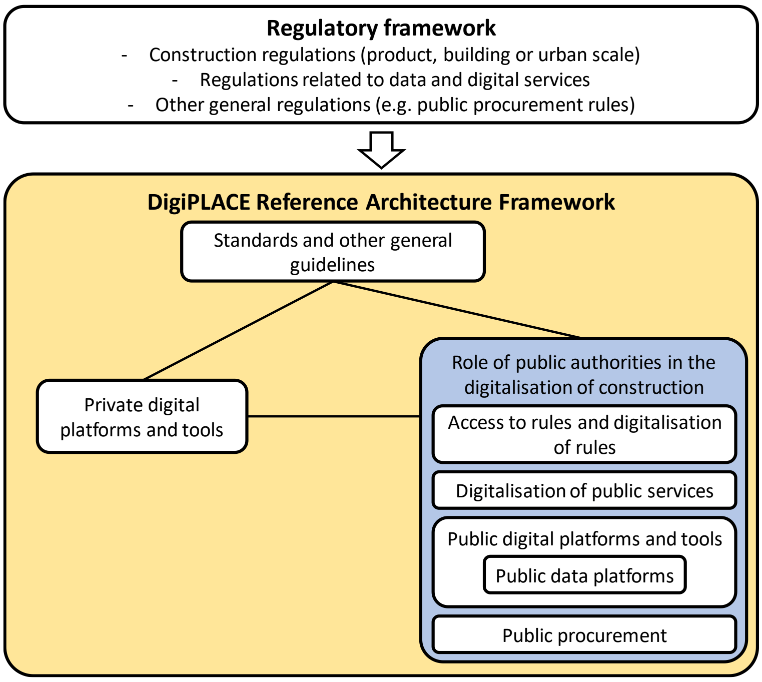


Figure 8: Regulatory framework, public authorities and the Reference Architecture Framework

Hence, as summarized by Figure 8, regulations appear in two different ways in relation with the present framework:

- First, the regulatory framework constitutes a **base external reference**, that **determines in large part the structuration of information**, and the design of tools and processes
- They also appear when analysing the role of public authorities in the digitalisation of construction, with several issues: improve access to rules across Europe, harmonize the way they are formulated in a digital-compatible way, develop compliance checking digital tools...

2.2.3 Standardisation works

With regards to standardisation works, DigiPLACE is not intending to act as a standardisation body, and to propose new standards. This framework pursues a dual objective:

1. Help reach a **common understanding** of the ongoing evolutions, by highlighting the role the different standardisation works have in addressing the identified challenges of digitalisation, and **mapping the different initiatives in a common vision**
2. Help bridge the gap between standardisation works and implementation, by providing guidelines on the way public or private stakeholders can **implement the standards to address these challenges**

CORE GUIDELINES: ENABLE INTEROPERABILITY AND DATA SHARING IN CONSTRUCTION

3 Pillar 1: interoperability, common language and processes

3.1 Mapping of the standardisation context: main concepts and references

Ongoing standardisation activities have been described in previous deliverables of the project (see D4.4-§4.4.3, and D5.1, §2.2 and §4). This paragraph synthetizes the main references, as well as their interrelations, in order to provide a mapping of the standards mentioned in the rest of this document.

3.1.1 Proprietary formats, open standards and interoperability

As highlighted in D4.4-§4.4.2, open standards are not the exclusive way to develop interoperability in digital construction platforms. We observe the development of communities of users and ecosystems of services around proprietary platforms. The example of office software is also mentioned, where interoperability developed on proprietary formats.

Without questioning the potential of proprietary approaches, the interview of Prof. dr. Žiga Turk (University of Ljubljana, Slovenia) in D4.4-§4.4.3), highlights the important role of open standards:

- They provide a reference or starting point for the software developers, i.e., a schema to be improved upon.
- They can provide the lowest common denominator for information exchange among software that did not choose to interface with a given proprietary schema or proprietary API. In BIM, they can play the role of DXF that has been the lowest common denominator for exchange of CAD information in architecture and engineering
- They provide a neutral representation that authorities can demand for procurement and permit processes. It is not possible for authorities to ask for information in a format that is proprietary
- Standard formats are safer for long-term preservation of information. It is much more likely that information in a standard format will be readable after decades or even centuries than information in the format of a software vendor that happened to be market leader at the time when the building was designed. Therefore, the use of open standards, together with an appropriate governance, is important for **data sustainability and resilience**
- They provide an environment for the publicly funded academia to contribute to the progress of BIM technology in a vendor neutral way.

Beyond this, the open standards approach for the digitalisation of construction is necessary to overcome the silos between the different domains, scales and lifecycle stages, thus enabling:

- the digital continuity over the full life cycle of any construction works
- cross-domains and multi-scale digital twins, as it is not possible to imagine a single software or even platform integrating all the domains and activities

3.1.2 The actors of international BIM standardisation and the openBIM® approach

Open standards and collaborative processes are key to allow interoperable digital workflows beyond the perimeter of proprietary platforms/tools.

Standardisation activities around BIM involve:

- ISO, through ISO/TC59/SC13 “Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)”
- CEN, through CEN/TC 442 “Building Information Modelling (BIM)”

BuildingSMART international (bSI)[2] is an international industry body driving the digital transformation of the built asset industry, and promoting the OpenBIM[3] approach, through pre-standardisation works.

Several important standards promoted by bSI have been endorsed by ISO and CEN. In Europe, CEN/TC442 stands as a primary reference, and coordinates with bSI to align possibly different approaches. Figure 9 depicts these relations between them.

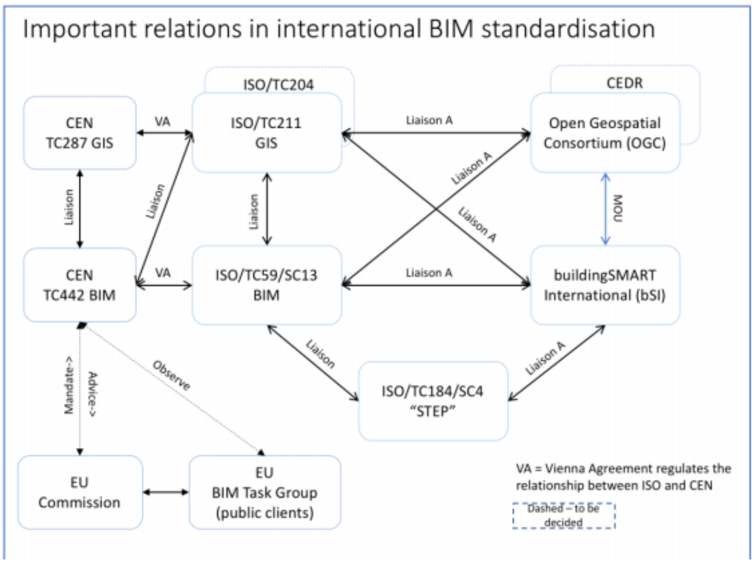


Figure 9: Important relations in international BIM standardisation. Source: CEN/TC 442 BIM - Business Plan - version 2020-12-15

The OpenBIM approach has been described in D5.1-§4.3. Its principles recognize that:

- Interoperability is key to the digital transformation in the built asset industry
- Open and neutral standards should be developed to facilitate interoperability
- Reliable data exchanges depend on independent quality benchmarks
- Collaboration workflows are enhanced by open and agile data formats
- Flexibility of choice of technology creates more value to all stakeholders

---

[2] https://www.buildingsmart.org/standards/bsi-standards/

[3] “What is openBIM®?”. BuildingSMART. https://www.buildingsmart.org/about/openbim/openbim-definition/

- Sustainability is safeguarded by long-term interoperable data standards

Beyond the standards themselves, OpenBIM is the base for the development of open source initiatives, such as the BIMserver and other initiatives from the opensourceBIM collective.

Finally, Figure 9 also highlights the connections with standardisation activities in the field of geographic information. **Open Geospatial Consortium (OGC)** is an international industry body for pre-standardisation driving the digital transformation of the non-built environment and promoting the OPenGIS approach. The importance of enabling smooth integration of BIM and GIS data is developed in §3.3.2 below.

3.1.3 Standards for data interoperability: the three sides of the triangle, or the three floors of the building

As stated in CEN TC442 Business plan[4], "*efficient interoperability requires a set of standards and implementation. The three pillars of interoperability are:*

- *a standardized way to store and exchange data models and implement them in software packages securely where necessary;*
- *a common understanding of terminology and data-semantic structure;*
- *an agreed set of information delivery specifications for the information sender to support the processes of the information recipient.*

An efficient object-based interoperability is conditioned by three sets of standards:

- *Data Model standards to specify data structure for entities, geometry and related properties as well as classification for exchanging data models. The data model ensures exchange of object-based information;*
- *Data Dictionary standards to specify data structure for defining data-semantic concepts (entity, property, classification...) and relations between them;*
- *Process standards to specify how to describe the required information supporting a given process".*

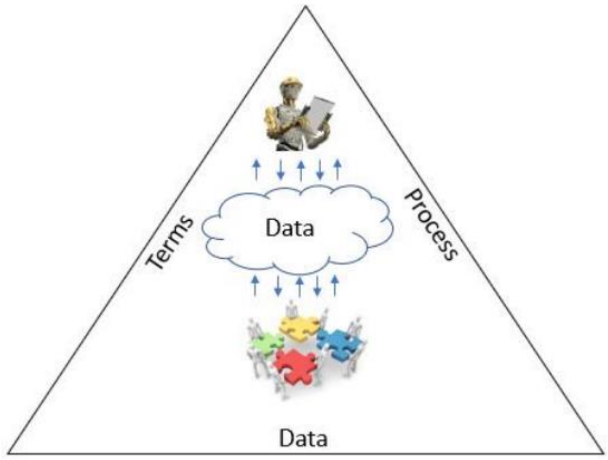


Figure 10: the three sets of standards for efficient object-based interoperability. Source:

[4] https://standards.cen.eu/BP/1991542.pdf

CEN/TC 442 BIM - Business Plan - version 2020-12-15

Works at the CEN TC442 address all three dimensions (see D4.4, Figure 32 for the list of CEN/TC442 Working Groups and Taskgroups).

Figure 11 provides another illustration of the same idea, dividing standardisation works (at the date of December 2018) into three groups represented as the three floors of a building:

- An upper floor for processes and data exchange: information management, BIM execution plan, IDM, IDS, etc... ISO 19650 constitutes an important step to set a common framework of concepts in this field (further developed in §3.5.2 below)
- An intermediate floor for data formats: IFC, BCF, etc…Model View Definition (MVD) specifies a subset of a BIM model to meet an exchange requirement. As such, it is at the junction between the intermediate floor and the upper floor
- The lower floor for terms and semantics: data dictionaries, classifications, etc... This level of standards is key for achieving semantic interoperability. Important standards include the recently published EN ISO 23386 and EN ISO 23387, described in §3.2.3 below. Following the image, BIM objects would sit at the junction between this lower floor and the intermediate floor, as they integrate object data into BIM models.

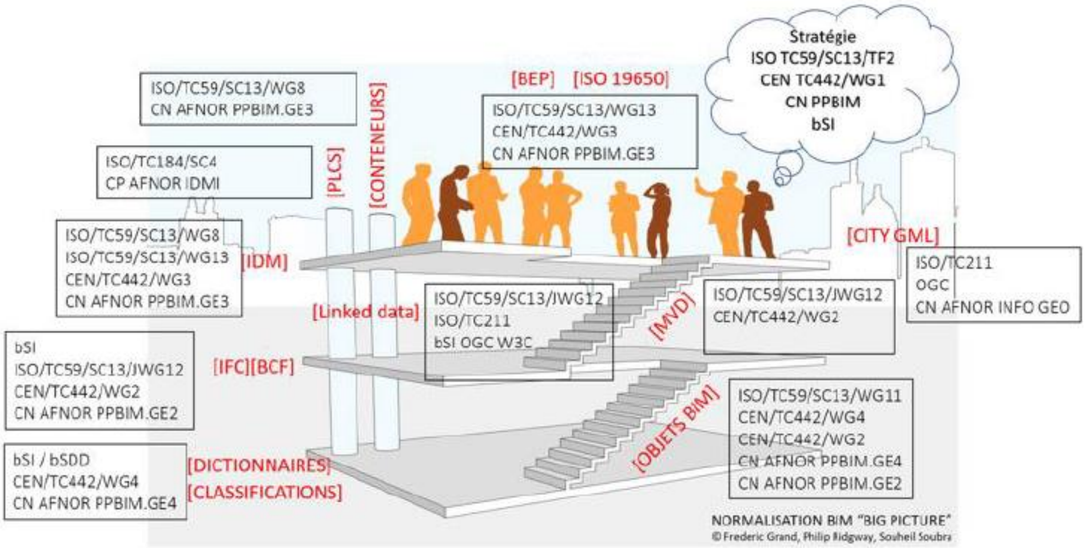


Figure 11: mapping the different standardisation and normalisation works: the three floors of the Building. Source: French strategy for BIM standardisation and normalisation works, final report, December 2018

Concerning the intermediate floor, standards for data models include the following:

- **IFC**[5] or "Industry Foundation Classes", is a standardized, digital description of the built environment, including buildings and civil infrastructure. It is an open, international standard (ISO 16739-1:2018), meant to be vendor-neutral, or agnostic, and usable across a wide range of hardware devices, software platforms, and interfaces for many different use cases. The IFC schema specification is the primary technical deliverable of buildingSMART[6] International to fulfil its goal to promote openBIM®.
- **BCF**[7], "BIM Collaboration Format" allows different BIM applications to communicate model-based issues with each other by leveraging IFC models that have been previously shared among project collaborators. This can be done by utilizing a file exchange between software platforms or using a RESTful service that connects software platforms directly or to a dedicated 3rd-party BCF server acting as the hub for such communications.
- **COBie**[8], has been the only IFC-based non-geometric standard that conformed to International Alliance for Interoperability and buildingSMART alliance technical standards for Information Delivery Manuals and Model View Definitions. Aside from geometric coordination, which has now been largely integrated directly into design software, COBie is the most widely used open standard for the delivery of building information in use today.
- **CityGML**[9], is an open data model and XML-based format for the storage and exchange of virtual 3D city models. It is an application schema for the Geography Markup Language version 3.1.1 (GML3), the extendible international standard for spatial data exchange issued by the Open Geospatial Consortium (OGC) and the ISO TC211.
- **gbXML**[10], Green Building XML schema was developed to facilitate the transfer of building information stored in CAD-based building information models, enabling interoperability between disparate building design and engineering analysis software tools. gbXML has the industry support and wide adoption by leading BIM vendors.
- Other standards in the openBIM® initiative for further BIM analyses, including QTO, time schedules, cost estimates, operations and maintenance data, sensory data, …

3.1.4 Further standards for exchanging and accessing the data

Alongside data standards & agreements (including both data formats and terms) and processes, the upper angle of the triangle in Figure 12 identifies another category of standards, related to data exchange and access to data. API standards and file serialisation standards are additional (syntactical) agreements to access data that is exchanged according to semantic standards. For example, CEN TC442/WG2 is working on the open data exchange between platforms of different vendors via an open CDE API.

---

[5] ISO 16739-1:2018: "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries", https://www.iso.org/standard/70303.html

[6] "Industry Foundation Classes (IFC) - An Introduction", https://technical.buildingsmart.org/standards/ifc/

[7] BIM Collaboration Format (BCF), is now a buildingSMART International openBIM standard. Developers can find more information about supporting BCF in their products through the open GitHub repositories, https://github.com/buildingSMART/BCF-XML and https://github.com/buildingSMART/BCF-API

[8] "COBie Standards and Guidance", https://cobie.buildingsmart.org/reading-list/

[9] CityGML by the Open Geospatial Consortium (OGC), https://www.ogc.org/standards/citygml

[10] gbXML is a type of XML file that has over 500 types of elements and attributes that allow you to describe all aspects of a building. https://www.gbxml.org/About_GreenBuildingXML_gbXML

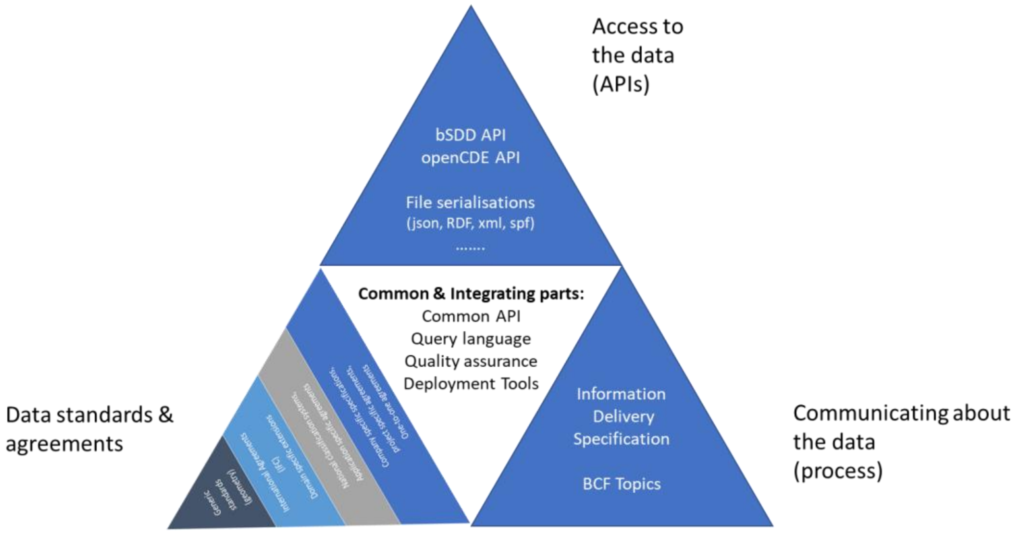


Figure 12: data standards, standards to access to the data, and standards to communicate additional information about the data. Source: bSI

Recently published ISO 21597, ICDD (Information Container for linked Data Delivery), is of utmost importance for the interoperability of a set of platforms. This ISO has 2 parts: ISO 21597-1:2020 describes the container itself. ISO 21597-2:2020 is dedicated to link types.

3.1.5 Guidance for standards implementation: references

Alongside the standards themselves, some actors provide guidance on standards' implementation: standardisation bodies themselves, public authorities, federations…The following example was produced by CEN TC442: CEN/TR 17439:2020 - Guidance on how to implement EN ISO 19650-1 and -2 in Europe.

3.2 Focus on product data

3.2.1 Context

This Reference Architecture Framework needs to be aligned with already existing frameworks (and primarily regulations, as was stressed in §2.2.2 above), such as Construction Products Regulation (**CPR**), Low Voltage Directive (**LVD**), Machinery Directive (**MD**), **REACH** etc. As these regulations and directives are using the CEN/CENELEC standards, and express the **common European technical language** in construction, the Reference Architecture Framework aims to absorb these standards and develop machine readable "building blocks" that hold the rules for CE-marking (and also Smart CE marking). From these "building blocks" or Construction objects we need to put in all the essential characteristics and non-essential characteristics for windows, walls, pumps, etc.

In this way we can develop a common Data Template that can hold information from European standards, national standards, or market requirements.

The purpose of this is to develop the properties or information that we need for **exchanging requirements** set by building regulations, client requirements or circularity programs to meet EU Green Deal, or simply how we deliver a hospital or a school.

No one can dispute the fact that construction is complex. Any construction endeavour includes different phases, involves many actors, and follows local and international requirements. Another factor that contributes to this complexity, is the length of the project lifecycle which can span over many decades.

Furthermore, during all different stages, an enormous amount of information needs to be communicated between the **planning, designing, building and operating** parties. How each actor understands a 'construction object' and the information they need to deliver or request about it depends mainly on **their role and respective point of view in the process**.

It is also important to understand already existing work as the Smart CE marking project that has made a digital version of the Declaration of Performance (DoP)[11]. Smart CE marking is the link between the physical product and the DoP. It is the access to this extensive and valuable information provided in a harmonised digital format. This work has been aligned with the EN ISO 23386 and the EN ISO 23387 (see §3.2.3 below).

A good example is the specification process within a project. Let's examine a typical situation where a construction object, for instance, a window, is to be specified and purchased.

> *A building contractor applies for and wins a tender to design and build a school. His design team creates multiple iterations of the spaces. After agreeing with the client, the created model is published and shared with the project team for the next detailed design stage. The MEP engineer would be interested in what the area of the windows is and what the thermal transmittance coefficient of the whole window is. Of significant importance is also the airtightness that the window ensures, as well as the type of glass – there will be different requirements for windows on the north facades and the west facades. The electrical engineer would also be interested in the window, but more precisely, the glazing area of the window since it is important for the calculation of space illumination. The environmental assessor would gather all technical and building requirements, as well as respective Environmental Product Declaration in order to proceed with the LCA assessment. All the information generated by these actors may reflect on the price so it should be made available to the cost engineer.*

Moreover, these actors **need different granularity and parts of the information**. Nevertheless, in the end, they should be able to make sense of it together and finally have a fully operable asset.

A digitally enabled construction industry is the future. However, the question remains: in the complex construction environment**, what would be the best approach to manage objects and systems in digital processes?**

The objective is that instead of the manual process of requesting various types of information, **the construction demand side and construction supply side are united in a common digital environment**. This means that all construction actors and, more importantly, the software systems that they use, are interconnected and can 'talk' to each other.

[11] Smart CE marking is the link between the physical product and the Declaration of Performance (DoP) https://www.construction-products.eu/services-jobs/smart-ce-marking

3.2.2 The common technical language

For this to happen, firstly, **there is a need to align the 'language'**, i.e. the different terms used by different actors. Here comes the help of the **'data dictionary'** in construction. A data dictionary translates the meaning of a 'window' or 'width' to any language in the world, including the universal 'machine' language. It is a place where one can find what means what, so that the same term in Italy is equal to that in France, Singapore or the States.

Secondly, **every piece of knowledge should be referenced by a credible source**. The national and international standardisation bodies, such as the European organisation CEN or the American ASTM International, put forward technical standards for a wide range of materials, products, systems, and services.

Although standards are, in general, voluntary, **regulations such as the CPR (Construction Products Regulation) rely on the standards' common technical language** in order to create a safe, competitive and level playing field for construction actors.

Furthermore, standards are referenced in various national regulations, as well as the Eurocodes, thus making them an inseparable part of the information requirements about construction assets.

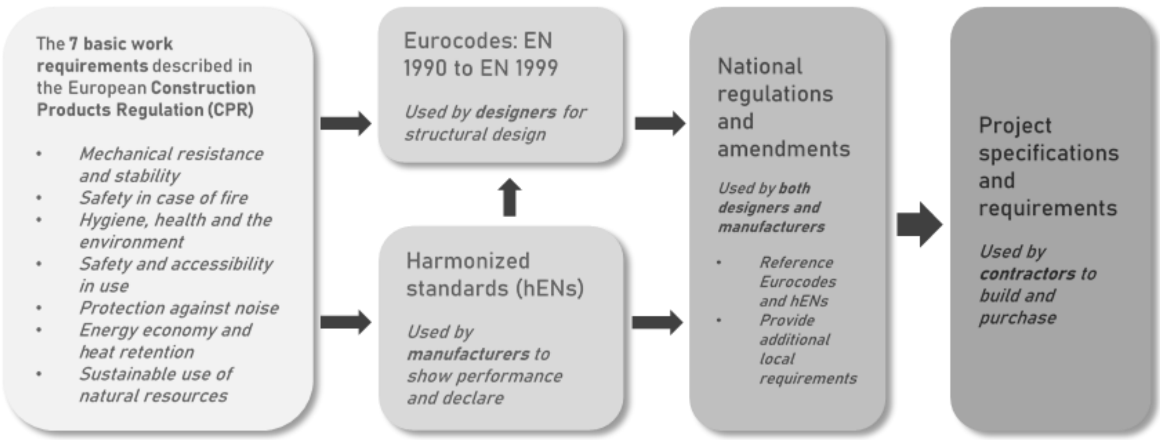


Figure 13: links between CPR requirements and technical standards. Source: Cobuilder

Standards and technical specifications provide a common language and a clear reference to what parameters a specific market requires. By studying these standards and by applying them, it is ensured that there are no duplicates of knowledge, only synonyms or local variations, thus preserving the quality of the information in the cloud and helping the global community to create new knowledge according to best practices.

From the perspective of the various construction stakeholders, this would mean better, faster and more efficient collaboration. Having a credible common description, there will be no more confusion in the terminology. Going back to our example of the window, **this means a single common approach of measuring its 'thermal transmittance', avoiding the confusion in understanding if the thermal transmittance relates to the frame, glazing, or the whole window.**

3.2.3 The common digital language

This paragraph intends to explain the **EN ISO 23386**:2020 Building information modelling and other digital processes used in construction — Methodology to describe, author and maintain properties in interconnected data dictionaries and the **EN ISO 23387**:2020 Building information modelling (BIM) — Data templates for construction objects used in the life cycle of built assets — Concepts and principles.

To ensure that all properties are universally understood, both by machines and humans, the standardisation bodies CEN and ISO published recently the standard EN ISO 23386, which was based in particular on the French norm XP P07 150 (2014). The main purpose of it is to make information machine-readable and ensure the quality of the data – thus creating trust in information requested and delivered.

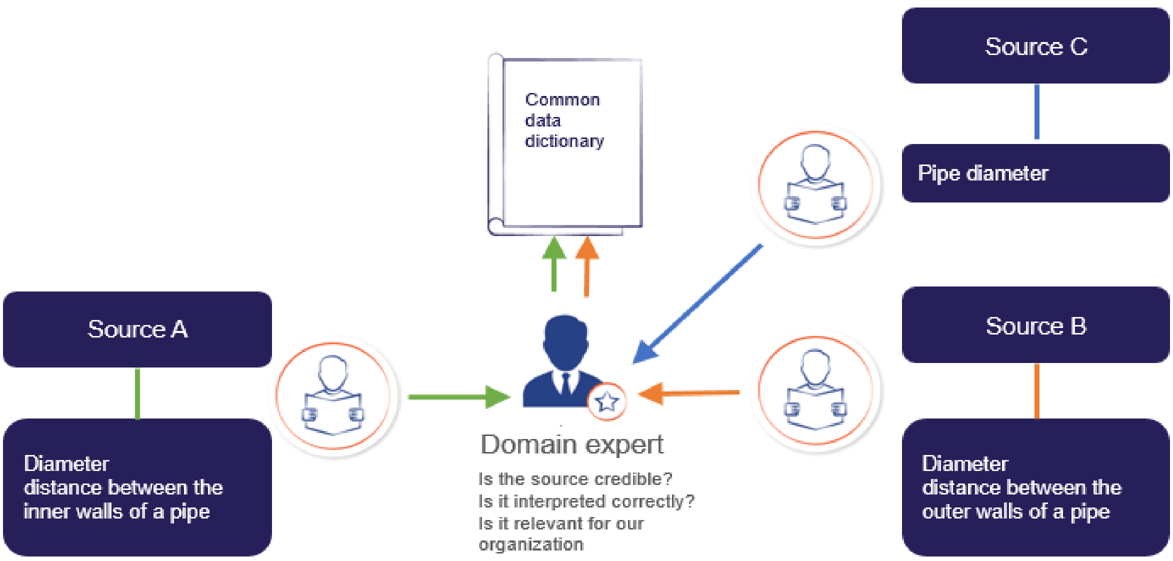


Figure 14: system of validation of digital content in EN ISO 23386. @Cobuilder AS and its licencors @1997-2020

EN ISO 23386 provides a rigorous system of validation of all digital content. It defines how properties and property groups shall be established by knowledgeable, trusted experts in a data dictionary, as well as how this content shall be mapped to other data dictionaries (Figure 14). Figure 14: system of validation of digital content in EN ISO 23386. @Cobuilder AS and its licencors @1997-2020

In a dictionary following the new EN ISO 23386 standard, **the definition of a property is not provided by only a name and a textual description**. The definition is expressed by the entire set of attributes permitting a **seamless understanding of the property** (**Errore. L'origine riferimento non è stata trovata.**).

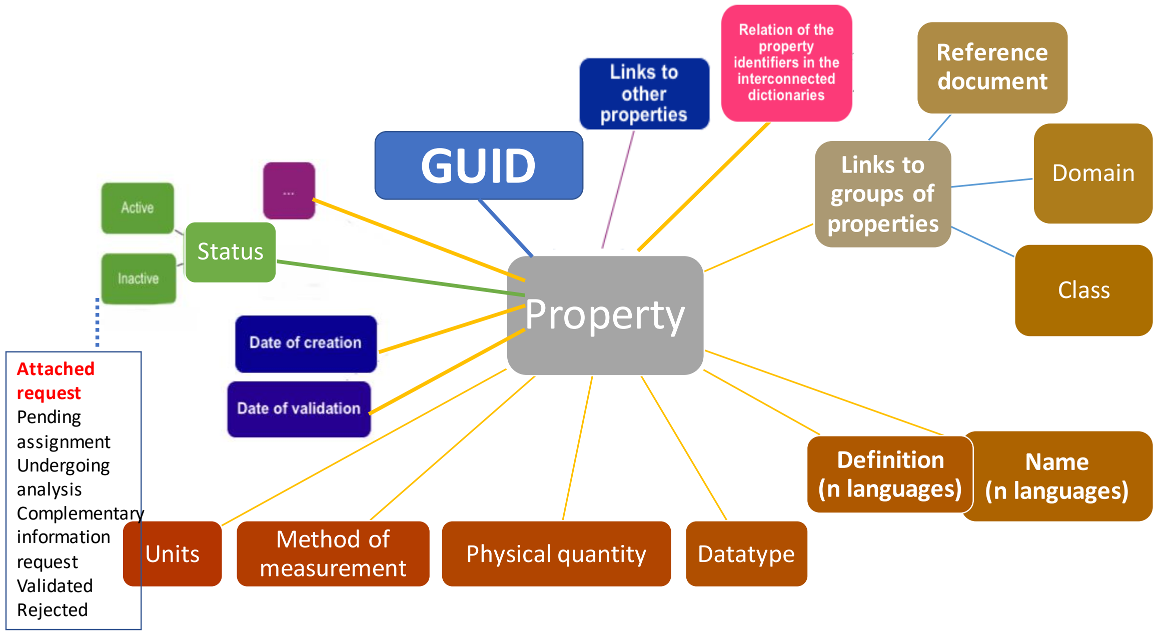


Figure 15: definition of a property in EN ISO 23386. Source: AFNOR

Aligned with this, the **Data Template structure** proposed in the new standard EN ISO 23387[12], is specifically developed to **serve and incorporate the various information needs of all actors in the construction industry** – be it for streamlining internal processes in construction or manufacturing or

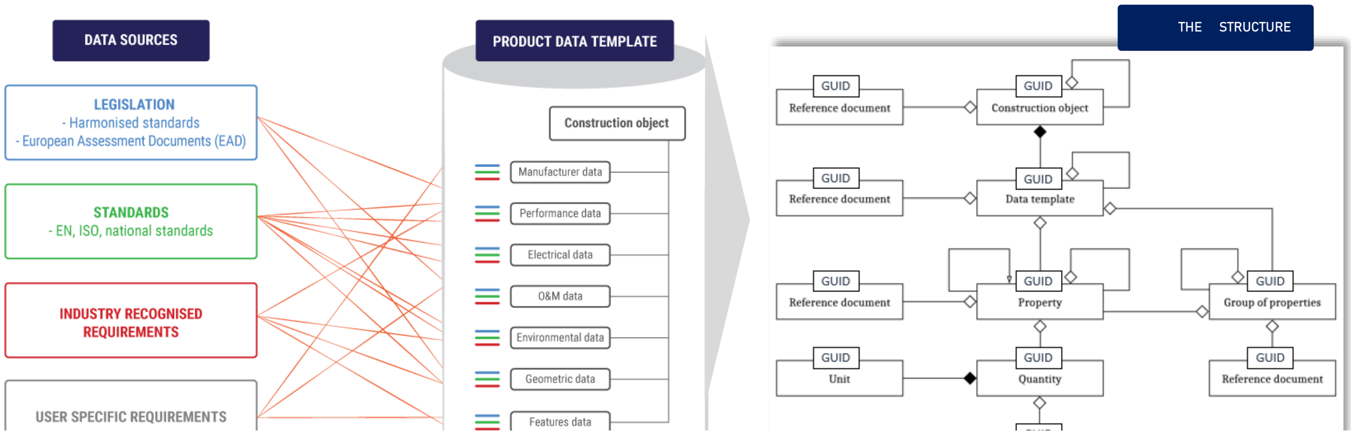


Figure 16: Data template structure proposed by the standard EN ISO 23387. @Cobuilder AS and its licencors @1997-2020

information exchange.

12 https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_LANG_ID:64242,25&cs=1770646CC6500A6BCDEC443392F6E801A

Thus, EN ISO 23387, EN ISO 23386, together with the relevant technical specifications and standards, create a trusted common technical and digital language for the construction industry.

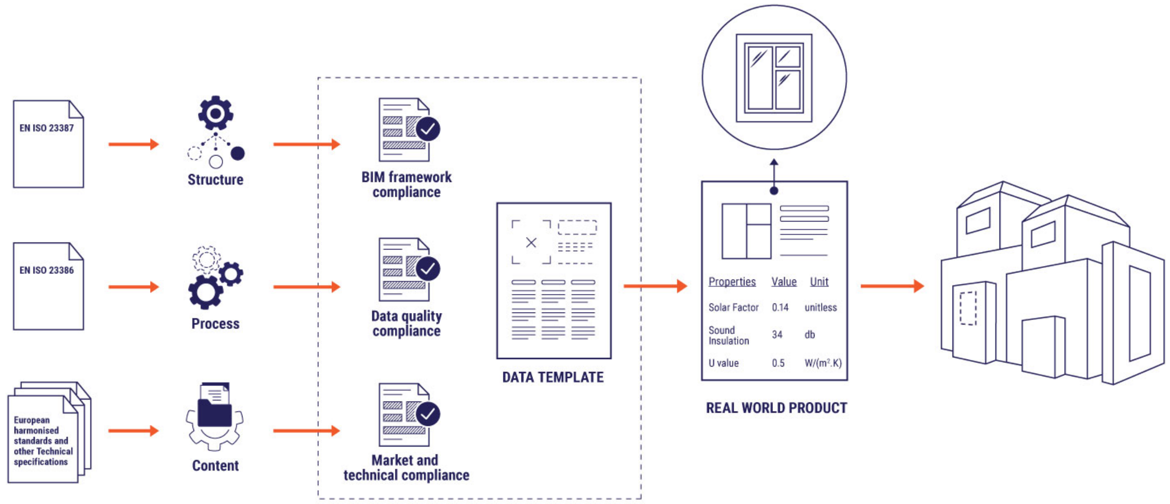


Figure 17: illustration of the trusted common technical and digital language for the construction industry. @Cobuilder AS and its licencors @1997-2020

Digitalisation is necessary not only for the sake of optimizing the complex construction process – it is a means towards a more sustainable built environment. That is why, the Data Template approach is seen as a vital part of the Construction Products Europe's Sustainable Built Environment Vision.

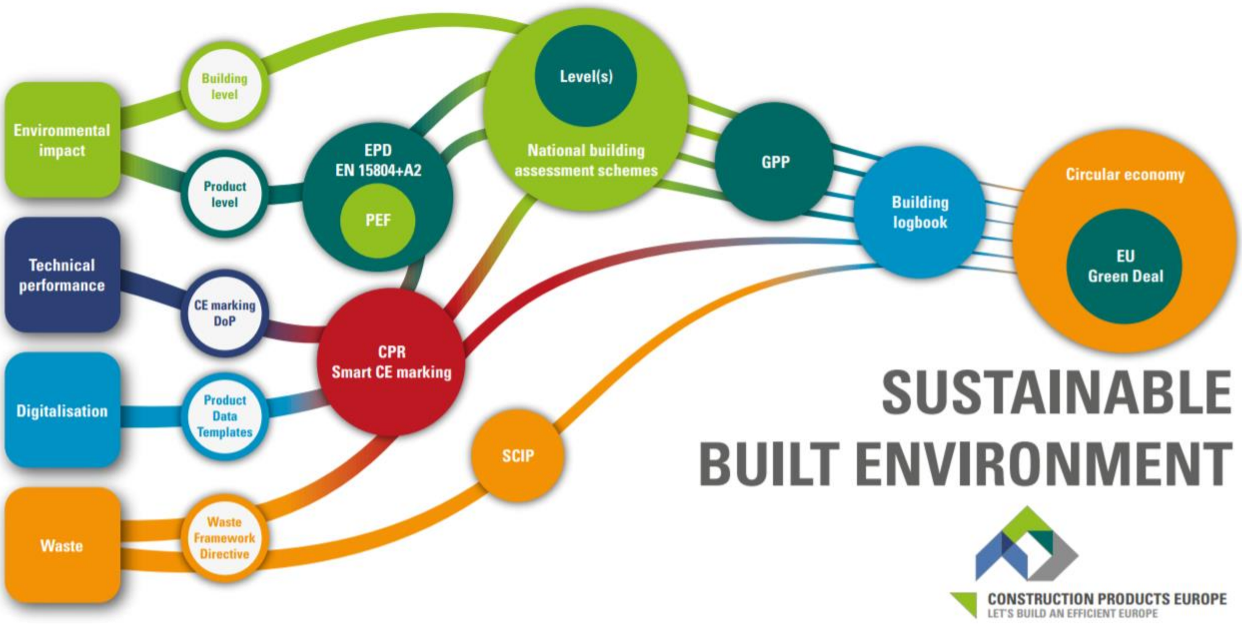


Figure 18: Construction Products Europe's Sustainable Built Environment Vision. Source: CPE

3.2.4 Towards a European data dictionary

The standards EN ISO 23386 and EN ISO 23387 mentioned above are meant to be used to set the Asset Information Requirements (see section 3.4 below), for a manufacturer to structure their product catalogue, to deliver the right data between parties, to use a standardised set of data in CAD software tools – where the data can be trusted.

In the future, all the data could be contained in a network of European dictionaries where stakeholders can govern the information to avoid duplicates of content, and to support translation to all EU languages. The construction industry could then have one way of describing assets and could benefit from the opportunities that linked data and open standards like IFC create.

Many concrete questions were identified in D4.4-§4.5.2, and respondents considered it was too soon to answer them: who will actually define the properties? Who shall watch over the accuracy of the data dictionary (DD)? Will local/national data dictionaries be necessary? Who shall promote the use of the DD? How will commercial initiatives be handled? By which party or parties should these dictionaries be managed (Commercial initiative? Government? Standardisation bodies? CEN? A mixture of all of them?) What is the link between DD and required documents (DoP, LVD, digital passport, …)? Should the use of a data dictionary be mandatory?

Today, a common European dictionary does not exist. It is mentioned in CEN TC442 business plan. The Building Smart Data Dictionary initiated by bSI (see D5.1, §2.2 and §4.3) is an example of implementation by an industry body. Some countries (e.g. Norway, Sweden, Denmark, France) have started to create dictionaries following the mentioned standards. It is however crucial that national initiatives follow a common European approach where the content is governed on a European level. The proposed "European dictionary" would then emerge as a network of dictionaries with a common governance and based on the same framework.

Guidelines:

- Initiate a common European dictionary, as a network of (national) dictionaries with a **shared European governance**, and based on the standardized framework

3.3 Further guidelines regarding standards and interoperability

3.3.1 Semantic interoperability is key

Handling the complexity and diversity of construction semantics in interoperable digital processes relies on **semantic interoperability**, which stands out as the cornerstone of interoperable digital platforms. This is the target of the standards related to terms and semantics (lower floor of the building).

Focusing on product data, §3.2.3 above has introduced the concepts of properties, data dictionaries, and product data templates. Semantic interoperability is key to e.g. automatically find manufacturer products to match a BIM dataset.

In §3.4.3 below, the role of semantic interoperability is asset lifecycle information management is explored in a more general way, through the description of the Semantic Modelling and Linking standard under development in CEN/TC442.

To gain a better understanding of the importance semantic interoperability, one needs to understand the difference between a syntactical language and a semantic language. A 'language' that provides interoperability on a syntactical level is not enough. This only allows tools that support this 'language' and structure to open a file and see the structure. The tool does not understand what the content inside the file actually means. A 'file format' is a good example of a syntax standard. Everyone tool that supports .docx can open the document, but the tool does not understand the context. This is the same for XML, TTL and Product Data Templates.

The semantic interoperability is what differentiates a syntax standard from an actual semantic data standard. Using agreed naming and definitions allows tools to understand the content inside a file and automate use-cases.

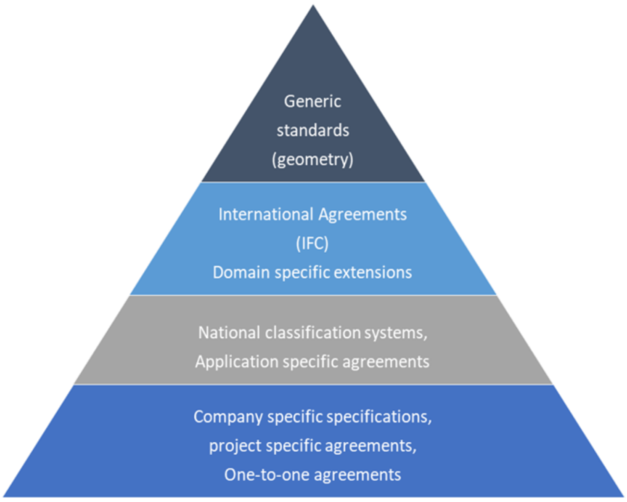


Figure 19: pyramid illustrating the different levels of standardisation. Source: bSI

To understand the respective role of the different sets of standards to achieve this, it is useful to take a step back, and explain the different levels of standards and specifications, already described in D5.1-§2.2, and illustrated by Figure 19. On the top are very generic standards. Examples are on how to describe geometry, topology, or structure. There are little semantics on this level.

To add semantic meaning, specialized standards are made. For example, the IFC standard defines a spatial structure for built elements. Further specialisations for domains in IFC are defining what the definition of a wall is, but also a door, roof, and many other entities.

An international standard that needs large consensus is usually generic. This allows a broad adoption. IFC only contains entities and definitions that have reached global consensus. This is usually not enough for specific day to day use-cases. That is why national classification systems are used to further specialize the global consensus. Agreements that focus on specific domains are also widely used. The ETIM standard is a successful international standard specifically used in the MEP domain.

On the bottom of the pyramid, the one-to-one agreement between just a small number of people can be very effective for specific use-cases that only exist in a niche environment. An agreement on what property to use for the exchange between just 3 organisations for example can be created very fast and can be very useful, but is only effective for these 3 organisations. The more generic and broadly used an agreement is, the more it becomes a standard. The more specific it is, the more it stays an agreement or specification.

Somewhere in the middle are the national classification systems (CoClass, NISFB, OmniClass, etc), the agreements within specific industries (ETIM, etc). These can be called standards within the domain or region for which they are used.

More local standards, or data standards for specific use-cases, are not intended to be part of IFC. More generally, IFC is not intended to bear all the semantics used in the construction sector: properties, classifications, data templates...

Data dictionaries, mentioned in §3.2.3 above, are made to enable the handling of these semantics in BIM models. For example, the buildingSMART Data Dictonary can be used also to map the IFC schema to international taxonomies like classification systems.

Finally, the **linked data** principles, described in D5.1-section 3.9 and further developed to in §3.4.3 below, contribute to semantic interoperability by making the definition of terms and concepts an open and collaborative process.

3.3.2 Integration of BIM and GIS data, and federation of models

The present framework does not apply only to buildings, but to the construction sector in general, including infrastructures, for which the proper management of geographic information is crucial.

In this field, the INSPIRE directive ("Infrastructure for Spatial Information in the European Community") sets up common implementing rules in a number of specific areas: Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting.

It also sets up a framework for actual sharing of spatial data, either voluntary or mandatory. The INSPIRE web portal supports best practices in terms of data sharing.

Integration of BIM and GIS data is of the utmost importance to enable the development of territorial digital twins (see §3.4.2 below and §8.4.1 below), which might themselves play an important role in the management of environmental transition and climate change action.

Two digital worlds are living in parallel. The first one is embedding the construction process based on CAD, and then BIM models. The second one is embedding the process for describing the built and non-built environment in using geomatics and GIS. Translation was the way for the communication between the two worlds: CAD to Geodatabase, for instance. Including a difference between the building sector and the infrastructure sector: Most of the CAD systems used by the latter have already implemented geo-referencing and real coordinates.

With BIM, the digital continuity is required in the information delivery process for the common data environment management (see §3.4 below). With the concept of "shared" information, the translation approach is failing (using a translator like FME to translate a CAD file to a shaped file, or to translate an IFC file into a cityGML file). The concept of "models federation" is growing: a Revit file can be fully embedded in a geodatabase[13] or in mapping only IFC and CityGML until a defined LOI, in using a common ID for the same object. For a more detailed LOI, the IFC content is no more translated but

[13] A common work between Autodesk and ESRI

connected.

Open standards have been introduced within this domain to facilitate the interoperability process. Evolving with technology, GIS domain evolved in implementing interoperability. This has started from implementing file format convertors, to developing standards interchange formats such as GML, CityGML, GeoJSON, to (proprietary but) open data formats such as shapefile, and today integration of standardized GIS Web Services such as WFS (Web feature service), WMS (Web Map Service) and WCS (Web Coverage Service) which are developed by the Open Geospatial Consortium (OGC). Anyway, the best long-range solution for geospatial data interoperability is based on web services.

Consequently, GIS models and deliverables are inside the concept of data container such as defined in ISO 19650 for the CDE.

3.3.3 Access to standards and governance

As part of the identification of key use cases (see D5.1-§2.2), the question of accessibility to the standards has been raised, as well as of management of their development. The following guidelines have been proposed

- Publish all kinds of standards in a publicly available repository (GitHub for example) to engage with a broad community. More generally, the idea of free accessibility to the standards has been mentioned
- Define a process for end-users to engage more to help develop the standard and help create user-guides for end-users.

3.4 Asset Lifecyle Information Management and Digital Twin

3.4.1 Towards collaborative environments along the assets´ life cycle

The implementation and widespread of the BIM methodology has overcome the traditional Document Management Systems (DMS)[14] that have been used in business environments since the 1990s; that offered a central data repository for digital documents and the provided various administrative, search and distribution facilities for use in company activities and decision-making processes.

Moreover, in addition to the designs that are created using the tools related to the BIM methodology, digital technologies are increasingly used in all stages of construction lifecycle: scanning technologies for existing buildings and sites digital models development; design and management information harvested and used at the site through mobile devices, assets´ performance monitored with sensors (georeferenced data, occupancy, activity state) and scanning devices (3D laser scanning); and automated or intelligent facility management based on algorithms (AI) and data gathered by building automation systems (BAS) and sensors.

The continuous use of digital models and data across different disciplines and life cycle phases is paving the way to the called “BIG BIM”. The terms “little BIM” and “BIG BIM” describe the extent of BIM

[14] Schapke SE., Beetz J., König M., Koch C., Borrmann A. (2018). “Collaborative Data Management”. In: Borrmann A., König M., Koch C., Beetz J. (eds) Building Information Modeling. Springer, Cham. https://doi.org/10.1007/978-3-319-92862-3_14]

usage. The terms “Closed BIM” and “Open BIM” distinguish between the exclusive use of software products from a single vendor and the use of open, vendor-neutral data exchange formats[15].

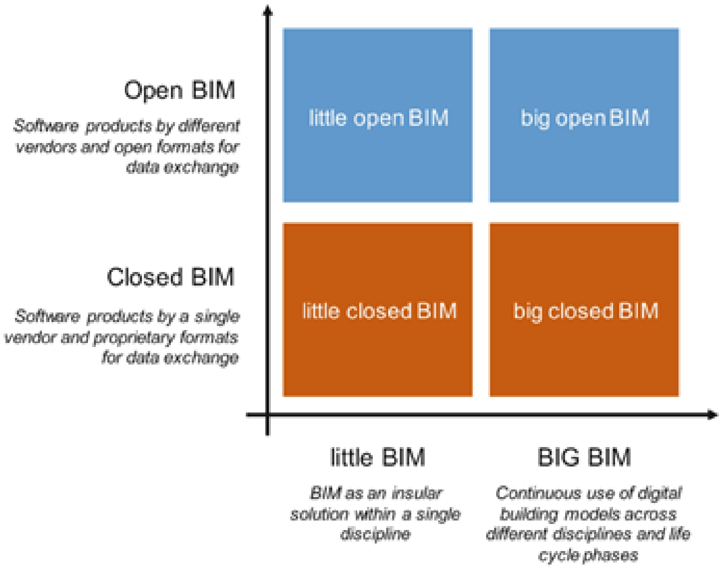


Figure 20: illustration of “little BIM” and “BIG BIM”[16].

There are several challenges associated to this:

- Ensure the continuity of information all along the lifecycle of the construction project (see Figure 21).
- Handle large volumes of heterogeneous data (Big Data) that will be produced at each lifecycle stage
- Ensure the interoperability with the different tools used along the lifecycle, including the operation phase (Building Management Systems, Energy Management Systems, Integrated Workspace Management Systems, Computerized Maintenance Management Systems, Asset and Property Management,…)

[15] Borrmann A., König M., Koch C., Beetz J. (2018). “Building Information Modeling: Why? What? How?”. In: Borrmann A., König M., Koch C., Beetz J. (eds) Building Information Modeling. Springer, Cham. https://doi.org/10.1007/978-3-319-92862-3_1

[16] Borrmann A., König M., Koch C., Beetz J. (2018). “Building Information Modeling: Why? What? How?”. In: Borrmann A., König M., Koch C., Beetz J. (eds) Building Information Modeling. Springer, Cham. https://doi.org/10.1007/978-3-319-92862-3_1

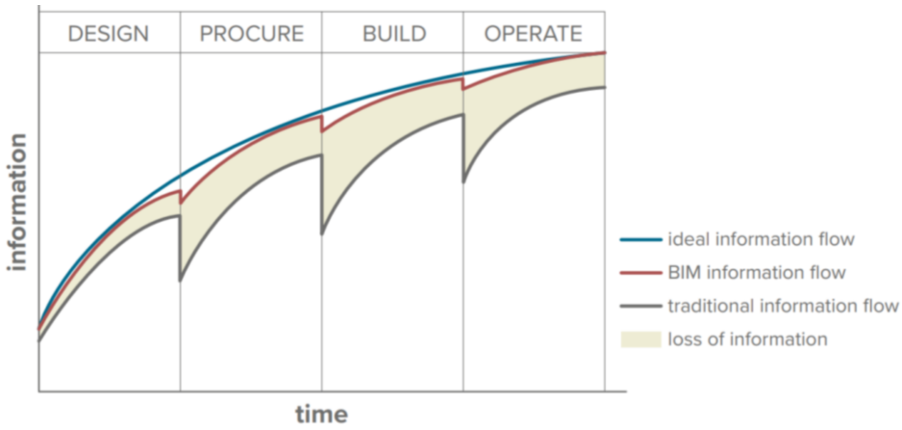


Figure 21: Knowledge base throughout the project lifecycle[17].

3.4.2 The Digital twin concept

Enabling an ecosystem of **digital twins** all along the lifecycle was identified as one of the key use cases (D5.1, §2.7) of future construction digital platforms.

In the Digital Twin approach, all the data describing the real world is being continuously and seamlessly ingested, modelled and analysed. A digital twin connects to its physical counterpart, allowing it to follow the physical asset, assess its status and finally learn based on the information received from it. The digital twin can be used during the whole life cycle to make simulations, perform different forecast analysis, and make predictions about the future behaviour and use of the physical asset. It could also contain the information about the activities that act upon the physical asset. As such, one of the key benefits is that it allows to simulate the impact of different physical occurrences on the physical asset. With the help of these insights, the digital twin can propose, make decisions or even decide and perform actions itself on the physical asset.

A digital twin integrates: (1) static asset information, process information and dynamic monitoring data, (2) models and learning, and (3) simulation and decision making for a physical asset over its lifecycle. A digital twin works best when used by all stakeholders involved with this asset, who consequently need access to the information, models and simulations.

In other words, a BIM model represents the digital asset such as designed, such as built or such as maintained. The digital twin is using the BIM model, in a dynamical way: the BIM model is upgraded with real time information to represent or to simulate the asset such as working: under construction or under operation.

A common conceptual framework for digital twins is progressively emerging, as several ongoing works aim to propose common definitions for digital twin concepts, and reference architectures (see references below).

Finally, territorial digital twins, integrating building-scale data with other territorial data (e.g.

[17] Source: Eastman, C., Teicholz, P., Sacks, R., & Liston, K (2011). “BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors”. Hoboken, NJ: John Wiley & Sons.

transportation, energy nerworks…) might play a key role in managing the environmental transition of territories, and climate change action.

References

- ISO/IEC JTC 1/SC 41 WG6 work related to Digital Twins - https://www.iec.ch/dyn/www/f?p=103:14:12649024968960::::FSP_ORG_ID,FSP_LANG_ID:27186,25
- bSI paper "Enabling an Ecosystem of digital twins"
- White paper "Digital twin definitions for buildings", published as part of the H2020 Sphere project
- IET paper about digital twins - https://www.theiet.org/impact-society/factfiles/built-environment-factfiles/digital-twins-for-the-built-environment/
- Vision and reference architecture proposed by IBM: https://developer.ibm.com/articles/what-are-digital-twins/
- Scientific publications, such as:
    - Calin Boje, Annie Guerriero, Sylvain Kubicki, Yavine Rezgui (2020). « Towards a semantic Construction Digital Twin: Directions for future research », Automation in Construction, Volume 114, June 2020

3.4.3 Background of the guidelines for Asset Lifecycle Information Management

In the lifecycle of buildings or infrastructure, assets need to be managed across their entire life cycle, involving programming, design, building, operation and decommissioning (as defined by ISO 19650 series), and the supply chains supporting those phases. Vast amounts of valuable data about the assets are created, communicated in a diverse range of incompatible formats and according to various incompatible data structures - and are often lost again. In order to manage the assets more efficiently and effectively according to the standards practised in asset management (as defined by ISO 55000 series), data needs to be findable, accessible, interoperable end reusable (FAIR)[18].

Asset Lifecycle Management covers both Project Management and Asset Management as defined in ISO 19650. It covers the delivery (program, design, build) phases and the operational phase of an asset's life-cycle. Asset Lifecycle Information Modelling (ALIM) refers to all the information-specification and processing activities such as data creation (like via BIM/GIS software), capturing (like through inspection, monitoring or 3D scanning), transformation, analysis/calculation/simulation and decision support. It is an umbrella-concept bringing together the more technical concepts, such as:

- BIM,
- Construction objects and their properties (EN ISO 23386 and EN ISO 23387)
- Geo-spatial Information Systems (GIS/GEO),

---

[18] See FAIR Principles - GO FAIR (go-fair.org), based on: Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 3, 160018 (2016). https://doi.org/10.1038/sdata.2016.18

- Systems Engineering (SE),
- Monitoring & Control (M&C), and
- Ontologies that enrich all previous; or just standalone, define the precise data needs for people, projects, organizations, countries etc. in a semantic way.

For the present framework two aspects are crucial: (1) being able to understand data of others by using a **standard for semantic modelling and linking**, and (2) being able to actually link data of individual parties/sources by using a **network of ontologies**.

3.4.3.1 Standard for semantic modelling and linking

Making data FAIR is crucial for any platform. FAIR data implies that parties in the process can Find data, have Access to it, are able to Interoperate with it and can Reuse it. The following elaborates on the need for handling data on different levels of semantic richness and the need for different ways to have access each other's data. Next, the technology of semantic web (SW) and linked data (LD) is introduced, and the need for a standardised way of applying these in the construction sector. These guidelines are based largely on the **work initiated at CEN/TC442 on a Semantic Modelling and Linking (SML) Standard.**

Data exist in many forms, ranging from documents that require human interpretation (such as pictures, drawings and pdf files), to computer application specific files (such as CAD files), and semantic rich computer interpretable files (such as linked data). Ideally, we would only use semantic rich and fully computer processible and interpretable data. However, it is technically not yet possible to replace all documents, made for human interpretation, by semantic data. Therefore, in the foreseeable future, platforms should support this hybrid situation, with data on multiple levels of semantic richness and abstraction.

Parties want to have access to each other's data in different ways, depending on the nature of their collaboration and contractual agreements. Basically, they want to exchange or share data. When data is exchanged one party sends (a copy of) his/her data to the next party. In the ultimate form of data sharing, data remains at the source and relevant parties are given the URI (the unique internet address) and access rights to that data. In a less far-reaching form of sharing, parties send (most often a copy) of their data to a central point, e.g. a platform, where all parties have access to it. Which way of giving access to data is used depends on many factors. In the ideal situation data remains at the source and access rights are managed accordingly. However, technically this is not yet possible for all situations and the consequences of this approach to working with changing partnerships over the lifecycle are not clear yet. Therefore, in the foreseeable future, platforms should support all three ways of giving access to each other's data. It is important to note here that access to the approved version of the data is essential (i.e. the latest approved / updated version).

The world wide web consortium (W3C) provides technologies to solve these two needs. W3C provides a stacked approach for linking computers, documents, data and knowledge, using integrated protocols. For example, the HTTP protocol is used to link documents over the internet. The W3C also provides so-called linked data (LD) and semantic web (SW) technologies which can give data a common form (syntax) and meaning (semantics), making data FAIR in a vendor neutral fashion, both for exchanging and sharing.

Without repeating a deep analysis here, we have chosen for the W3C Linked Data / Semantic Web approach as primary technology. Most of its advantages stem from the fact that this LD/SW approach is fully Internet/WWW-based since it is defined by the W3C and the Internet/WWW is utilized as the underlying communication infrastructure. In short: W3C took their existing WWW, being itself already on top of the Internet, and added 'computer-processable' (Linked Data) and, next, 'computer-interpretable' (Semantic Web). Because of this, LD/SW automatically realises the key principles 'solid' (W3C), 'shared' (100% international & generic) and 'separated' (by the distributed nature of the web). LD/SW itself added more 'solidness' (fully based on logic & mathematics) and 'strength' (being feature-complete by offering standard formats, languages and access mechanisms).

It should be noted that other potential integrating technologies ISO 10303 STEP technology (from ~year 1984), OMG Object-Oriented/Model-Driven technology (from ~year 1994) and W3C XML technology (from ~year 1998) are much less internet based and are moving towards a LD/SW version.

The W3C languages are based on first order logic and are very powerful. To ensure that semantic data is easily accessible by others a Semantic Modelling and Linking (SML) Standard[19] for data modelling in the built environment has been developed under the flag of CEN TC442. This standard originated from the modelling and linking guidelines as developed in the EU project V-Con and elaborated in the CEDR project INTERLINK[20]. Managing asset lifecycle data conforming to the CEN SLM ensures users of a platform FAIR data that can be exchanged and shared.

3.4.3.2 A network of ontologies supporting a network of datasets

Many parties are involved during the lifecycle, often each with their own purpose and perspective on the asset, leading to different requirements on which model views and data are relevant. They have their own specific data requirements, but also want to use and build upon data of others in the process. Likewise, other partners want to access that data too. The first prerequisite to do so is to model the data conforming to the CEN SLM standard as described above. The second prerequisite is to apply this in a network of ontologies. This section elaborates on potential of such a network of ontologies.

When following the CEN SML approach each domain models its data in a so-called (domain) ontology. An ontology is a shared abstract view of a part of some real-world domain used for some specific purpose. An ontology is essentially a set of concepts, value types, attributes, relations, constraints and derivations. Typically, a taxonomy (specialization hierarchy) or sometimes a meronomy (typical decomposition hierarchy), or both, constitute the 'backbone' of an ontology.

Each domain should make an ontology for the data it covers. Some examples of such domains are design of assets, spatial planning, systems engineering and inspection. When both the data (LD) and semantic web (SW) technologies conforming the CEN SML standard for a common form (syntax) and meaning (semantics) are used for such a domain ontology, all parties in the sector know which data this domain manages. When the LD/SW technologies conforming to the CEN SML standard are also used for representing the domain data of a specific asset, all partners in the project can access and reuse the domain data.

Each domain should follow open standards for data representation whenever possible (see3.1 above). When these standards are represented in a format conforming to the CEN SMLS, their data is also accessible for others, as long as the ontology is known. It is encouraging to see that these BIM and GIS standards are moving towards LD/SW. The ISO 233386 and 87 community is also discussing the connection to the linked data world. The better we all follow uniform modelling standards, such as defined in the CEN SML standard, the easier the linking of different domains will be.

A first step would be to translate the formats of these current standards to a uniform linked data format; this can often be done rather straightforward, allowing synchronisation between the currently

[19] CEN/TC 442 / prEN 17632: Semantic Modelling and Linking (SML) Standard for data modelling in the built environment.

[20] See Home | INTERLINK (roadotl.eu), and D4. Principles for a European Road OTL

prescribed format and the linked data format of ontologies and conforming datasets. An example is the ifcOWL[21] version of ifc. The EU BIM4EEB[22] project is for example making use of ifcOWL and LD to support efficient renovation planning in buildings through various toolkits for different stakeholders. These standards could also be expressed in a uniform linked data format, such as the linked data / semantic web languages. A second step would be to follow the modelling and linking guidelines from the CEN SLM standard for these standards completely. Be aware, this re-modelling requires substantially more effort, but also decreases the effort needed for linking substantially.

When connecting the ontologies of the domains, a network of ontologies emerges which spans all data to be shared in the lifecycle of an asset. In the past, many tried to make one big data model (or ontology) to span all information of an asset in its lifecycle. Alas, this so-called 'mother-of-all-models' proved to be impossible to develop, let alone to agree upon in a broader context. The domains developed their own data standards and their own eco-systems around those. Replacing those by a new 'mother-of-all-models' proved to be an illusion. However, these different domain perspectives have quite some data and data structures in common. Therefore, to simplify the linking between domain ontologies, a **neutral core ontology should be placed as central point of linking**. This core ontology should focus on those aspects (almost) all parties in the process agree upon. For the construction industry this could very well be the taxonomy and/or meronomy (the asset breakdown structure) as it is conceived by the main users. And preferably, an open standard that is accepted, or even mandatory, in the sector. For example, for roads this could well be the INSPIRE Road Transportation Network model, with its main classes in a taxonomy and its typical decomposition in a meronomy, as suggested by the CEDR-INTERLINK project.

3.4.3.3 The example of the Digital Construction Ontology Suite

The Digital Construction Ontology Suite (DICO)[23] is an existing initiative aiming to provide the essential concepts and properties of construction and renovation projects, thus paving the way to the integration of information from different decentralized sources over construction lifecycle. The DICO version 0.3 has been refactored to comply with the new version of BFO, Basic Formal Ontology, (ISO/IEC 21838-2) standard, also, to make DICO easier to use by applications, a uniform naming of instantiated classes and related properties was provided by defining equivalent terms for many BFO terms. At this stage, DICO has not aligned with ongoing works concerning the SML standard.

3.4.4 IoT data

One of the domains that is important for the digital twin is Monitoring & Control. Also in this area the internet becomes more and more important, resulting in an Internet of Things (IoT). An interesting development here is from the W3C Web of Things (WoT) Working Group. The Thing Description (TD) it proposes can be used to locate things in buildings. IoT devices are seeing an exponential rise in different industrial sectors, and the construction sector is no different. These devices allow for monitoring and control of different aspects of a physical asset (e.g. lighting, temperature, humidity, ait

---

[21] ifcOWL - buildingSMART Technical

[22] BIM4EEB - https://www.bim4eeb-project.eu/

[23] DICO - Digital Construction Ontologies. https://digitalconstruction.github.io/

quality, mould, presence, etc.).

The AIOTI (Alliance for Internet of Things)[24] leads Europe's efforts in standardisation of IoT standards (https://aioti.eu/aioti-wg03-reports-on-iot-standards/) with multiple standardisation bodies (https://aioti.eu/structure/collaborations/) .

The current state of hardware technology has allowed the existence of increasingly powerful and economical devices, with high autonomy and resilience that are integrated into reality and can measure, control and act on it. This mixture of technology and reality is what is commonly known as physical cyber systems.

The following diagram shows a typical architecture of a cyber-physical system in which business reality is transformed into simulation using Digital Twins thanks to the convergence of IoT digital technologies.

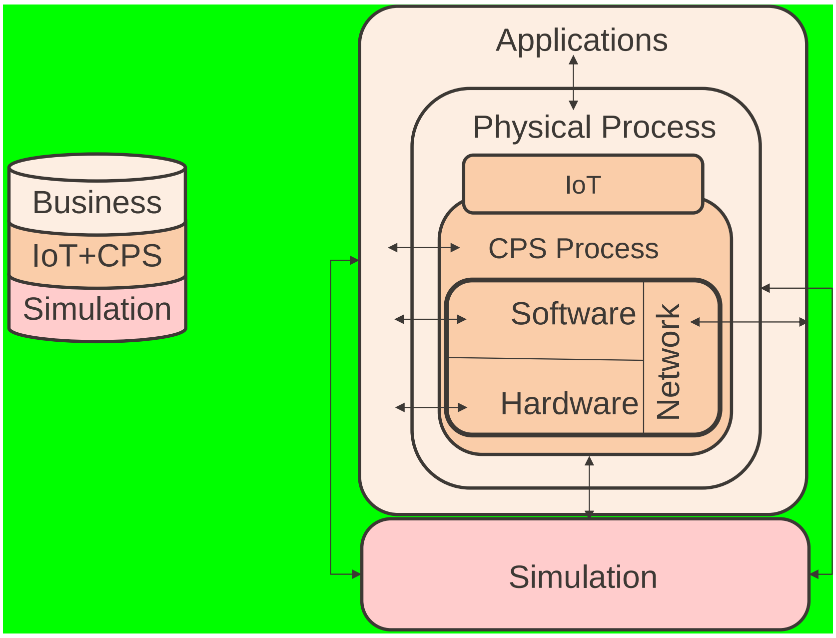


Figure 22: IoT, Cyber Physical Systems and the Digital Twin

Applied to the construction sector, this scheme would be valid in the different phases of the value chain, from planning to delivery.

Despite major advances such as the FIWARE framework and the references mentioned in §3.4.2 above, there is still a need of convergence and harmonization concerning the handling of IoT data in digital twins along projects and assets lifecycle (e.g. on the ontologies to use to describe metadata).

References:

- FIWARE framework
- W3C Web of Things (WoT) Working Group, proposing the "Thing Description" (TD)

[24] AIOTI - https://aioti.eu/

- The AIOTI (Alliance for Internet of Things)

3.4.5 Synthesis of related guidelines

To enable Asset Lifecycle Information Management integrating data from multiple sources and from multiple domains, platforms should follow these guidelines:

- Data should be liberated and shared per domain
    - Make data FAIR
    - Use the open standards accepted, or even mandatory, in each domain
- Data structures (or ontologies) should be published and machine interpretable
    - Standardise the language used for representing data structures
    - Use W3C - linked data / semantic web languages to represent these standards in ontologies and asset specific datasets
    - Preferably following the CEN Semantic Modelling and Linking (SML) Standard
- The current ICT landscape is hybrid and will be so for a long time, with a coexistence of:
    - Documents tagged with meta data
    - Structured data
    - Structured semantic data, using the CEN SML, which could well serve as the linking pin between all kinds of data
- Big-mama model, Mother-of-all-Models does not exist
    - Combine the ontologies of existing (open) standards in a network of ontologies
    - With a shared ontology consisting of a common vocabulary, taxonomy and/or meronomy as a core
    - Which follows the most commonly accepted standards in the sector
    - Further discussions appear necessary on the way to implement this vision, building on existing practices and initiatives

3.5 Collaboration and information management processes, Common Data Environments

3.5.1 Common Data Environments: introduction and needs.

A Common Data Environment (CDE) is an **“agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process”**; an “information container” being a “named persistent set of information retrievable from within a file, system or application storage hierarchy" [25].

ISO 19650 is a major advance to set common principles for information management and CDEs.

If we refer to BIM maturity levels[26] that were previously referred to, CDEs provide the needed technological support for BIM maturity levels 2 and 3.

The implementation and deployment of the CDEs is a widely acknowledged practice to change the working culture, to increase the productivity and to speed up the digitalisation of the Construction Industry[27][28][29][30] thanks to its ability to:

- **Implement a collaborative working environment**: improved coordination and teamwork, both internally and across teams, connecting models, and project data in one environment, ensuring a single source of project truth where project participants have access only to what they are authorized to access.
- **Increase productivity**: Reducing the time and effort required to check, version, and reissue information, reducing the time and cost of producing coordinated information, enabling the extraction of selections of the latest approved data, minimizing coordination checks. Shared information reduces the time and cost in producing coordinated information, and any number of documents can be generated from different combinations of model files.
- **Benefit from processes digitalisation**: Providing a highly secure and neutral environment capturing a full audit trail of the built asset, facilitating reuse of information to support construction planning, estimating, cost planning, facilities management… Ownership of information remains with the originator, although it is shared and reused, only the originator shall change it. Administrators and IT professionals have better control of data and information, creating more security.

3.5.2 Key guidelines from ISO 19650

3.5.2.1 Information container statuses

In a CDE, ISO 19650 defines four main statuses[31] that follow the workflow and information

---

[25] ISO 19650-1:2018: "Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles". https://www.iso.org/standard/68078.html

[26] BIM maturity levels. https://www.designingbuildings.co.uk/wiki/BIM_maturity_levels

[27] "What's a Common Data Environment and Why It Matters [Infographic]", Autodesk Construction Cloud. https://construction.autodesk.com/

[28] "Cloud-based Project Management for Your Entire Organisation", Viewpoint a Trimble Organisation. https://www.viewpoint.com/en-gb/

[29] "Common Data Environment (CDE): What You Need to Know for Starters", Oracle Construction and Engineering Blog. https://blogs.oracle.com/construction-engineering/common-data-environment-cde-tutorial

[30] "What is a common data environment (CDE) in construction?". Oracle. https://www.oracle.com/industries/construction-engineering/what-is-cde-and-bim/

[31]"Common data environment CDE", BIM Wiki Home. https://www.designingbuildings.co.uk/wiki/Common_data_environment_CDE

management:

1 Work in progress (WIP): this area is used to hold unapproved information for each organisation;

2 Shared (or client shared) area: this information has been checked, reviewed and approved for sharing with other organisations, perhaps including the client;

3 Published: this information has been authorised or accepted by the client or their representative (often the lead supplier (designer/constructor)), and

4 Archive: this area is used to create a constant record of progress throughout the lifecycle as well as all transaction and change orders.

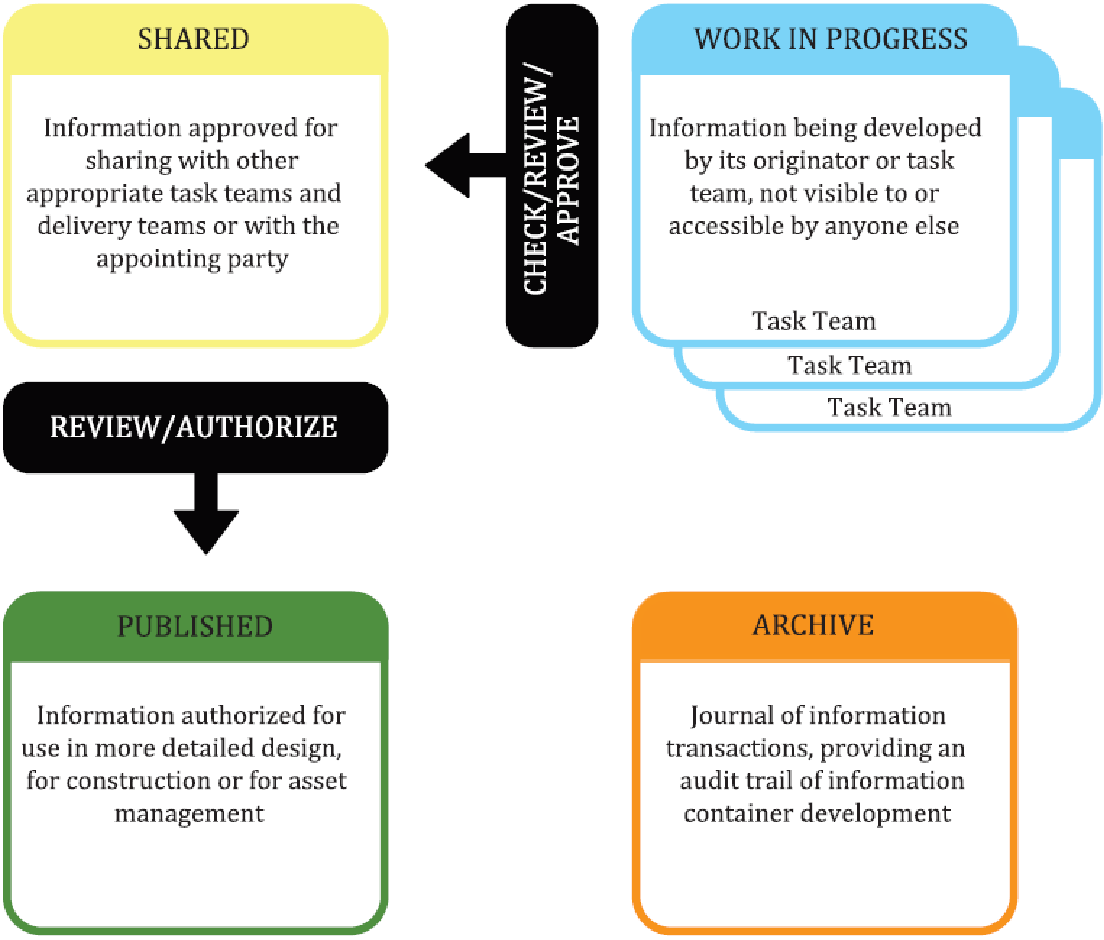


Figure 23: The Common Data Environment document approval statuses. Source: ISO 19650-1

3.5.2.2 Management through metadata

The ISO 19650 series makes it clear that authors keep strict control of their information throughout its development. It is recommended that this is achieved by the author using metadata assignment. This communicates what version the information container is at and the purpose for which it can be used.

ISO 19650-1 clause 12.1 recommends the following metadata assignment to information containers within a CDE:

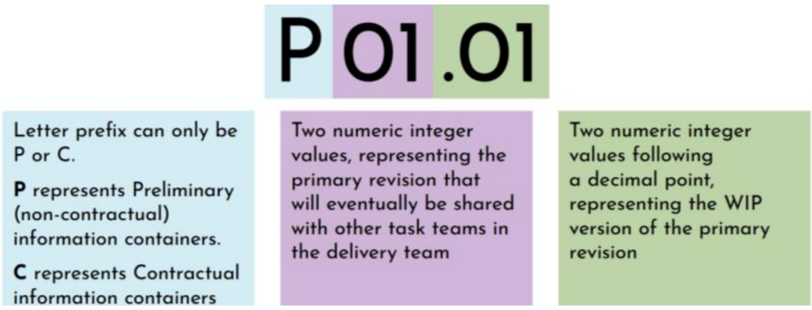
- **A revision code.**
- **A status code.**

ISO 19650-2 clause 5.1.7 then requires that the CDE enables assignment of these codes plus the assignment of:

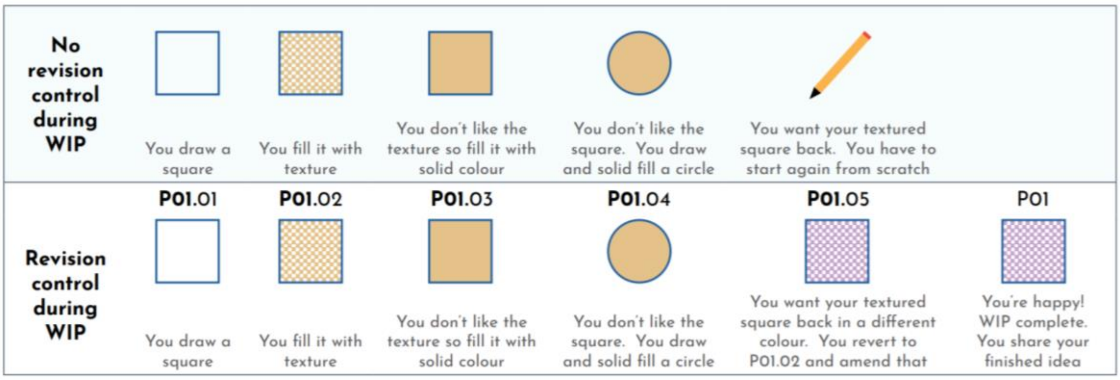
- **A classification code.**

The scope of the metadata assignment may expand beyond the recommendations and requirements of the ISO 19650 series, for example to include asset-focused information.

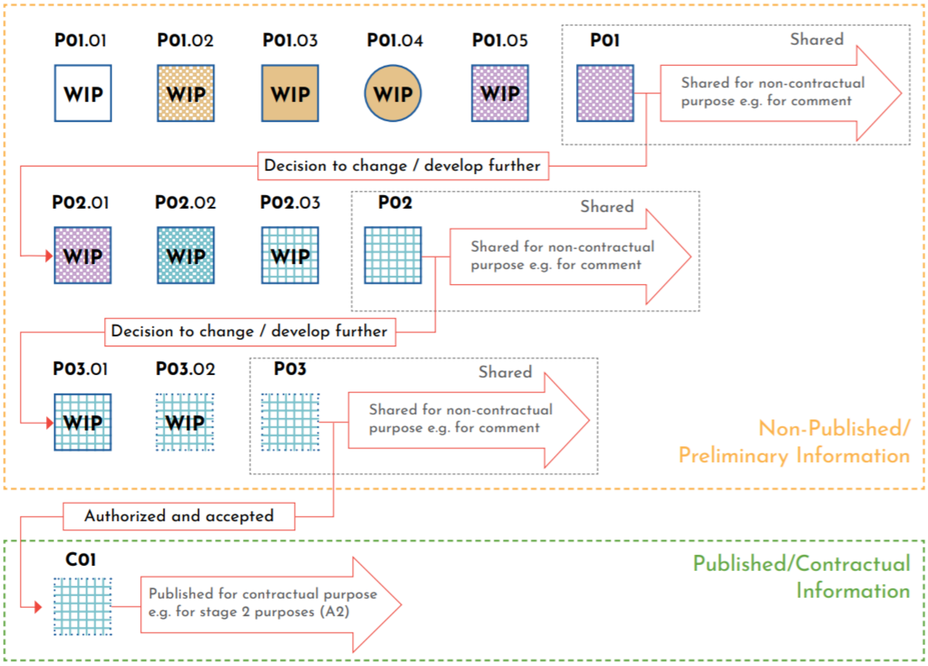
The ISO 19650-2 clause 5.1.7 requires that information containers be assigned classification metadata in accordance to ISO 12006-2. Uniclass 2015 is compliant with ISO 12006-2 and is the preferred classification system in the UK. It is referenced in the ISO 19650-2 UK National Annex. Uniclass 2015 contains multiple classification tables which can be used to classify different types of information containers.



a) Explanation of the ISO 19650-2 UK National Annex revision system.



b) WIP version control using the ISO 19650-2 UK National Annex approach.



c) Metadata for different states: WIP, Shared revisions and Published using ISO 19650-2 UK National Annex approach.

Code	Description	Revision
Work in progress (WIP)		
S0	Initial status	Preliminary revision and version
Shared (non-contractual)		
S1	Suitable for coordination	Preliminary revision
S2	Suitable for information	Preliminary revision
S3	Suitable for review and comment	Preliminary revision
S4	Suitable for stage approval	Preliminary revision
S5	Withdrawn*	N/A
S6	Suitable for PIM authorization	Preliminary revision
S7	Suitable for AIM authorization	Preliminary revision
Published (contractual)		
A1, An, etc.	Authorized and accepted	Contractual revision
B1, Bn, etc.	Partial sign-off (with comments)	Preliminary revision
Published (for AIM acceptance)		
CR	As constructed record document	Contractual revision

* Status code S5 is no longer used and has been withdrawn

d) Table 2: ISO 19650-2 Table NA.1 - Status codes for information containers within a CDE in the UK National Annex.

Figure 24: Information management according to ISO 19650. Source: UK BIM

Framework[32].

3.5.2.3 Information Requirements

There is a common industry misconception that the CDE is a technology solution only; ISO 19650-1 clause 11.1 clarifies that a range of technologies might be required but the most important aspect is the process or "workflow". It is this combination of "Solution" and "Workflow" that principally defines the CDE (see ISO 19650-1 clause 3.3.15 Note 1). Information Requirements management represents one of the main concepts of ISO 19650: BIM is a process of information delivery in accordance with requirements management coming from the systems engineering approach, developed for other industries. It includes:

- **Organisational Information Requirements (OIR) –** those pieces of information needed to answer or inform high-level strategic objectives within the asset owner/operator in relation to the built assets owned, operated, used or managed by them.
- **Asset information requirements (AIR) –** those detailed pieces of information needed to answer the organisational information requirements.
- **Project information requirements (PIR) –** those pieces of information needed to answer or inform high-level strategic objectives within the asset owner/operator or project client organisation, in relation to a particular built asset project.

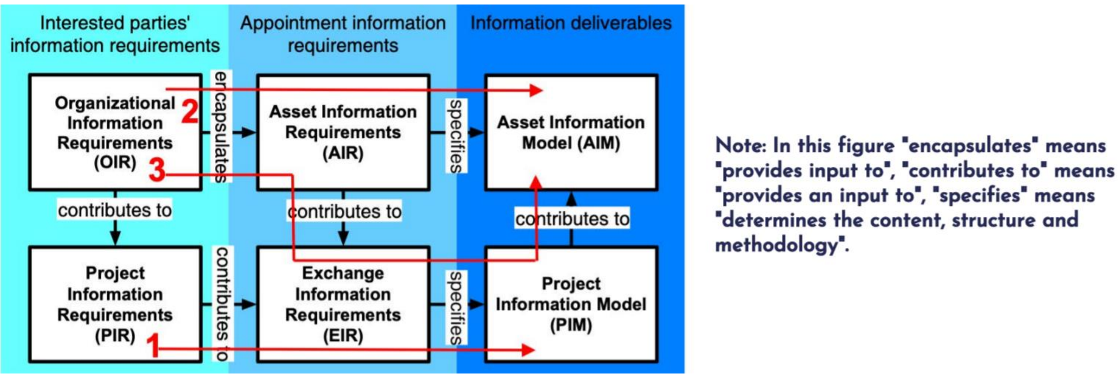


Figure 25: Different types of information requirements and information models, according to ISO 19650. Source: EFCA BIM Task Force[33].

[32] "Information management according to BS EN ISO 19650 Guidance Part C. Facilitating the common data environment (workflow and technical solutions)". Edition 1 September 2020. UK BIM Framework. https://www.ukbimframework.org/wp-content/uploads/2020/09/Guidance-Part-C_Facilitating-the-common-data-environment-workflow-and-technical-solutions_Edition-1.pdf

[33] "BIM and ISO 19650 from a project management perspective. BOOKLET ON ISO STANDARD 19650 Information management using building information modelling". European Federation of Engineering Consultancy Associations (EFCA). https://www.efcanet.org/sites/default/files/2020-01/390764_BIM%20booklet.pdf

3.5.3 Level of Information Need

To specify information requirements, ISO 19650 refers to the concept of Level of Information Need.

This concept is being standardised within CEN/TC 442/WG 2 (“Exchange Information”) in a series of standards of which only the first part is known as a draft prEN17412 (2019) “Building Information Modelling - Level of Information Need - Concepts and principles”. Overall, the series of future standards will help to define what is required from a BIM in terms of precision and information:

- the purposes of the information to be delivered
- information delivery milestones for the delivery of the information;
- actors who are going to request and deliver the information;
- how detailed objects should be modelled in one or more breakdown structures for the same family of objects:
    - LOG Level of Graphics (what is needed +precision of detail);
    - LOI Level of Information: Alphanumerical information (properties, requirements)
    - DOC Documentation (any document needed to be attached with extra information or metadata)

There are also local initiatives aiming at better defining level of information needs (e.g. “BIM ILS” in the Netherlands, “Modelleerrichtlijnen” in Belgium).

3.5.4 Towards machine-readable information requirements, IDS

There are parallel works at CEN/TC442 and bSI on Information Delivery Specifications (IDS). IDS intend to enable the definition of information requirements **in a semantic and machine-readable way**. A project specific IDS can be used as the contract for delivering semantic data. Authors can use the IDS to check the content before it is stored, and clients can automatically validate if the needed data is available.

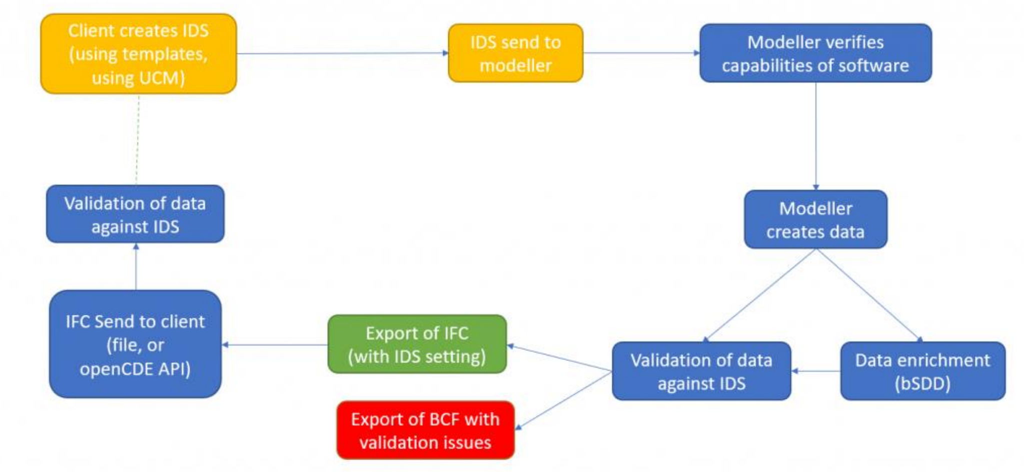


Figure 26: process for the use of Information Delivery Specification. Source: bSI

3.5.5 Other references

Finally, we can also mention the VISI[34] open norm for digital communication and information exchange in construction projects, developed by the CROW institute in the Netherlands.

4 Pillar 2: control over the use of data

4.1 Data storage, security and sovereignty

4.1.1 A security-minded approach

Because of the move towards higher levels of integration between sectors, there is a need to address inherent vulnerabilities and take appropriate and proportionate measures to protect:

- built assets and environments;
- personnel and other occupants or users of built assets, including the built environment's citizens, encompassing residents, business, visitors and commuters;
- data and information, including that which is commercially sensitive or constitutes intellectual property; and
- societal, environmental and/or commercial services.

This requires a "security-minded approach"[35] able to understand and routinely apply appropriate and proportional security measures in any business situation to deter and/or disrupt hostile, malicious, fraudulent and criminal behaviours or activities. As a summary, it is a holistic approach, taking into consideration personnel, physical, cyber and cross-cutting security, overseen by good governance with clear lines of responsibility and accountability.

The successful implementation of a security-minded approach relies on organisations recognising the potential issues and working with their supply chains in order to protect and limit access to the detail of, and information about, sensitive assets.

ISO 19650-5:2020[36], in its Part 5: "Security-minded approach to information management", specifies the principles and requirements for security-minded information management at a stage of maturity described as "BIM according to the ISO 19650 series", and as defined in ISO 19650-1, as well as the security-minded management of sensitive information that is obtained, created, processed and stored as part of, or in relation to, any other initiative, project, asset, product or service. It addresses the steps required to create and cultivate an appropriate and proportionate security mindset and culture across organizations with access to sensitive information, including the need to monitor and audit compliance. The approach outlined is applicable throughout the lifecycle of an initiative, project, asset, product or

[34] https://www.crow.nl/thema-s/informatiemanagement/visi

[35] "Security for digital construction". Centre for Digital Built Britain. University of Cambridge. https://www.cdbb.cam.ac.uk/AboutDBB/Security

[36] ISO 19650-5:2020: "Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 5: Security-minded approach to information management". https://www.iso.org/standard/74206.html

service, whether planned or existing, where sensitive information is obtained, created, processed and/or stored.

To address security issues, the GAIA-X initiative (see 4.2 below) promotes a security-by-design principle.

References:

- ISO 19650-5:2020 Part 5: "Security-minded approach to information management"
- ISO/IEC 27k series related to information security
- GDPR (General Data Protection Regulation[37])

Example of the Kroqi platform

In KROQI (see further references in § 8.3 below), the data storage of the EDMS is distributed on two datacentres located in France. A RAID 10 architecture, combining redundancy and data distribution, ensures optimal resilience of this infrastructure and prevents data corruption. For the Construction and middleware, it is hosted on Google Cloud servers in Western Europe, and benefits from the security procedures specific to these cloud services. KROQI uses digital certificates based on SSL technology. These certificates make it possible to encrypt data during exchanges. Besides, KROQI is being analysed by some state services in order to be registered for sensitive uses.

4.1.2 IT and OT security

Furthermore, due to the deployment of IoT devices, and to the increasing connections between digital twins and their physical counterparts, cybersecurity[38] is gaining importance for the construction sector. It is necessary to **address both IT (Information Technologies) and OT (Operational Technologies) together.**

This issue has not been developed during the discussions, but deserves attention for the definition of the strategy roadmap (WP6).

4.1.3 Data sovereignty

The use of international digital platforms and services by European construction stakeholders, including cloud services, raises the question of data sovereignty.

Construction digital platforms should ensure transparency on the guarantees they provide

---

[37] https://eur-lex.europa.eu/search.html?qid=1601637851922&text=gdpr&scope=EURLEX&type=quick&lang=en

[38] García de Soto, B.; Georgescu, A.; Mantha, B.; Turk, Ž.; Maciel, A. Construction Cybersecurity and Critical Infrastructure Protection: Significance, Overlaps, and Proposed Action Plan. Preprints 2020, 2020050213 (doi: 10.20944/preprints202005.0213.v1).

concerning both data ownership and data sovereignty

Furthermore, stakeholders should have the possibility to choose services guaranteeing data sovereignty. Ensuring the availability of such services, by offering an alternative to international services that might not comply with European requirements, is part of the rationale for public initiatives in developing European digital construction platforms (see §8.3.1 below).

Several initiatives aim to address data sovereignty issues, which scope does not limit to the construction sector:

- The GAIA-X initiative (see §4.2 below). The ecosystem promoted by GAIA-X "should allow both the digital sovereignty of cloud services users and the scalability of European cloud providers"[39]. Federation services proposed should include "sovereign data services which ensure the identity of source and receiver of data and which ensure the access and usage rights towards the data"
- The International Common Data Spaces Association[40][41], which aims to guarantee data sovereignty by an open, vendor-independent architecture for a peer-to-peer network which provides usage control of data from all domains. The association published a reference architecture model for the International Data Spaces

4.2 Connection with the GAIA-X initiative

As already highlighted in the previous section, there are strong common interests between the GAIA-X[42] initiative and DigiPLACE.

This section intends to:
- Introduce the GAIA X initiative
- List the common issues for the next steps (common use cases)
- Identify links and common requirements
- Discuss how the construction industry should be integrated in GAIA-X, and identify the relevant actions to be included to this end in the strategy roadmap

4.2.1 Introduction to GAIA-X

What is GAIA-X

"GAIA-X is a project initiated by Europe for Europe. Its aim is to develop common requirements for a European data infrastructure."[43]

[39] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html

[40] https://www.fraunhofer.de/en/research/lighthouse-projects-fraunhofer-initiatives/international-data-spaces.html

[41] internationaldataspaces.org/our-approach/

[42]. https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html

[43] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html

"With GAIA-X, representatives from politics, business and science from France and Germany, together with other European partners, create a proposal for the next generation of a data infrastructure for Europe: a secure, federated system that meets the highest standards of digital sovereignty while promoting innovation. This project is the cradle of an open, transparent digital ecosystem, where data and services can be made available, collated and shared in an environment of trust".

Representatives from seven European countries are currently involved in the project.

Why

"Within the GAIA-X project, we are developing the foundations for a federated, open data infrastructure based on European values. 'Project GAIA-X' connects centralised and decentralised infrastructures in order to turn them into a homogeneous, user-friendly system. The resulting federated form of data infrastructure strengthens the ability to both access and share data securely and confidently."

Who

- *French and German government*

« To keep the momentum which this project currently enjoys, we believe that the presentation to other EU Member States should take place as soon as possible using this Franco-German position paper as a basis. This does not preclude the Franco-German process to continue in parallel. »[44]

- *Who is involved and can join?*

"More than 300 organizations from various countries are already involved in GAIA-X. Still, the project is open to new European interested parties to join us in its development. Participation in the project is also possible for market participants outside Europe who share our goals of data sovereignty and data availability."

GAIA-X Use cases

GAIA-X aims to cover eight use cases: Industry4.0/SME, Smart Living, Finance, Health, Public Sector, Mobility, Agriculture, and Energy.

[44] Franco-german position on Gaia x. https://www.data-infrastructure.eu/GAIAX/Redaktion/EN/Publications/project-gaia-x.html

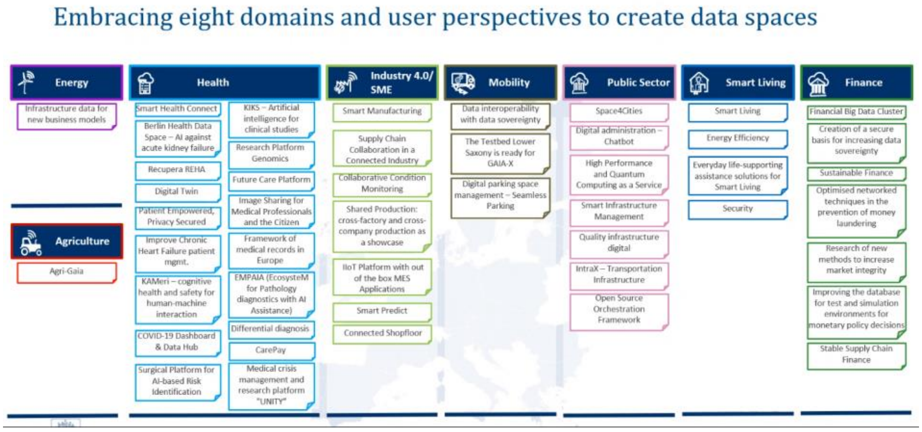


Figure 27:*GAIA X Use cases*

4.2.2 GAIA-X Architecture

GAIA-X is set to be an Infrastructure and Data Ecosystem according to European values and standards. This overall mission drives its architecture. It employs digital processes and information technology to facilitate the interconnection between all participants in the European digital economy. By leveraging existing standards, open technology and concepts, it enables open, consistent, quality-assured and easy-to-use innovative data exchange and services. Additionally, GAIA-X will become a facilitator for interoperability and interconnection between its participants, for data as well as services.

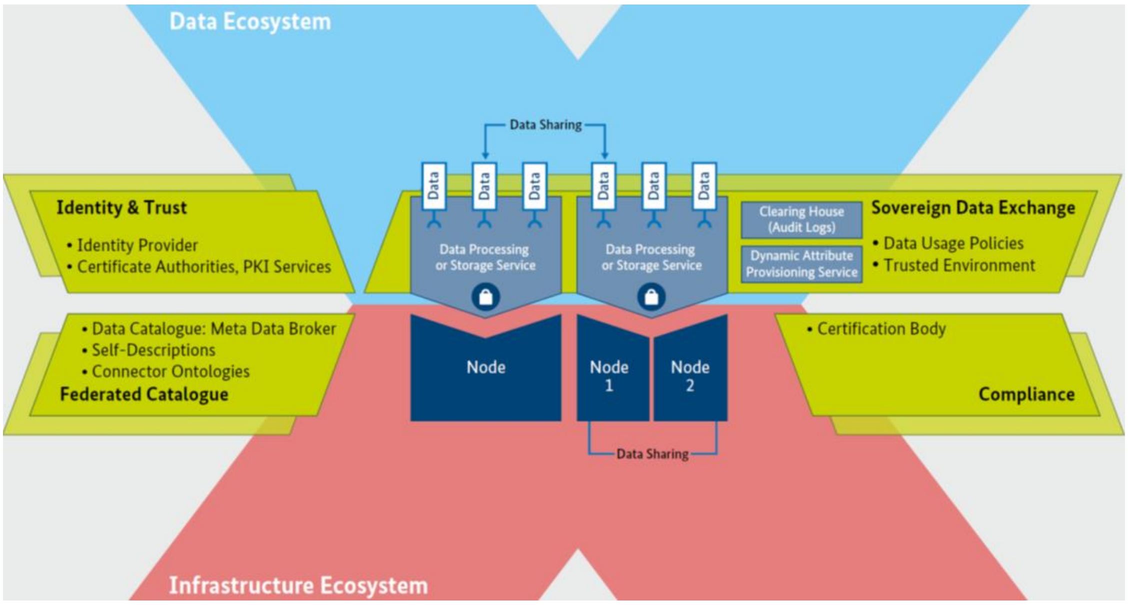


Figure 28: GAIA-X Data Sovereignty Services overview[45].

[45] "GAIA-X: Technical Architecture". Release – June 2020. https://www.data-infrastructure.eu/GAIAX/Redaktion/EN/Publications/gaia-x-technical-architecture.html

"The components can be provided interoperable across multiple nodes. The necessary interfaces, services and products should be harmonized by standards and be easily identified and used in a central repository for all participants."

Concretely, GAIA-X intends to provide federated services, which "technical implementation fill focus on the following areas:

- the implementation of secure federated identity and trust mechanisms (security and privacy by design);
- sovereign data services which ensure the identity of source and receiver of data and which ensure the access and usage rights towards the data;
- easy access to the available providers, nodes and services. Data will be provided through federated catalogues;
- the integration of existing standards to ensure interoperability and portability across infrastructure, applications and data;
- the establishment of a compliance framework and Certification and Accreditation services; and the contribution of a modular compilation of open source software and standards to support providers in delivering a secure, federated and interoperable infrastructure.

The initial set of federation services will be expanded. The roadmap is aligned with the development of ecosystem participants' requirements."

4.2.3 Links and convergence between DigiPLACE and GAIA X

There are important connections between GAIA-X and the present framework, in terms of:

- Use cases, in particular for GAIA-X use cased related to the public sector (Spaces4cities, InfraX-transport infrastructures, Smart City data platform) and Smart living (including energy efficiency)
- Issues addressed: standardisation, interoperability, data sovereignty, ownership, security, trust..

However, the construction sector is not identified as a target sector for GAIA-X, and related important keywords are missing from its strategy, such as digital twins.

4.2.4 Actions list

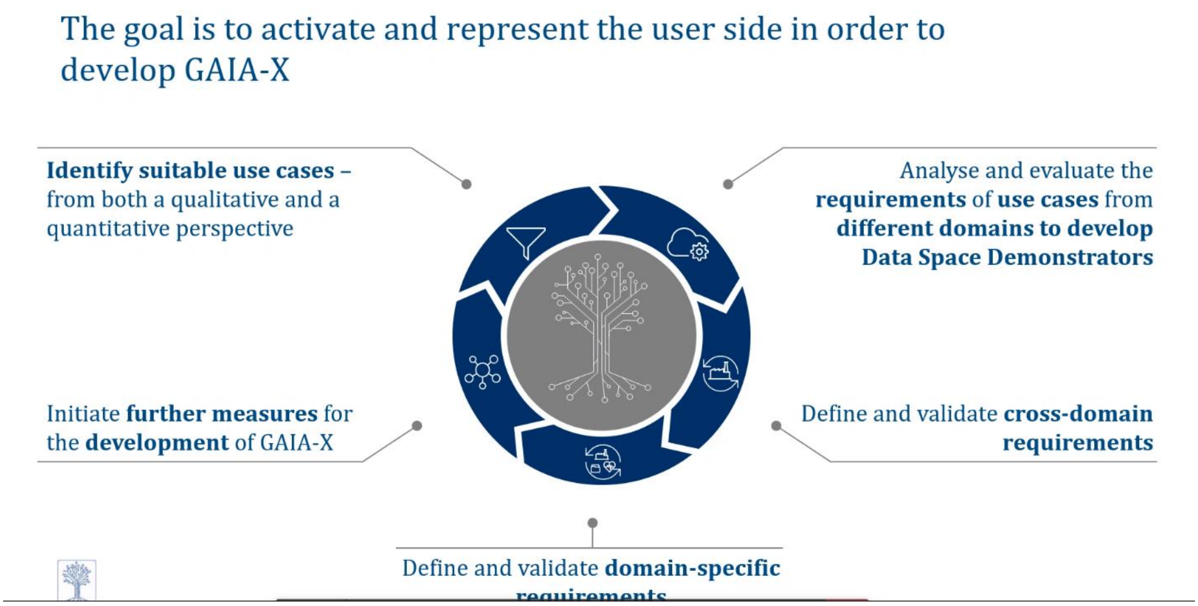


Figure 29: Expected involvement of users to identify and develop GAIA-X use cases. Source: GAIA-X

Proposed actions as part of the definition of the strategy roadmap

- A common workshop between GAIA-X and DigiPLACE would be of interest
- A proposal of common roadmap to seek convergence between the construction industry approach and GAIA-X

4.3 Data ownership

Several issues are identified in relation to data ownership:

- In terms of personal data, platforms must comply with GDPR (General Data Protection Regulation[46])
- In terms of business relations, construction stakeholders should have control over the use that is made of their data.

As identified in D4.5, many companies create and transfer data to different software solutions, and could be unconsciously creating added value for other (software) companies. They might also be training unwillingly AI-applications which can become one day the future competitors of these same companies, without ever being implicated or compensated).

After the debates that have taken place in recent years around these issues, many service providers

- [46] https://eur-lex.europa.eu/search.html?qid=1601637851922&text=gdpr&scope=EURLEX&type=quick&lang=en

display some guarantees on the fact that they do not use user's data, and that ownership remains to the user. Data is often encrypted, preventing other undesired use.

Transparency from software vendors should be generalized, through harmonized transparency requirements.

4.4 Data qualification and trust

The use of BIM and digital twin along projects and assets' lifecycle raises questions concerning data qualification ant trust: is the data reliable? who is responsible for editing it and keeping it updated? is it qualified/certified by a third party? Which version of the model should be considered?

This is of special importance for the data with contractual value. For companies that remain responsible for the construction (elements) long after construction completion, it is vital to stay in control of the final data/drawings, and that it complies with their intentions until the end (e.g. liability issues due to changes in the models).

ISO19650 principles for information containers statuses (see 3.5.2 above) and versions management contribute to address these issues, although many questions remain open.

The use of blockchain technologies and smart contracts is an important perspective.

As part of the identification of key use cases (see D5.1-§2.7), ACCA software mentioned several use cases for which they intend to deepen the use of blockchain technologies:

- protection of intellectual property, attribution and traceability of responsibilities,
- certification of processes,
- application of smart contracts to the construction process,
- monitoring and certification of data collection from digital instruments

A concrete example of the use of blockchain would be to certify and sign an IFC file to make it immutable over time.

AREA SPECIFIC GUIDELINES: LEVERAGE INTEROPERABILITY AND DATA SHARING N CONSTRUCTION

5 Environmental performance

Environmental Performance of the built assets is a broad topic, covering regulations, economical aspects, technology and even social aspects. The increased digitalization in the construction sector brings in significant impacts all along the life cycle of built assets, and their associated value chains. Indeed new, interoperable, software tools, web-based platforms and other digital systems play a key role in decreasing the impacts of our buildings and cities on the natural environment, from their planning and design, to their construction, actual operation, and eventually end-of-life.

Those applications have been addressed in DigiPLACE, under a deep investigation of the following topics: the widespread use of Level(s) framework (section 5.1), the Life Cycle Assessment methodology applied to the built environment domain (section 5.2), and the circular economy concept in the construction sector (section 5.3).

5.1 Level(s) EU framework

Launched officially at the end of 2020, "Level(s) is the first-ever European Commission framework for improving the sustainability of buildings, living by the values of flexibility, resource efficiency, and circularity"[47].

According to the official documentation[48], Level(s) is divided into three areas, each with its own subject matter and desired outcomes:

- *resource use and environmental performance during a building's lifecycle*
- *health and comfort*
- *cost, value, and risk*

This flexible, project-adaptable, user-focused, framework aims to be useful to a wide range of stakeholders, from planning, to design, financing and execution (Figure 30).

Figure 30: A new framework for all (extract from https://ec.europa.eu/environment/topics/circular-economy/levels_en)

---

[47] http://www.ectp.org/news-events-newsletters/news/news-detail/official-launch-of-levels-a-sustainable-buildings-framework-for-all-get-involved/, accessed on January 4th, 2021

[48] https://ec.europa.eu/environment/topics/circular-economy/levels_en, accessed on January 4th, 2021

The key initiatives envisioned by the EC for spreading this framework have been defined for 2020-2022. Amongst other, one can notice **the need to provide digital tools ("web-based support tool") enabling to inform as well as to use Level(s). Training is also expected**, which more and more rely on digital means (e.g. blended learning or e-learning).

This kind of applications directly refer to UC #1 *Access to frameworks, specifications and regulations*, where "access" refers to standardizing the presentation of information in the various platforms that might host it, so that the end-users are better guided in the search for information.

5.2 Life Cycle Assessment

5.2.1 Lice Cycle Assessment applications in the built environment

Life Cycle Assessment refers to a methodology enabling to quantify the environmental pressures, the trade-offs, and potential improvements considering the full life cycle of built assets from design to recycling.

"Because LCA takes a comprehensive, systemic approach to environmental evaluation, interest is increasing in incorporating LCA methods into building construction decision making for selection of environmentally preferable products, as well as for evaluation and optimization of construction processes" (Cabeza et al. 2014[49]). Various applications can be foreseen in relation with LCA from product scale, to building, building stock and even city levels. According to Cabeza et al., those applications might be related to e.g. construction products selection or building systems and construction processes evaluation. Specific applications have been researched as well for the early

[49] Luisa F. Cabeza, Lídia Rincón, Virginia Vilariño, Gabriel Pérez, Albert Castell, Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review, 2014, *Renewable and Sustainable Energy Reviews*, 29. https://doi.org/10.1016/j.rser.2013.08.037.

design phase by Zabalza Bribián et al[50] (Figure 31).

These various applications rely on tools and databases enabling impact assessment, and the authors note that so far, a multitude of methodological approaches are applied to case studies that remain hardly comparable.

Table 3
Application of LCA to the building sector [21].

Type of user	Stage of the process	Purpose of LCA use
Consultants advising municipalities, urban designers	Preliminary phases	Setting targets at municipal level Defining zones where residential/office building is encouraged or prohibited Setting targets for development areas
Property developers and clients	Preliminary phases	Choosing a building site Sizing a project Setting environmental targets in a programme
Architects	Early design (sketch) and detailed design in collaboration with engineers Design of a renovation project	Comparing design options (geometry/orientation, technical choices)
Engineers/consultants	Early design in collaboration with architects, and detailed design Design of a renovation project	Comparing design options (geometry, technical choices)

Figure 31: Users and purposes of LCA in early design phase

Still, LCA appears as a comprehensive methodology more and more applied. There is no doubt that it will be standardized either through a regulatory manner, at national or EU level, or through private certification schemes (Green Building Rating/Assessment schemes). **Therefore, several challenges are highlighted in relation with the need to 1) smooth the access to buildings products description and building characteristics data through the availability of adequate standards, 2) standardize the products' impact data and 3) their access through APIs. Moreover, decisions associated with buildings and cities are more and more expected to happen in real-time, so 4) the use of dynamic data is also of importance. As mentioned before, the 5) availability, transparency and flexibility of LCA applications' methodologies appears essential too. Last but not least the 6) increasing digital tools and databases enabling LCA for construction applications need some guidance and clarification for their users[51].**

In France, the upcoming new regulation on building environmental performance (RE2020) include requirements for both energy and LCA performance. It will provide an example of application of LCA calculation in a regulatory context. It is based on the dedicated INIES database for products' environmental data.

Besides the Life Cycle Assessment per se, the challenges identified above would also apply to **other schemes involving checking and assessment**, such as the Energy Performance assessment (to deliver the Energy Performance Certificates and other energy performance calculation associated with

[50] Zabalza Bribián I, Aranda Usón A, Scarpellini S., 2009, Life cycle assessment in buildings: state-of-the-art and simplified LCA methodology as a complement for building certification. *Building and Environment*, 12:2510–2520.

[51] The initiative to sort and classify LCA tools and databases published as part of Level(s) 2020 documents aims to clarify the scope of those tools and databases: https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581681499/Criteria_for_assessing_LCA_tools_and_data_v1-5.pdf. Accessed January 5th, 2021.

EPBD) which requires some level of **calculation methodology harmonization**[52],

5.2.2 Towards BIM-based LCA calculation

These challenges are associated with the ongoing and increasing development of IT solutions (software systems, web-based platforms) and align with the previously defined *UC #2 Checking and assessment processes towards environmental performance (incl. Level(s), EPC, LCA).*

Buildings LCA calculation relies on the availability of products' LCA data, with Environmental Product Declarations (EPD) being the most prevalent framework. There is currently an important knowledge gap between the world of LCA and the world of BIM, illustrated by Figure 32. In order to achieve BIM-based LCA calculation, works are underway to enable the use of EPD and other generic LCA data in BIM processes, through standardized machine-interpretable data sheet formats (**ISO/DIS 22057 - Sustainability in buildings and civil engineering works – Data templates for the use of EPDs for construction products in BIM).**

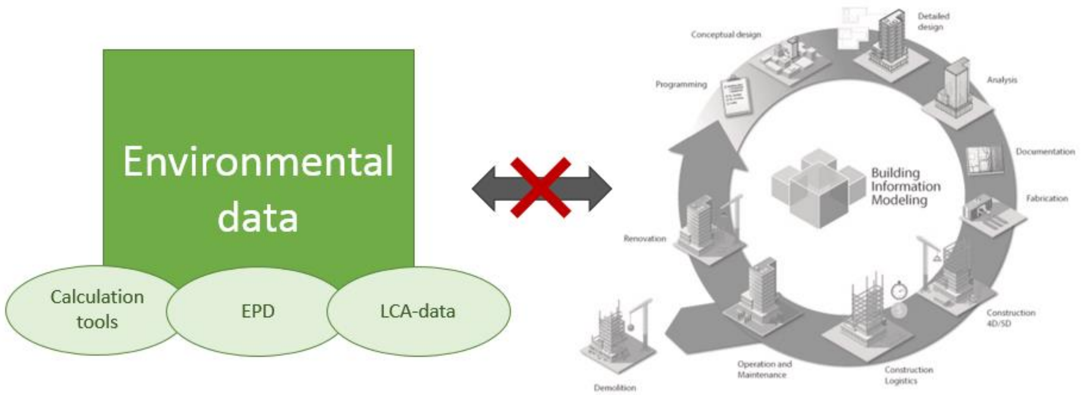


Figure 32: illustration of the knowledge gap between Environmental data specialists and BIM specialists. Source: Cobuilder

5.3 Circular economy in the construction sector

The Environmental Performance of the Built Environment also tackles the technical, economic and social ability to reduce its impact through limiting the extraction of resources and fostering their re-use through the promotion of a virtuous circle approach so that those resources are used in the most efficient, non-destructive way for as long as possible.

Nowadays, Construction and demolition waste (CDW) accounts for about 25%-30% of all waste

---

[52] In its EPBD Implementation Guidelines (2019) document, EPEE (European Partnership for Energy and the Environment represents the heating, cooling and refrigeration industry in Europe) strengthens the need to promote and uptake EU standards (Priority 3). It recommends the harmonization of energy performance calculation methods, through standardization at EU level, while it is mostly defined through national regulations at the moment. https://www.epeeglobal.org/wp-content/uploads/EPEE-EPBD-Implementation-Guidelines-2019.pdf, access January 5th, 2021.

generated in the EU[53]. CDW arises from activities such as the construction of buildings and civil infrastructure, total or partial demolition of buildings and civil infrastructure, road planning and maintenance. One can consider that ca. 50% of this amount is currently recycled in most EU countries, however the majority of CDW is destined for backfilling and other low value applications (downcycling). But for instance, in North-West Europe countries, the reuse and high-quality recycling (and even upcycling) of CDW remains below 3%.

Numerous challenges prevent a broad adoption of such deconstruction practices. First, they are usually relatively costly, compared to usual demolition, and require more time. There is also a limited sharing of technical knowledge and best practices associated with deconstruction projects so far. Moreover, the professionals lack tangible information on the potential value of the deconstructed products, and the absence of (regional) markets for those products is a barrier. The limits associated with the current status of the construction products regulations, and their application for re-used, recycled or upcycled products, is another important challenge.

Regulations, certifications and a poor digitalisation level of the construction sector are amongst the key factors hindering better exploitation of those existing construction products stocks.

Digitalisation is a priority to unlock the barriers mentioned above, enabling the instantiation of the circular economy principles in the building sector **through the vision of "buildings as (digital) material databank which gathers all information on materials (origin, volume, environmental data, etc.) used in a building from construction to disassembly".**

This concept is linked to the UC #3 Data spaces for environmental performance in construction described in D5.1.

5.3.1 Conditions for building(s) as digital material bank

This approach requires 1) documenting the products' properties, in a standardized way, and providing 2) information to ensure an optimal and efficient use during its lifetime. Besides, the 3) ability of disassembling and 4) envisaged re-use should be documented from the initial product design and production phase.

Given the highly fragmented value chain associated with the life of construction products, it appears clear that 5) a flexible management of this information is required. Workflows need to be adaptable, data management is required to be decentralized as core data can belong to several parties and again APIs need to be standardized.

The Product Circularity Datasheet developed on the initiative of the Ministry of Economy of Luxembourg[54] is a perfect example of such implementation. The structure of the document covers all these aspects, and follow the definition of the related ISO/CEN standards. Its implementation in machine-readable and BIM-compliant environments should rely on ad-hoc standards as well, especially when it comes to structuring the properties of construction objects and organizing information exchanges workflows.

[53] https://ec.europa.eu/environment/waste/construction_demolition.htm

[54] https://pcds.lu, access on January 5th, 2021. Current version of PCDS at the time of writing this deliverable is v3.2s.

SECTIONS		STATEMENTS (EXAMPLES)
1	GENERAL INFORMATION	
2	COMPOSITION	THE PRODUCT CONTAINS > 75-95 % POST-CONSUMER RECYCLED CONTENT BY WEIGHT THE PRODUCT DOES NOT CONTAIN SUBSTANCES OF VERY HIGH CONCERN FROM THE REACH CANDIDATE LIST IN CONCENTRATION ABOVE 0.1% BY WEIGHT
3	DESIGNED FOR BETTER USE	THE PRODUCT CAN BE MAINTAINED & REPAIRED BY UNTRAINED PERSONNEL AT THE LOCATION OF THE PRODUCT USE
4	DESIGNED FOR DISSASSEMBLY	THE PRODUCT IS DESIGNED TO BE INSTALLED AND DEMOUNTED USING REVERSIBLE CONNECTORS
5	DESIGNED FOR RE-USE	THE PRODUCT IS DESIGNED FOR RE-USE AS-IS OR WITH MINIMAL MODIFICATION THE PRODUCT IS DESIGNED FOR COMPOSTING IN A HOME COMPOSTER

Figure 33: PCDS Luxembourg, 5 major sections describe the key characteristics of product circularity

The key elements of the required IT system, underpinning the use of PCDS is depicted in Figure 34. It shows the importance of the underlying **data structure**, but also the need for **data converters** (ensuring the transfer of data across the various data management systems), **data aggregators** (in this case to aggregate a products' PCDS from several sub-components PCDS sheets) and **standardized APIs** enabling data requests amongst the systems.

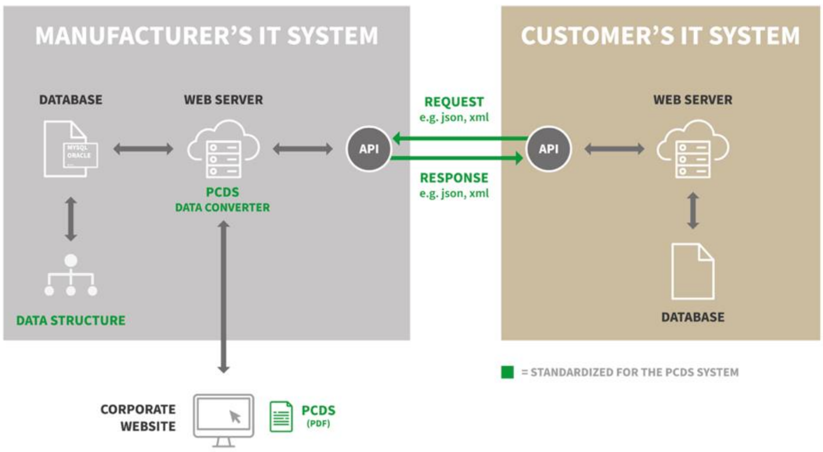


Figure 34: PCDS proposed IT architecture, extract from www.pcds.lu

5.3.2 Digital deconstruction

While this kind of initiatives primarily tackle new products and buildings, the deconstruction of existing buildings is of high relevance too.

Digital means can play several roles, amongst which:

- The development of **digitalised rigorous and collaborative processes** to deconstruction management, where digital information management would underpin the whole process, from initial inspections, materials' inventories to deconstruction scenarios and execution towards the further storage and reuse in new design projects.

- The support of **assessment methodologies of the key environmental and financial indicators** associated with the analysis of the deconstruction scenarios. In particular Life Cycle Assessment facilitated by BIM models can consider the emissions associated with the End of Life phase of the whole constructed assets down to their components/materials. This would directly inform the re-use / re-valorisation scenarios.
- The development of the **digital inventory tools based on 3D scanning technologies**, enabling rapid data collection on existing buildings (including AI, computer vision applied to objects recognition)
- The linking to the **BIM semantic model for the purpose of interoperability**, even including the generation of 3D BIM objects to be re-used in design software systems.
- The **evaluation of the re-use potential** based on the technical and practical analysis of the connections and the resulting disassembly potential for specific construction components.
- The development of digital marketplace platforms enabling the implementation of circular deconstruction on actual buildings / territories.
- The **securing of economic transactions**, relying on blockchain technologies and linked with the digital material passports.

5.4 Synthesis of guidelines associated with Environmental Performance

From the discussions and analysis of the various applications presented, the following guidelines have been established.

5.4.1 General guidelines

Considering the access (UC#1), checking/ assessment (UC#2&5) and repository (UC#3) features, the following general guidelines have been defined:

- Standards being key in the development and use of those digital systems, it is important to **streamline the access and the understanding** of this body of knowledge both to final users, but also to software developers who should implement it rigorously. Unified access (through public or private single points) might be provided. FAQs and examples might also be available freely and widely.
- **Interoperability of building datasets is a prerequisite** to various business applications. In the domains associated with EP, Open BIM IFC is required but might be associated to other formats like BEM formats (e.g. gbXML)).
- **Standardized manners to access IoT data (dynamic datasets) is also required** given the anticipated widespread of calculation methods requiring calibration from real datasets, and real-time performance assessment at operation stage.
- **Use of standards for describing buildings' products and components is essential** (according to principles describer in 3.2 above). Besides, the **Environmental Product Declarations (EPD) should also comply with data templates to be used in conjunction with BIM data** (ISO/DIS 22057).
- These products catalogues should be hosted in systems compliant with the **International Framework for Dictionaries (IFD – EN ISO 12006-3)** that allows all sorts of systems to take advantage of concepts that can be referenced from within a common framework.
- Those systems should also follow adequate implementation guidelines for data storage, including specifications of secured distributed systems enabling data access.

- Checking and evaluation tools should **document the applicable methodologies and information workflows in a standardized manner** (e.g. relying on standards like EN 15978 or harmonized EP calculation for the methodologies, and ISO 29481-1 and ISO 29481-2 for information exchanges)
- The tools should export the data (checking results / simulation) using **standardized presentations**, and even **provide APIs to feed public systems** (e.g. EPCs would be sent automatically to the national database systems).

5.4.2 Specific guidelines associated with generic dashboards of geoclustered buildings performance in EU (UC#4)

The systems enabling the dissemination, geoclustering and analysis of buildings performance are growing, serving several interests from private to public markets, and supporting national and EU policies. The following guidelines should be considered when designing such systems:

- The definition of **standard roles** for public/private users,
- The specification of the **querying capabilities** to enable e.g. cross Member States comparisons
- The **standardized visualisation**, including visual explanations of national characteristics e.g. in the calculation schemes, which will strengthen the appropriation and added-value to end-users.
- The capability for **automated reporting** to the Member States or the EC, e.g. for the establishment of reports

5.4.3 Specific guidelines associated with the Circular Economy

The following recommendations have been formulated from section 5.3:

- The need for **standardized product properties** structures (ISO 23386:2020, ISO 23387:2020).,
- Standards to follow (or perhaps establish) for **guiding the application of scan-to-BIM techniques** for the purpose of deconstruction. The expectation includes the required geometrical level of details and associated semantic enrichments required (LODs), and might take the form of a dedicated MVD.
- **Standards templates are required as well for the inventory of existing components**, and their re-use potential,
- **Standards for EPD declaration for 2nd hand** products should be available as well, considering that the usual EPDs are not specifically fitting this usage,
- **Geo-referencing of materials/components location and/or storage** is required to enable the development of 2nd hand product markets, through digital platforms

5.4.4 Other aspects to be considered

- The maturity of market stakeholders can strongly vary from one region to another. Hence, the deployment of digital solutions should take it into account, especially when new regulations or tools are requiring new computer-based procedures. DigiPLACE RAF guidelines should consider the **Digital & BIM Maturity assessment as a pre-requisite to the introduction of (mandatory) public software tools and platforms**.
- Training can attenuate the low digital maturity of certain actors. Recent means in Vocational Education and Training, like **elearning and blended learning** would contribute to disseminate

information and widely upskill the working force in the field of digital tools and platform for building's energy performance.
- The **sharing of best practices amongst Member States** has also been identified as an important recommendation associated with the RAF. Tools, databases or product templates for example, developed and used as Member States level, should be discussed and replicated through an EU-concerted process.

6 Large scale data sharing: European big data platform for the construction sector

In considering the European platform(s) for construction as a means to aggregate data and enable the development of innovative services, there are at least two aspects that need to be analysed and addressed in the platform(s) development.

First, the identification of what type of data may be involved in the process. Hence identifying relevant standards, existing sources and, where relevant, existing projects.

Second, the identification of the main layers/levels of data sharing, i.e. the analysis of how the data can be shared and what users are involved in the sharing process.

6.1 Types of data sharing

In this section a synthetic view of the data types that should be considered in the development of the platform(s) is reported. The following list aggregates the different sources and types of data, linking them to the main regulations and standards that must be used to define the data structure and, where possible, to examples of existing data sources and existing projects. It is not intending to be comprehensive, but rather to highlight the fact that data sharing in the construction sector happens in many different contexts, with distinct purposes.

Table 1: indicative list of typologies of data sharing in the construction sector

Data Type	Related regulations and standards	Examples of existing sources and projects
Data sharing on single Asset (project level)		
Data sharing within the project (CDE, collaboration)	ISO 19650-1:2019, ISO 19650-2:2019	Refer to D3.2 - Comparative analysis of existing platforms in the construction sector and in other sectors
Operation phase data (digital twin, maintenance, etc.)	ISO 19650-3:2020	Refer to D3.2 - Comparative analysis of existing platforms in the construction sector and in other sectors
Products data		
Manufacturers catalogues	EN ISO 23386, EN ISO 23387-	BIMrel (regional project – Italy)
Dedicated commercial catalogues	EN ISO 23386, EN ISO 23387-	BIMrel (regional project – Italy)
Declaration of performance	Construction Product Regulation (CPR)	BIMrel (regional project – Italy)

Smart CE marking	Construction Product Regulation (CPR), EN 17473 (smart CE), ISO 16757, ISO 16354, ISO 22014, EN ISO 23386, EN ISO 23387	
EPD databases (mostly national)	ISO 14025:2010, EN 15804:2019	Ecoinvent (international, private) EPD database environdec
Circular economy, Material passports, Cardle2cardle		BAMB2020 (H2020 project)
Other sharing of data within the scope of the supply chain		
Resources availability	-	
Costs	-	
Sharing of assets-related data beyond the scope of a single asset / organization (large scale sharing. Different sharing models are possible: B2B, Business to Governments…)		
Project data (design, costs, performance)		
Operations data		
Environmental performance data		
Sharing of other business data		
Public open data, data related to public services		
Building permit data		
Building logbooks - Data for the owner/user only		BIM4EEB (H2020 project)
Building logbooks - Data for public authorities (private to government)		BIM4EEB (H2020 project)
Building logbooks - Openly shared data		BIM4EEB (H2020 project)
Territorial data: geographical data, public infrastructures, utilities, open GIS data, territorial 3D data, urban digital twin, etc.	ISO 19115	
Transversal: environmental performance data		
Buildings (operations)		
Buildings (project)		
Products		
Territorial scale: regional, national, European		

6.2 Sharing levels

Considering the possibility to use platform as enables or services based on data captured from the industry, it is fundamental to identify the “sharing level” associated to each data type and/or each specific data according to the data source. Usually, the identification of sharing levels is based on two dimensions, i.e. the data type and the user type. Hence, for example, in a sharing environment defined ad project level a specific user can see, operate, upload, etc. specific data types according to his/her role. The same approach can be applied at higher levels, such as the ones covered by construction platforms. However, in this scenario the identification of users and data type should follow a more general approach. A first structure should be based on a three sharing levels, i.e. open data, statistical data, and confidential data (Figure 35).

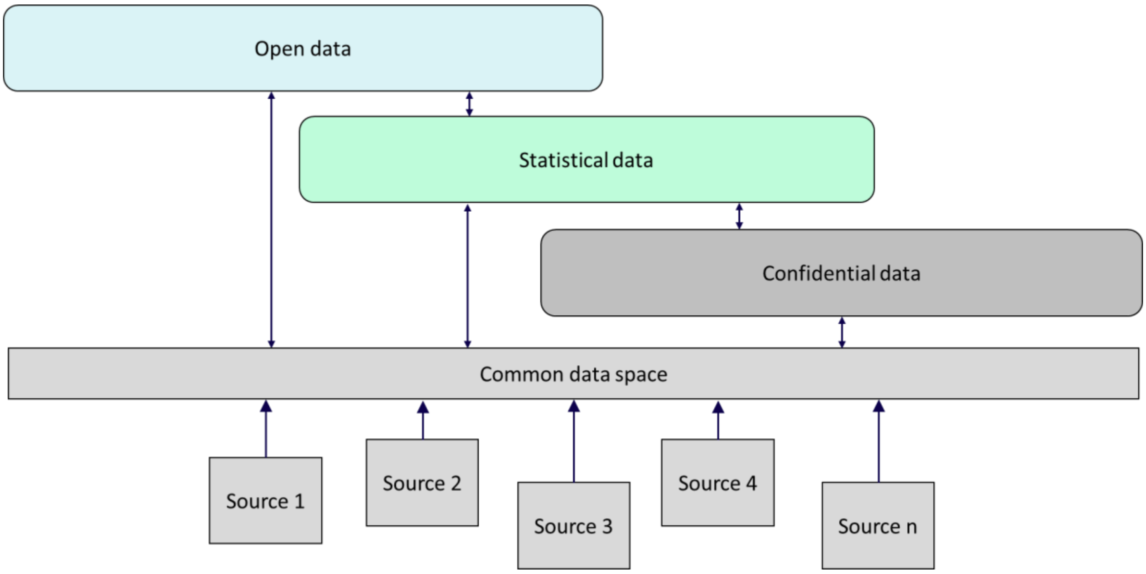


Figure 35: sharing levels structure

Each level is associated to specific data types and the accessibility is allocated according to the user types such as private companies, public administrations, associations, etc. As better explained in the next section where two possible scenarios are presented, according to this structure it is crucial to provide a) services that can allow the data accessibility also to stakeholders that are not able to work with raw data (supporting SMEs), b) open API and a standard data structure to allow data mapping between existing environments (common data environments, other platforms, public databases, etc.) and the European platform, c) maintain the control of data privacy on the users guaranteeing data security and data privacy based on users willingness.

6.3 Analysis of key scenarios

This section proposes two possible scenarios defined according to the previous classification of data types and sharing layers/levels.

6.3.1 Public sources scenario

Figure 36 represents the schematic structure and flow of a possible scenario based on public or open data sources. Starting from a public data source such as public databases, open data repositories, etc. (S1, S2, S3, Sn, etc. in the figure) the data structure of each source can be related to those defined in the platform identified as common data space in the figure. Being a public or open data source, the data can be assigned to a statistical data or open data level (flow 1 in the figure). The use of this data can be based on services already included in the platform or developed by third parties (public and/or private) that can exploit the data source to provide new services or simply provide services to facilitate the accessibility to the available data (flow 2 in the figure). Of course, there should always be a filter allowing public bodies in limiting the sharing of national sensitive data such as airports, police stations, etc.

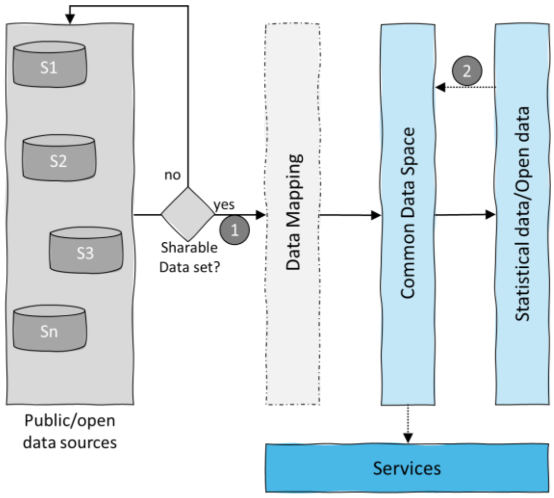


Figure 36: key scenario for public/open data sources

Table 2: SWOT analysis for the public sources scenario

Strength	**Weaknesses**
• Ad hoc services that can be based on statistical and open data. • One entry point to manage data from multiple sources.	• Need of ad hoc integration with existing data sources.
Opportunities	**Threats**
• Growth of services enabled by the platform environment. • Increase the digital culture of construction stakeholders. • European, national and/or regional regulations that can promote the opening of public data toward the platform.	• Willingness of public authorities in allowing data integration between existing system and the platform. • Willingness of software houses and other developers in providing connecting interface between their systems and the platform.

6.3.2 Private sources scenario

Figure 37 represents the schematic structure and flow of a possible scenario based on private data sources. Starting from a private data source such as a Common Data Environment (CDE) defined at project level, an ERP system of a company, etc. (S1, S2, S3, Sn, etc. in the figure) the data structure of each source can be related to those defined in the platform identified as common data space in the figure. Being a private data source, the data need to be checked by the data owner (i.e. who manage the data or who is the responsible for the data source) to identify what type of data can be shared according to the three level structure proposed (open data, statistical data, confidential data). Hence, the data can be shared with other as completely open or by statistical representation or, if confidential, can be used through the platform remaining accessible only for specific subjects as defined by the data owned or inherited according to the rules defined in the data source environment (flow 1 in the figure). The use of this data can be based on services already included in the platform or developed by third parties (public and/or private) that can exploit the data source to provide new services or simply provide services to facilitate the accessibility to the available data (flow 2 in the figure).

This perspective highlights two other critical needs of the platform architecture. First, it needs to related not only data but also rules from other environments. This is because for confidential data, the structure of permissions may be complex and already defined in the data source environment and it would be difficult to repeat it in another environment reducing the willingness from stakeholders to use the platform. Second, as already mentioned in the introduction, the platform needs to maintain the control of data on the data owner promoting transparency.

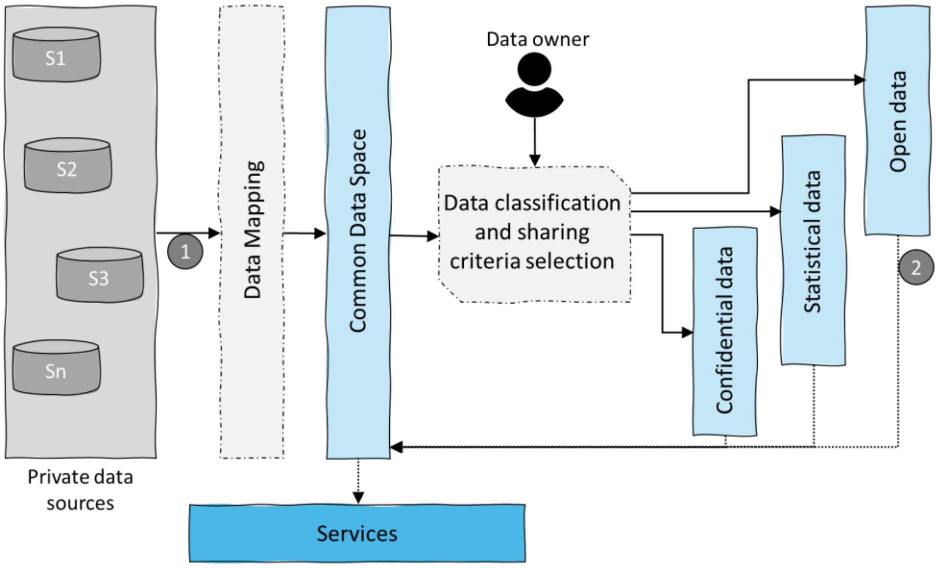


Figure 37: key scenario for private data sources

Table 3: SWOT analysis for the private sources scenario

Strength	**Weaknesses**
• Ad hoc services that can be based on confidential, statistical and open data. • One entry point to manage data from multiple sources.	• Competencies required to select and evaluated the data classification before sharing. • Need of ad hoc integration with existing data sources.
Opportunities	**Threats**
• Growth of services enabled by the platform environment. • Increase the digital culture of construction stakeholders.	• Willingness of private stakeholders to share their data. • Willingness of software houses and other developers in providing connecting interface between their systems and the platform.

6.4 Synthesis of related guidelines

Following the perspective of a European common data space for construction, the following guidelines should be considered in the development of platforms. It is worth highlighting that these guidelines can be used for the development of more than one platform that may be focused on a specific subset of data type and/or a specific type of data source. The following points should be considered in the reference architecture development:

- Need of services that can allow the data accessibility also to stakeholders that are not able to work with raw data (supporting SMEs).
- Need of open API and a standard data structure to allow data mapping between existing environments (common data environments, other platforms, public databases, etc.) and the European platform.
- Maintain the control of data privacy on the users guaranteeing data security and data privacy based on users' willingness.
- Need to relate not only data but also rules from other environments and/or data sources.
- Data sharing should be based on three main levels, open, statistical and confidential. Confidential level should be controlled according to permissions that can be inherited from data source environments.
- Large scale data sharing should rely on the existing Common European Data Spaces, and the GAIA-X initiative (see 4.2 above).

7 Business, market and collaboration

7.1 Interoperability between platforms and tools for improved collaboration

7.1.1 The ambition to configure collaborative platforms like a LEGO

To comply to the EIR (see §3.5.2.3 above), project partners need to setup a delivery approach. In the BIM execution plan, several use cases will be selected and described to support primary processes. Project partners will select and detail use cases based on capability and return on investment considerations. Delivery processes need to be detailed, information exchanges to be agreed and planned. Applications need to be selected and configured and interoperability between solutions is to be checked.

As project team compositions differ between projects, a "LEGO" vision is proposed, enabling the following:

- Each partner can bring in its applications and services, libraries and platforms.
- Predefined Processes and Exchange Requirements, based on the selected use cases, can be deployed and configured to project specific needs
- Open applications and services can be configured easily based on the selected use cases.
- Routines to verify the exchange requirements are automated
- The **Business Process Model and Notation (BPMN)**, supports the orchestration of tasks to be performed by partners and services.
- Platforms and tools support not only a chain of tasks, but iterative processes and exploration of many variants
- SME's are capable of setting this up themselves.

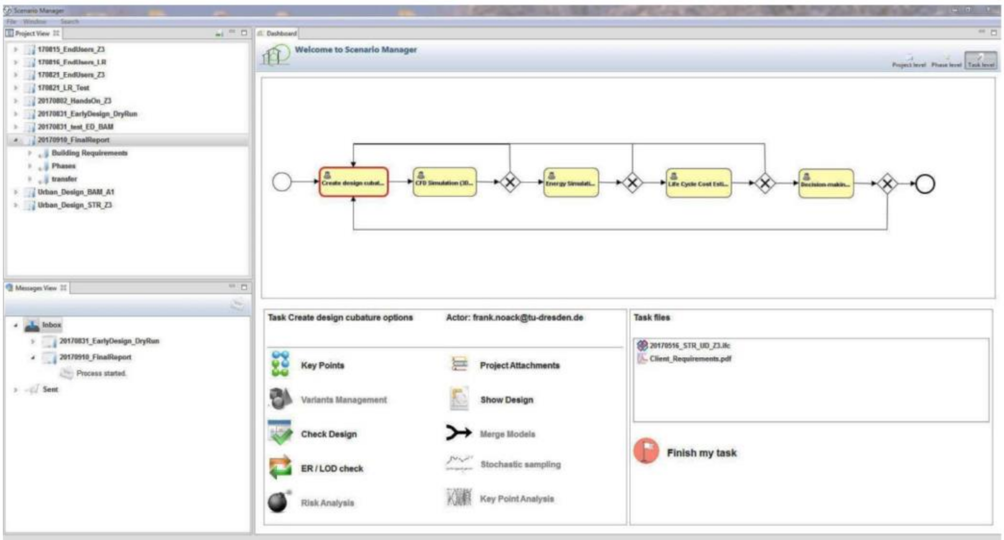


Figure 38: Scenario Manager from EEEmbedded[55] project – orchestrating tasks and services based on use case BPMNs

7.1.2 Challenges to address

Towards this "LEGO" ambition, several challenges need to be addressed, and the gap with the as is situation needs to be precisely characterized:

1. **BIM execution plans remain word documents and Exchange Requirements are defined with big EXCEL tables as annexes.**

The purposes per ER are not always clear / checking outputs and inputs against the ER is to be configured. LOIN specifications start considering the purpose of the exchange requirement. The sum and consistency of LOINs for all purposes in a phase will be of interest.

2. **It's too complex and time-consuming (for big companies & SMEs) to setup BPMNs, exchange requirement specifications, MVDs (specific per task, per use case), seek alignment for a chain of use cases, per project and team composition.**

Besides this, actors rely too much on their own MVD implementations, maintenance and MVD interoperability is not guaranteed. Standard, commonly understood, exchangeable and configurable IDM components appear necessary.

- The Information Delivery Specifications (IDS) developed by bSI (see §3.5.4 above) will allow for more dynamic / specific MVDs. IDS and LOIN developments are related.
- The recently adopted standard EN ISO 21597 "Information container for linked document delivery" (ICDD, see §3.3.2 above) allows to leverage on richer and semantic interoperability with multiple formats.

[55] Source document EEEmbedded project – D10.400 Final Project Report

- The semantic modelling standard CEN/TC 442 / prEN 17632 mentioned in §3.4.3 above contributes to address issues with data interoperability

3. Gaps between BEP, MIDP/TIDP (Master Information Delivery Plan and Task Information Delivery Plan as mentioned in ISO19650) support tools, Exchange Requirement specification and MVDs specification tools need to be addressed.

Besides that, it is difficult to share and re-use the existing IDMs and MVDs. BPMNs should be more than a swim lane visualisation with tasks and positioning of exchanges - they should actually support the orchestration of tasks for actors and services, as part of the collaboration platform(s).

- A study[56] under bSI umbrella reviewed existing efforts, identified gaps to achieve an integrated process, and proposed the development of an IDM configurator and a framework for an integrated IDM/MVD specification and delivery process and proposed future steps.

4. To Re-use IDMs, a central location with a collection of IDMs is needed.

- A collection of IDMs based on ISO 29481-1: 2016. is currently available / built up by a community of experts under the umbrella of buildingSMART. The project titled "Use Case Management" was initiated and developed by buildingSMART Switzerland. Home | Use Case Management (buildingsmart.org)
  Use cases descriptions include a GUID and title, list benefits, objectives, list basics and distinctions, have attachments and contain links to more detailed information
  Users can search and filter on language, bSI chapter, sector, status, maturity Grad and lifecycle stage and get access to more detailed IDM information
- An older collection can be found via this link. https://technical.buildingsmart.org/standards/information-delivery-manual/idm-database/

5. **Collections of use cases highlight the need for a shared use case taxonomy and syntax**.

Without a shared classification and grammar for use cases, it is likely that miscommunication will continue in the sector, and that setups per project will continue to take too much time.

The reasoning is the following:

- There are manifold processes for planning, building and operations
- Many processes in the sector build on each other, processes are interlocked and interdepend
- Collaboration supported by a smooth information flow will only function if all involved parties share a common understanding of the processes.

[56] https://forums.buildingsmart.org/t/idm-configurator/380/6

See also this video on Information Delivery Manual (IDM) Configurator: Previous Efforts and Future Work

Use cases description involves the following:

- Use cases describe in general what results and performance the user expects from the process and systems
- More detailed technical descriptions describe how this performance is achieved
- Practitioners state a practice-oriented breakdown of use cases purposes, shared by all parties involved at sub-process levels is required to achieve common understanding and be able to link processes digitally.

In the current situation:

- with several available lists, digital construction organisations try to create an overview of BIM uses, b functions, model uses, use cases etc

Figure 39: illustration of available lists of BIM use cases, from 3 sources: BIM4INFRA (Germany), bSI Use Case Management, and a scientific publication

- National / international use cases descriptions are not coordinated
- A common definition of use cases is not available
- Syntax and classification are missing, causing a lack of common understanding

Several construction companies are starting to work on proposals towards a common syntax and classification for use cases. Supporting position papers are under construction in associations like HDB (German Construction Industry) and Encord, and discussed with FIEC, and standardization bodies (ISO and CEN).

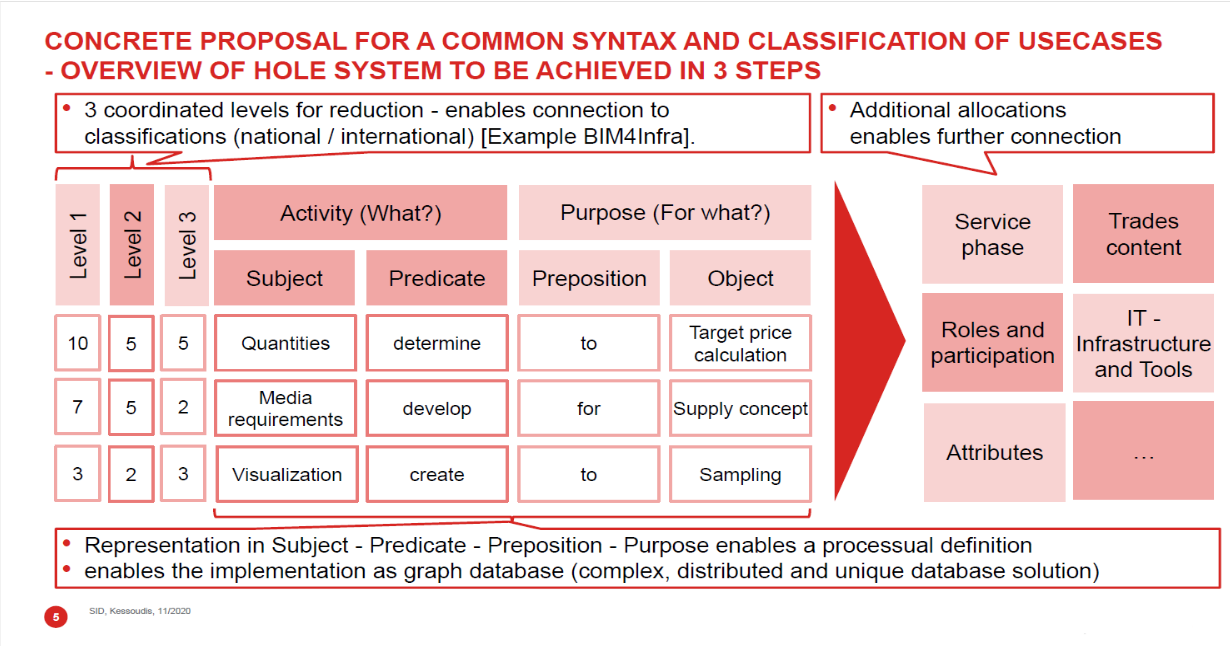


Figure 40: illustration of the initiated works towards common syntax and classifications of use cases

The proposal suggests a 3-step approach:

- Step 1: Define a common Syntax and classification
- Step 2 Definition of Semantics. The bSI Use Case Management environment could serve as the central location
- Step 3: Stepwise implementation of detailed information per use case, and creation of a base for ontology

6. **Verification of exchange requirements (types and values) is no guaranty for a compliancy with regulations and KPI's set by the project organisation.**

Verification of exchange requirements and verification of performance requirements are mixed up in various developments. Requirement decompositions, reasoning of (calculated) performance requirement, KPI definitions need to be captured in a structured manner. A plug and play platform should provide the ability to instantly verify applicable regulations and KPIs.

To this end, the AEC industry could build on **Systems Engineering Methodologies**[57], which are

[57] See:

- The Guideline for Systems Engineering within the civil engineering sector
- SE Standards (incose.org)

well known to other industries AEC is benchmarked with. The methodology would put several discussions in other perspectives and become a driver in quality assurance and product development.

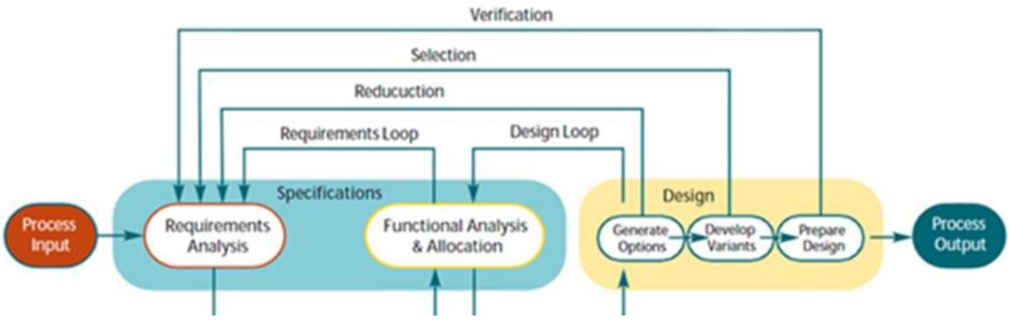


Figure 41: Illustration of the System Engineering approach – detailed process model by RWS (source: Leidraad System Engineering, RWS, 2009, page 41)

7.2 Link with ERP and CRM tools

7.2.1 Need of interoperability between BIM tools and financial management systems

The following requirement was identified in D4.5: *[…] platforms should combine construction, accounting, and financial aspects. In fact, SMEs usually do not have the capability of forecasting margins and they end up offering price quotations on an approximate way. Thus, digital software should be interoperable with financial management software to allow foreseeing an exact use of construction materials and give exact price quotations to clients.*

Interoperability, or proper configuration between BIM collaborative tools and financial management systems can help address this issue in several ways:

- Model based estimations can improve estimation accuracy, estimation recipes being filled with more accurate quantities and QTO from models allowing for more distinct groupings and use of more specific key figures.
- Key figures can be improved when actors improve accuracy of progress monitoring and allocation of resources and earned value methods are deployed.
- Historical data can be used better

Further guidelines are proposed:

- International benchmarking could also be improved by the use of ICMS International Construction Measurement Standards[58].

- A study on SE maturity in Dutch Civil & Building industry

[58] International standards and data for a global construction industry

- Electronic Data Interchange (EDI) standards should also be used to streamline communications between suppliers, wholesalers, construction- maintenance, MEP services providers and banking systems – and so contribute to accuracy of price quotations
- Digital exchange and processing of formal communication and transactions should be supported and automated. Examples: quotations, pricelists, conditions, products data, orders, order-conformations, QR codes, packing slips, and invoices.

7.2.2 Development of ERP and CRM tools in the construction sector

A vision of the current transformations of the construction industry couldn't be complete without addressing the evolutions of Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) tools.

Perspectives surrounding ERP tools have been described in D5.1-§3.8.5. ERP also iclude Supply Management Systems (SMS) and Product Lifecycle Management (PLM).

As identified in D4.4-§4.3.4, ERP systems found their way in the main architecture and engineering offices as well as with large contractors, and offer major advantages. But unfortunately, SMEs are again confronted with investment gaps and most often do not benefit from the technology. Furthermore, proper implementation is an issue for the diffusion of ERP solutions, and several studies focus on the analysis of best practices, experiences, etc. from the industry and the academic field.

ERP systems are usually based on relational or object-oriented databases developed according to proprietary structures where the physical structure, i.e. the organization and the construction of relations, methods, classes, etc. is in the knowledge of the provider company and not of the user. Hence, the difficulties in switching from one solution to another and to integrate new solutions that have not been already analysed and managed by the provider company. This could generate extra costs that in many cases hinder the creation of integrated flows, generating inefficiencies and lowering the impact of innovative solutions.

The integration of BIM in construction companies is one peculiar example of this issue. The information related to costs, costs analysis, scheduling, etc. are generated and managed using ERP solutions and it is difficult to create a dialog with information models to generate time and cost analysis (4D and 5D) that are coherent with the real structure and organization of the company.

On the other side, ERP solutions are moving towards the development of APIs that can be used to create integrated flows of information from one system to another. This trend may facilitate the development of integrated process. It relies on increased cooperation between the construction sector and the IT one.

Currently, there are some examples of BIM platforms able to operate in relation with other corporate information systems[59].

---

[59] Some examples on the market are:

.- BIM 360 & Enterprise Resource Planning (Microsoft Dynamics NAV): https://www.autodesk.com/autodesk-university/class/How-Handle-Hundreds-Projects-BIM-360-and-Integrate-ERP-2018#handout

.- IB Building 365- Microsoft Dynamics 365 Business: (in Spanish) https://youtu.be/PTV2VymUHeA?t=670 and https://www.ibermatica365.com/integracion-microsoft-dynamics-365-con-building-information-modeling-bim/

7.3 Digital supply chain and construction 4.0

7.3.1 Perspectives of digital supply chain

As identified in D4.5, platforms should facilitate the communication with the supply industry (technical data, costs, delivering dates, …). Digital communication could be stimulated, and new services can be triggered (customized production, grouped logistics etc.). As part of D5.1-§2.7, several of the identified key use cases of future construction digital platforms relate to this perspective: optimisation of the supply chain based on the integration of manufacturers' objects into BIM models, and integration of construction equipment in digital supply chain. The use of BIM models to **manage the link between design and manufacturing of pre-assembled elements** was also mentioned.

To gain a better view of the potential of transformation in this field, several references can be mentioned:

- Mc Kinsey's paper "The next normal in construction", June 2020
- BBRI prospective works
- Alain Waha and Sumit Oberoi's white paper "COVID-19 Stimulus for industrialised construction"
- The connected factories project, supported by the European commission through the factories of the future PPP (https://www.effra.eu/connectedfactories)

7.3.2 Object libraries and catalogues, use of BIM objects in construction projects

7.3.2.1 Generic objects and manufacturers' objects, processes

BIM objects include both generic objects, and objects representing specific manufacturers' products.

The generic objects are used in upstream design stages, and are assigned requirements or proposed performances. This raises a first set of questions: how to harmonize this process ? How to keep track of requirements and proposed performances ?... As already mentioned in 7.1.2 above, performance requirements and KPI definitions need to be captured in a structured manner. Further works are need on this point.

Libraries of generic objects are developing, often in connection with the design tools.

At a certain point in the design process, the generic objects with requirements or proposed performances, have to be replaced by commercially available products.

7.3.2.2 Use of standards for object catalogues and libraries

One of the key evolutions expected from the transition to BIM relates to the **use of BIM objects from manufacturers' catalogues**, which is likely to have wide-ranging implications on the supply chain: better use of products performance data to prescribe/choose construction products, cost estimates, management of invoicing and payments, link between design and manufacturing. For manufacturers, it could become a key aspect of marketing strategies, and could also present other benefits, such as a better forecast of demand.

Many of the challenges related to the development of BIM objects libraries and catalogues lie in standardisation issues, and have been developed in §3.1.5 above.

Indeed, as described in D5.1, §3.6, the BIM objects of industrial manufacturers are usually available on their websites or in dedicated libraries, public or commercial, used by operators to acquire the components they need in the a model, when the information is available. These include, for example, the NBS National BIM Library in the UK, or other commercial libraries (e.g. https://bimetica.com/, https://www.datbim.com/, https://www.bimobject.com/nl/product, https://cobuilder.com/en/).

Other objects, on the other hand, are modelled directly by professionals (e.g. the production systems to be formed on site aggregating multiple individual products) and constitute the knowledge of the latter. Each actor in the process, therefore, has its own library for its own models.

Currently, each library - public, private or commercial - uses its own rules for modelling and attributing properties to the objects. This makes it difficult for manufacturers to publish and keep their products / objects updated on the various libraries and, for users, to use different objects if they come from different libraries because they are not congruent with each other in terms of quality and quantity of data contained.

The export of objects in IFC, generally guaranteed by all libraries, obviously ensures the presence of data (exportable) but their non-parametricity (IFC objects) makes it difficult to actually use them directly in the models.

7.3.3 Machinery data

The need to facilitate the exchange of information between suppliers and users, and the perspective of integration in an integrated digital supply chain, also extends to construction equipment and machinery.

Besides BIM, simple evolutions are also required, such as a better availability of technical manuals through libraries. The ongoing revision of the Machinery Directive needs to be considered here, with possible provisions concerning technical manuals.

7.4 Fair competition, level playing field

As mentioned in the introduction, creating a **level playing field** for the digitalisation of the construction sector is one the objectives of the present framework. This applies to construction stakeholders, to digital services providers, and to the relations between them, to ensure that evolving business models guarantee a **fair distribution of the value across the value chain**.

By enabling the creation of open digital environments, several principles developed in the core guidelines contribute to this goal such as interoperability and the use of open standards. Transparency on data ownership issues by software providers is also part of the answer.

In §8.3.1 below, we develop the idea of setting up open platforms for BIM and other digital services, which are made possible by the very existence of these standards. As developed, the rationale for such platforms include their possible contribution to setting up a level playing field, in different ways:

- Ensure fees and access conditions adapted to all stakeholders, esp. SMEs
- In direct relation to the previous point, provide all stakeholders with an access to a set of BIM services allowing them to answer the requirements introduced in public procurement related to the use of BIM (see §8.2 below), to ensure an equal access to tenders to all players
- Create a platform opened equally to all digital services providers, independently from the big proprietary platforms, and guarantee an access to market for new entrants
- Avoid market capture by some players
- Reinforce the ecosystem of European digital AEC services

7.5 Contracts and faith

7.5.1 Standardisation of BIM-related contracts

The goal behind contracts standardisation is to secure procurement, and to provide harmonized contractual approaches to support the widespread adoption of BIM.

References:

- BBRis templates for protocols (contractual agreements) and BIM execution plans (non-contractual agreements), as part of the ClusterBIM initiative. They are based upon EN ISO19650, with a pragmatic approach

7.5.2 Enable Integrated Project Delivery Approaches

The advances in BIM processes CDE capabilities (§3.4 above) will be a key enabler to support the development of **integrated project delivery approaches**, which was identified as one of the key use cases of digital construction platforms (see D5.1, §2.7).

References for include the Integrated Projet Delivery concept, or the Alliance procurement model[60].

7.5.3 Smart contracts and blockchain

As already mentioned in §4.4 above, the use of smart contracting and blockchain technologies is promising to help address contractual issues related to the use of BIM: data certification, attribution and traceability of responsibilities, IPR….

[60] See for example :

- https://leanipd.com/integrated-project-delivery/
- https://www.researchgate.net/publication/334286238_Alliance_Procurement_Promises_Truths_and_Behaviours

7.6 Skills

The reskilling of the workforce to adapt to the digital transformation of the sector will be addressed primarily as part of the strategy roadmap (WP7 of the project).

In terms of platforms, the provision of educational content and tools is identified as one of the possible use cases of publicly-driven platforms (§8.3.3 below).

During the project, the need of developing reference frameworks of BIM and other digital competences was also mentioned, for example for supplier's maturity assessment. Currently, project owners or general contractors increasingly request SMEs to provide information about their digital skills. Some level of harmonization for this skills assessment could bring benefits on both sides.

References

- Belgium: CLUSTER BIM WG5 on the editing of a BIM-competence matrix (https://www.bimportal.be/nl/projecten/tc/publicaties-resultaten/de-bim-competentiematrix/)
- buildingSMART Professional Certification Program

8 Role of public authorities in the development of construction digital platforms

In the development of digital platforms for the construction sector, public authorities (at local, national or European level) are involved in multiple ways:

- they set the **regulatory framework** for developing and operating construction projects, at different levels (e.g. Construction Product Regulation, EPBD, fire safety, urban planning rules). Digitalization can concern these regulations and the related processes. There can also be regulations more directly targeting the digitalization of the construction sector (e.g. building logbook regulations in some member states, or some provisions of the public procurement directive)
- They manage the related **public services** (e.g. urban planning portals, building permit applications and delivery, network connections, procedures regarding works near underground networks, security and risk management services)
- As part of their **policies**, they support measures to improve e.g. the performance of the building stock and the security and health of inhabitants, for which digitalization can be a key enabler
- They own **public data** that should be made available to construction stakeholders
- They build, own and manage **public assets**
- They support the development of the **digital services market**, and set the framework to ensure a fair competition between stakeholders
- In relation with all previous points, they can set up **public digital platforms**, either to provide new services, or as part of the digitalization of existing ones

This multiple involvement of public authorities in the digitalization of the construction sector is illustrated in Figure 7.

Hereafter, we list the main topics where public authorities have a role to play in relation to construction digital platforms, identify associated guidelines, and discuss the different scenarios to consider.

8.1 Digitalized public services and regulations

As identified in D4.5, platforms could facilitate the application of (often local) rules and regulations. They could also facilitate all necessary and relevant communication with public authorities, at any stage of a project/asset lifecycle (e.g. building permits, obligatory performance calculations) This communication should be based on transparent protocols which are easy to use for companies without specific ICT knowledge. Platforms should offer a single-entry point for public databases and interface to authorities. Finally, D4.5 also underlined that this digital communication should be entirely focussed on limiting the efforts for the construction companies (it should decrease the work, not increase it).

Keeping this in mind, many benefits can be expected from the digitalisation of construction-related public services and regulations. Key topics are analysed hereafter, with guidelines for the integration of related services in a harmonized and interoperable digital environment.

8.1.1 Access to rules, digitalisation of rules and compliance checking

8.1.1.1 Access to regulations at European, national, or local level

Many European countries are providing their national regulations in a digital form, mostly online. Access to full text is normally free, but dedicated services with advanced user interface (from simple keyword search to more complex querying interfaces based on e.g. natural language processing) may be available under chargeable conditions. These databases are very useful for national practitioners in a first place (for designing projects), but in the context of a European market, it may be useful for a company to easily access and compute the regulation framework prevailing in a foreign country. This is where linguistic issues can arise, not only because of translation problems, but also when words can have different meanings from one country to another.

Guidelines:

- Develop throughout Europe a network of European, national, regional or local online regulations databases with multi-lingual user interfaces

References:

- Eur-lex portal [61]
- National digital portals for accessing construction rules, e.g. the Batipedia portal in France

[61] https://eur-lex.europa.eu/homepage.html?locale=fr

(only in French).

8.1.1.2 Digitalisation of rules and automatic checking of project compliance

Going one step further, construction stakeholders could benefit from tools or services to check the compliance of a project with the relevant regulations. These include the tools used by public authorities themselves in digitalized regulatory assessment processes (e.g. to deliver required authorizations), but also tools made available to construction stakeholders to check regulatory compliance at any stage of a project. Tools and services could be developed with the support of public authorities but are most often provided directly by market players. In the latter case, they can be certified by public authorities for use in different regulatory contexts (e.g. list of tools accredited for regulatory energy performance calculation). Finally, they can go beyond the strict framework of regulations by giving the possibility of checking compliance against a broader set of rules (professional rules, owner-specific rules...).

Today, the main problem to be solved (in addition to the language problems mentioned above) is the gap that exists between the way the rules (and the construction objects) are formulated in regulations and the technical specifications coming from a project (e.g. BIM models). In order to solve this problem, a semantic interoperability and linked data approach makes it possible to establish links and equivalences between concepts in a flexible and extensible way.

The process is further analysed in the following section, focused on the example of digitalized building permits.

Guidelines:

- Progressively engage into a process of **harmonization of the terms and concepts used in construction regulations**, applying principles of the RAF for semantic interoperability and machine readability, as developed in chapter 3 above (e.g. use of data dictionaries, linked data principles). Here we are not talking about harmonizing the rules themselves, which is a distinct subject not directly entering the scope of this framework. Harmonizing the way rules are formulated is already a key enabler for the development of digital services.
- Develop compliance checking services (e.g. based on semantic interoperability and linked data) that allow to link technical project data with regulatory requirements

References:

- Building Smart International Regulatory Room (https://www.buildingsmart.org/standards/rooms/regulatory/)
- CEN works on RIR (Regulatory Information Requirements) and RIM (Regulatory Information Models and Management)[62]
- CEN works on data templates based on harmonised technical specifications under the Construction Products Regulation (CPR)[63]

[62] See for example : First WD WI 442023 CEN/TR Guidance for understanding and using EN ISO 29481-1

[63] prEN 17473

- Research works on BIM-based checking concepts[64]
- The UK D-COM Network[65], led by Cardiff University and formed to drive forward the adoption of the digitization of regulations, requirements and compliance checking systems in the built environment

8.1.2 Digitalized building permit and other procedures

Description

The building permit is an example of application of the previous section. It is a typical example of digital service that public authorities should eventually be able to provide. This issue includes a business to government (B2G) part for the relations between construction stakeholders and authorities, and the management of procedures within the public administration. At some point, in order to streamline the entire process, gateways will have to be built between the two.

As mentioned in D5.1, the digitalisation can concern several aspects of the process, including:

- Submission (and retrieval) of any document related to the building permit application procedure in a digital format, on a dedicated B2G portal
- Automatic extraction of certain data from the digital model (BIM) of the project to complete all or part of the application forms
- Direct processing of the data contained in the digital model to check the compliance of the project with the regulations

Several key services are required to provide digitalized building permitting:

- A service that can manage and make available regulations in a digital form
- A checking engine, such as a rule engine, that can perform the logical task of regulatory checking
- A building permit service, capable of receiving results form a check engine, storing and managing them and making them available to stakeholders
- Other software tools that provide supporting data for the checking process i.e. simulation results, validated product data sets etc…

Interactions based on this vision are shown in Figure 42.

[64] See for example : Eilif Hjelseth (2016). Classification of BIM-based model checking concepts. Journal of Information Technology in Construction (ITcon), Special issue: CIB W78 2015 Special track on Compliance Checking, Vol. 21, pg. 354-369, http://www.itcon.org/2016/23

[65] http://www.dcom.org.uk

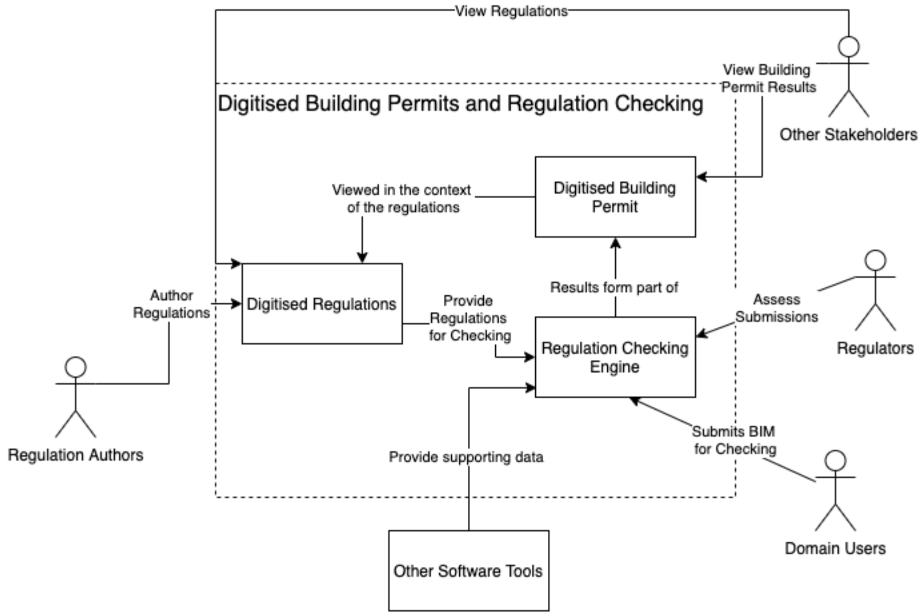


Figure 42: Stakeholders in Digitalized Building Permits and Regulation Checking

Different options can be considered:

- Public authorities could directly provide regulatory checking engines and tools, that could be made accessible through APIs, so that software providers can integrate them in their solutions
- Alternatively, the provision of such engines and tools could be left to the market. They could then be certified by public authorities for a use in a regulatory context.

Scenarios analysis

Eventually, there seems to be a strong rationale for the digitalization of building permits:

- Reduce time and cost for processing permit applications
- Harmonize administrative processes
- Simplify procedures for building owners
- Improve reliability, transparency and ability for stakeholders to anticipate compliance issues

Nevertheless, this digitalization requires major efforts on multiples aspects: harmonization and digitalisation of rules to make them processable, development of engines and tools and validation of their reliability for regulatory purposes, evolution of the regulatory processes themselves, evolution of tools and skills of the administration.

Hence, aiming for an immediate transformation does not appear realistic nor desirable, and public authorities should rather support a progressive transition by addressing these different aspects as part of the strategy roadmap. In order to progressively harness the potential of automatic compliance checking, they should continue experimenting the integration of these tools in the assessment process, in complementarity with manual processes.

Technical guidelines:

- Develop national B2G online portals to digitalize the exchanges between construction stakeholders (esp. building owners or developers) and public authorities, including, but not limited to, digitalized building permitting
- Provide access to building regulations / standards in a machine-readable way, by progressively applying principles of semantic interoperability, and connecting with data dictionaries initiatives. Engage an effort of harmonization of the formulation of urban planning rules
- Provide appropriate security and access management for the previous points – such that only authorised users/services can view/update building permits and regulations/ standards
- Prioritise the adoption of open standards (i.e. IFC, BCF, CityGML) as support technologies in application and processing procedures
- Where no suitable standards exist, new protocols/data formats should be developed, and released openly (e.g. data format for structuring and formulating construction regulation documents). Develop harmonized information requirements for specifying a digital building permit
- Once they exist, provide authoritative lists of services / software tools adapted for compliance checking and virtual building permit services (primarily at national level)

References:

- European Network for Digital Building Permits (https://3d.bk.tudelft.nl/projects/eunet4dbp/about.html)
- Several ongoing initiatives and experimentations (see for example: Estonian proof of concept as part of the e-construction initiative[66], Finnish experimentation project[67])
- The UK D-COM Network, led by Cardiff University and formed to drive forward the adoption of the digitization of regulations, requirements and compliance checking systems in the built environment

8.1.3 Building logbook

The introduction of building logbooks pursues several objectives, among which ensuring the continuity of information during the whole lifecycle of a building, regardless of the successive changes of ownership. This continuity would benefit to different policy objectives (e.g. environmental performance, circular economy, health, safety).

As mentioned in D5.1, there are several examples of building logbooks initiatives across Europe, as well as an ongoing European study (see reference below) to define strategical guidelines based on best

[66] https://eehitus.ee/wp-content/uploads/2019/07/e-construction-platform-vision-ENG.pdf

[67] http://www.kiradigi.fi/en/news/how-bim-is-revolutionizing-building-control-in-finland.html

practices.

Stored information can cover numerous aspects: building plans, regulatory compliance, environmental and energy performance, technical information about construction products or equipment.

Building logbooks can be of private initiative or required by regulations. In the latter case, public authorities need to define both the required content of the logbook, and the formats in which the information must be structured. **Through mandatory building logbooks, public authorities will thus play a key role in defining the minimal set of information requirements throughout the lifecycle of a building**.

The use of BIM models is considered as an important perspective for building logbooks.

In France, a 2020 legislation makes building logbooks mandatory for housing buildings ("Carnet numérique de suivi et d'entretien du logement"). The regulatory logbook will be operated by private services providers, certified by public authorities.

The generalisation of building logbooks would entail important progress in terms of building-related data availability. Maximizing the benefit derived from these data requires to define adapted frameworks to secure their sharing in compliance with the core principles of this framework regarding data security, privacy or ownership. To this end, different types of data usage are to be distinguished:

- Data for the exclusive use of the owner/user
- Data accessed and used by public authorities
- Data accessed by private service providers with the consent of the owner/user
- Other perspectives of large scale consent-based C2B or B2B data sharing
- Open data (based on anonymization and statistical processing)

Guidelines:

- Promote the digitalization of building logbooks beyond "digital paper", based on semantic interoperability
- Define BIM-related information requirements for building logbooks information
- Make them accessible online, with different access rights depending on the user's profile
- Connect building logbooks with other initiatives: Open data portals, European construction big data platform, LEVELs framework, services for environmental performance…

Other proposed actions for the strategy roadmap:

- Explore the opportunities of large scale data sharing generated by the wide adoption of building logbooks and set up the proper frameworks to harness this potential while preserving the core principles of this framework in terms of data security, privacy or ownership.

References:

- Study on the development of a EU framework for buildings' digital logbook68. The study reviews relevant public and private initiatives related to building logbooks in order to identify business models, good practices with respect to usage, data management and digitalisation, and the critical gaps that still need to be addressed in these domains. The study intends to propose an action plan to be implemented
- Various initiatives identified in the study, such as in Germany (Gëbaudepass), Portugal (CASA+), France (Carnet numérique du logement) or Belgium (Woningpas)

8.2 Public procurement

Public procurement represents a significant share of the construction sector's activity, and moves to digitalise its processes will be an important driver for the transformation of the sector as a whole.

As reminded in D5.1 (§2.3.9), "*the EU supports the process of rethinking public procurement process with digital technologies in mind. This goes beyond simply moving to electronic tools; it rethinks various pre-award and post-award phases. The aim is to make them simpler for businesses to participate in and for the public sector to manage. It also allows for the integration of data-based approaches at various stages of the procurement process*"[69].

The use of digital tools and processes in public procurement offers a range of benefits such as: significant savings for all stakeholders, simplified and shortened processes, greater innovation and new business opportunities by improving the access by companies, in particular across borders.

The management of calls for tenders with BIM-based approaches was identified in D5.1 as one of the key use cases related to the digitalization of public procurement. It should be designed to support circular and green public procurement, and to improve access to tenders.

The EU directive on public procurement (2014/24) encourages the adoption and implementation of BIM in public construction projects within the 27 EU member state. So far, Netherlands, Denmark, Finland, Norway and Italy are among a few countries that have set mandatory requirements for BIM adoption in state-owned procurement processes, while other countries have preferred to rely on incentives or support. The revision of the Public Procurement Directive of 2014 is not expected in the short-term. Some evolutions are likely in relations with the Green Public Procurement initiative of the European Commission.

Guidelines:

- Initiatives to support BIM-based public procurement or make it mandatory should follow harmonized approaches based on the core guidelines of this framework (use of open standards, semantic interoperability, definition of information requirements)
- Organize the sharing of best practices based on the most advanced initiatives, to progressively generalize and harmonize these approaches

[68] https://ec.europa.eu/growth/content/study-developing-eu-framework-digital-logbook-buildings_en

[69] https://ec.europa.eu/growth/single-market/public-procurement/digital_en

- Make sure that the digitalisation of procurement processes does not exclude some stakeholders (esp. SMEs), by providing them with an access to adapted tools and knowledge (see §8.3.1 below)
- Support Circular and Green Public procurement

References:

- Tenders Electronic Daily (TED[70]), the electronic version of the complement to the Official Journal of the European Union (OJ) dedicated to public tenders
- EU directive on public procurement (2014/24), that encourages the adoption and implementation of BIM in public construction projects within the 27 EU member states.
- Green Public Procurement initiative[71] of the European Commission
- Mandatory BIM-related requirements set in several member states (e.g. Netherlands, Denmark, Finland, Norway and Italy)
- As part of BIM2022 plan (France), an action is dedicated to the elaboration of a digital booklet about the use of BIM in the call for tender phase

8.3 Perimeter and architecture of public digital platforms

8.3.1 Publicly driven open platforms for BIM and other digital services

The possible role of public authorities in facilitating the access to BIM services was discussed in D5.1-§2.6.2. Two options have appeared in the discussions:

- Give access to tools and services directly through public platforms (either at European or MS level)
- Or just provide a directory of existing tools/services/platforms (both public and private), to help stakeholders navigate through the existing offer, and make informed choices, based on the assessment of a set of criteria aligned with public policies (e.g. degree of "openness", interoperability, compliance…)

Open platforms for BIM and other digital services would provide an architecture to integrate free and commercial services in meaningful workflows for AEC use cases.

The goal would be to create an orchestration system that coordinates different public and private services in order to propose the best integrated user experience with the integration of various public and commercial "open" services. Such a system would propose a good cooperation framework where construction use cases workflows are implemented with the integration of different providers' services. The platform could ensure standard ways to integrate data between services as well as mechanisms to share revenues between the different integrated tools.

End-users could have the opportunity to choose combinations of different open tools to fulfil the

[70] https://ted.europa.eu/TED/browse/browseByBO.do

[71] https://ec.europa.eu/environment/gpp/index_en.htm

same requirements, that could be based on set of configurable use cases as proposed in D4.5.

As described in D4.5, for individual companies, understanding, creating, and maintaining the necessary data structure and workflow for their actions is often (too) complex. Platform functionalities could facilitate this work through the use of templates, sample structure, (inter)operability checks etc. (even if the platform could not integrate or provide all necessary tools or functionalities, it could provide an environment that integrates tools to check interoperability.

The figure below provides an overview of the relations between the concepts depicted in the following sections.

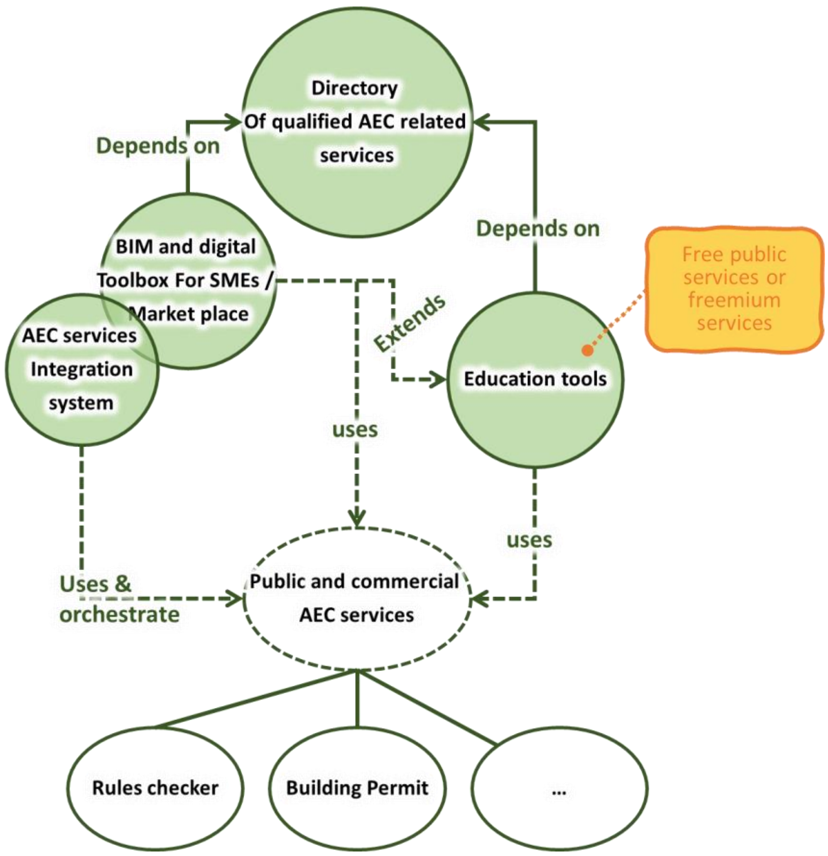


Figure 43: integrating public and commercial services through open platforms- relation between the different aspects

8.3.1.1 *Examples of existing initiatives*

Several examples of public or industry initiatives have been described in previous deliverables, such as:

- BIMio project by BBRi in Belgium (see D4.4, §4.6.2)
- Kroqi platform in France (D3.2-§2.2, and D4.4-§4.6.3, D5.1-§2.6.2)
- INNOVance in Italy

8.3.1.2 *Rationale for public or open platforms*

Before all, the use of the term “public” needs to be qualified. Kroqi is a public-private initiative, as its financing and governance is shared between public authorities and construction stakeholders, within the frame of the French “Plan BIM 2022”. The BIMio project is developed by BBRi, which regroups 90,000 Belgian companies, and is a “common industry initiative” rather than a public one. More generally, the involvement of public authorities in such initiatives can take several forms. Hence, the term “public platforms” is used as a simplification.

A first rationale behind such initiatives is to promote the use of collaborative and BIM services by SMEs by providing them with an easy access to an adapted toolkit. This aims to avoid a gap between the large structures with the financial and human resources needed to adopt new technologies, and smaller players for which transition costs are more difficult to absorb. As described in deliverable D4.4, SMEs often make punctual use of BIM tools and services, thus not justifying the purchase of expansive proprietary licenses. As was discussed during the project, SMEs need very specialized, easy to use tools, directly related to their day-to-day activity.

Providing all stakeholders with an access to a set of BIM services aligned with the guidelines of this framework may also be an essential corollary to the **requirements introduced in public procurement related to the use of BIM** (see §8.2 above**Errore. L'origine riferimento non è stata trovata.**), to **ensure an equal access to all players.**

Beyond SMEs, Kroqi is intended to promote and accelerate the adoption of BIM and collaboration services by the construction sector as a whole. The public support is thus intended to give an impetus to the digitalization of the sector, and, beyond this initial transitory phase, to facilitate the continuous adoption of innovative solutions. This argument in favour of a public support depends on the assessment of the actual market offer, in terms of access conditions by all stakeholders (esp. SMEs), and of ability to promote innovation and new entrants.

The “utopia” proposed in deliverable D4.4 provides a vision of what is expected by construction stakeholders in terms of access to BIM services: *a fully integrated tool (platform) as a Swiss pocket knife or a PDA full of apps, which are easy to use (plug-and-play), affordable and allow to concentrate all data and treat these to optimize building design and construction activities*. As highlighted in D4.3, open standards are not the only way to achieve this utopia. Neither are public platforms, and we currently observe the development of communities of users and ecosystems of services around proprietary platforms.

Besides the issue of fees and user access conditions by small players, public platforms could however be justified on the supply side by the objective to set up a **level playing field** equally opened to all providers, and fostering competition and innovation, based on a set of shared principles as defined in this framework (e.g. the use of open formats, possibility of data exchange with public authorities). Such open platforms **would avoid market capture by some players and guarantee an access to market for new entrants** independently from private platforms. Their model should ensure a fair distribution of value along the value chain.

European public platforms could **promote European software vendors** in several ways. They would boost their products functional values by associating them to other European public or commercial partners’ tools via the orchestration mechanisms, thus **reinforcing the ecosystem of European digital AEC services** (especially when compared to big international players proposing fully integrated proprietary platforms).

The compliance of the proposed services with European principles would be ensured either by: i) assessing and scoring the respect of a set of agreed criteria (e.g. openness, interoperability), hence driving end-users to the best-scoring offers, or ii) by applying some of these criteria as necessary conditions to be enrolled on the platform, if justified by European policies. An example here would be the compliance with European principles in terms of **data security, data sovereignty or data ownership** (see §4.1 above).

8.3.1.3 Business model and public support

After an initiation phase in which all Kroqi's collaborative services were free, a fee policy has now been defined, though keeping in mind the objective of accessibility by all stakeholders (esp. SMEs). A perimeter of free base services is maintained, and most of the SMEs still benefit from it ("freemium" approach). This underlines that publicly driven open platforms are not necessarily free, and that sustainable business models can be found. Public financing should be seen as a targeted support, primarily during the initiation phase, and based on a cost-benefit analysis. It would decrease in the long run, even if public authorities should remain involved in the governance in the long run.

Moreover, public platforms are not intended to provide a "cheap" alternative to services already offered by the market, thus creating unfair competition, but should focus on policy objectives and unmet needs.

8.3.1.4 Importance of vendor neutrality

Public initiatives in the field of access to BIM and digital services must preserve vendor neutrality.

In the example of Kroqi, the first third-party services integrated into the platform have been selected through a "call of expression of interest" process, ensuring a fair treatment of the private service providers. This process will be repeated, but it is not clear at this stage whether it is adapted for the inclusion of new services beyond the initial "demonstration" phase, in a fully operational phase. Other appropriate ways of enrolling new services while ensuring vendor neutrality are still to be defined.

8.3.1.5 European versus national platforms

Although it originated from a national initiative, a public digital platform such as Kroqi can theoretically be used by any international user. However, the interface is in French, and some services can be specifically adapted to the French context.

The generalization of such public platforms at European level could take several forms:

- The replication of such initiatives by other member states, with a comparable model. This replication could be incentivized/supported by Europe. Connections could be established between the different national platforms, e.g. to share some common services in order to improve overall efficiency, and more generally to mutualize part of the initiatives
- The creation of a new European public platform offering this kind of services. It would be available in the different languages. It might difficult in this schema to provide proper adaptation of the services to the national contexts (e.g. national construction rules, and possible connections with other national websites/platforms)
- A combination of the two approaches, namely a European platform, connected with a network of national platforms. This option is certainly the most adapted, as it combines the objectives of market integration, harmonization and mutualization on the one side, and the need of adaptation to national contexts on the other side.

8.3.1.6 Directory of digital AEC services, with assessment of criteria aligned with EU policies

As an alternative or a complement to directly granting access to digital services, a public platform could just provide a list of AEC services (both private & public) that match some criteria to be defined, aligned with EU policies and the present framework, such as openness, interoperability, fair competition and access for new entrants, or security requirements. That would be a real value for European stakeholders to help them make informed choices among business tools. They could rely on a list of the most reliable & state of the art AEC European services for their IT tools choices and be sure about services reversibility options.

Regarding software vendors, this directory could be associated with an enrolment portal where they would describe their offer, and provide a link to their tools for an automatic testing (e.g. validate SSL is activated, certificate is correct, validate HTTP headers, or evaluate IFC export functionalities or other interoperability criteria…).

Preserving vendor neutrality remains a crucial issue in this approach.

Guidelines:

- Create a directory of European digital AEC platforms and services
- Define a set of criteria to assess the platforms and services, aligned with the objectives described in §8.3.1 above, and more generally with EU policies and with the present framework

References:

- Example of the LEVEL(s) framework, providing a list of available tools for environmental LCA calculation[72], together with a list of LCA databases. Criteria are defined for assessing software and databases. The lists are presented as non-exhaustive

8.3.1.7 Scenarios analysis and synthesis of the guidelines

Table 4: Synthesis of the arguments related to the creation of publicly driven open platforms for BIM and other digital services

Arguments in favour of publicly driven open platforms for BIM and other digital services	- Provide a BIM and collaboration toolkit readily accessible by all stakeholders, including SMEs, and that can be used to answer the requirements related to the use of BIM in public procurement - Give an impetus to the digitalization of the construction sector, in a transitory phase - Create a level playing field through a platform that is opened equally to

72 https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581681499/Criteria_for_assessing_LCA_tools_and_data_v1-5.pdf

	all providers, and designed to: - promote innovation and new entrants (esp. small players) - guarantee market access to all stakeholders independently from proprietary platforms - foster competition, avoid market capture by some players, ensure a fair distribution of value across the value chain - promote European vendors and increase the technical value of smaller players' services by integrating them, thus reinforcing the ecosystem of European digital AEC services - Ensure the respect of European principles in terms of data security, data sovereignty or data ownership
Points of Caution	- Vendor neutrality must be preserved, through adapted processes to enrol and assess the services - Publicly supported platforms/services should not compete unfairly with market offers, and should focus on policy objectives and on unmet needs during a transitory phase. A balanced business model must be looked for, not hindering business initiatives
Alternative solutions to consider	- Rather than setting up public platforms, public authorities could direct the market towards meeting the above objectives. This could be done either by the way of incentives or regulations - In any case, different scenarios are possible concerning the degree of involvement of public authorities in initiating open platforms meeting the above objectives. This calls for further dedicated studies and projects.

Technical guidelines:

- The platform should provide the ability to coordinate various standardized software products in order to create high added-value AEC services:
    - Use micro-services / PaaS architectures allowing services discovery and services composition
    - Create an innovative Orchestration system to compose services with the possible composition of commercial and public software products, e.g. IFC enrichment→ IFC checking→ IFC simulation→building permit …
- Promote open software products integration, hamper vertical integration to allow open and fair competition
- Integrate an assessment of interoperability criteria, or tools to check interoperability capabilities
- Offer an open, one-stop platform for stakeholders
- Promote standards and openness for editors (ensure reversibility), based on the core principles of this Reference Architecture Framework

Other guidelines:

- Promote Co-opetition business model, expand the ecosystem of European digital AEC services

8.3.2 European big data platform for the construction sector

Big data platforms do not necessarily involve the public sector. Some private services propose cross-companies data sharing, and there can be business models for B2B big data platforms (e.g. the Skywise platform in the aeronautics sector). Nevertheless, there is a strong rationale for public initiatives in the field of big data platforms for the construction sector: a much more scattered sector with a lot of small entities, a continued need of standardisation efforts to enable large-scale data sharing, and the importance of public data. In several other sectors, Europe has already engaged in this direction (e.g. European initiatives for big data platforms in the agriculture of healthcare sectors, analysed in WP3).

A European big data platform for construction should build on the existing framework of European Common Data Spaces.

Beyond these considerations about its necessary integration in the perimeter of public platforms, this topic is further developed in the dedicated chapter 6 above.

8.3.3 Educational content and tools

To help European stakeholders in their transition to use IT-enabled processes an tools, offering educational contents and courses appears necessary (especially for SMEs), on the example of the agriculture and farming sector, where there are digital industrial platforms that are focused on training in using new machines or products. The educational contents must be very pragmatic and help non-technical users to start using most appropriate IT tools depending on their activity. An educational service may encompass different aspects:

- **AEC Educational content**: a content management system is meant to organize and centralise courses and educational contents for European stakeholders. These contents (documents, videos, etc.) need to be adapted and tailored to each country (language, regulations etc.).
- **Free toolbox for educational purposes**: These tools can be used free of charge by European citizens in order to train themselves to use innovative AEC IT Services. Ideally, the toolbox contains services of different types, from public services (like online cadastre, building permit service etc.) to collaboration services like online model sharing and annotations (with BFC compatibility) or model rules checking. If the different types of services can be integrated in a meaningful workflow (for example set of tools dedicated to renovation processes), the user experience will be better.
- **Commercial toolbox for educational purposes**: Alternatively (and in complement of free educational tools), commercial tools can be made accessible through a European educational toolbox. Commercial services proposed in this educational context must propose decent freemium options so that stakeholders can use them free of charge for education purposes. Commercial toolbox for educational also need to match constraints from the directory of construction digital services (see §8.3.1.6 above)

The last two points represent another use case for publicly driven open platforms discussed above. Here, again, the need for a public initiative depends on the available market offer, and on the way it considers educational purposes. Most software vendors do have specific access conditions for students and academics. Other types of users can benefit from free trial periods and freemium offers.

8.3.4 Sharing of best practices and innovation

Another possible use case for public digital platforms is to provide environments for the sharing of best practices and innovation results. This can involve companies, universities or research centers. Successful implementations of BIM and other Construction 4.0 approaches could for example be shared on such platforms.

The idea is also to share the results of research projects to improve appropriation by the industry.

This is considered important especially for the small and medium companies that don't have the resources to follow research and innovation actions.

8.3.5 Synthesis concerning the perimeter and architecture of European public digital platforms

The table below lists the different types of services to integrate in the perimeter of public platforms. It identifies those that should be accessible through a European platform, and those for which National platforms appear more adapted (e.g. for a better adaptation to National context). For most categories, some shared services are likely to be proposed at European level, while others would remain at the level of National platforms, with a connection between the two. If we take the example of access to construction rules, a National platform would give access to National rules, and would redirect towards the European platform to access all common European rules. Access to digitalization standards and big data platforms would sit primarily at European level, while access to digitalized public services such as building permit is more likely to remain at National level.

Many of the mentioned services already exist, both at European level and at National level, at least in some member states. As already mentioned, the new European public digital platform for the construction sector would actually take the form of network of National platforms, connected to one shared platform at EU level. Concerning individual services:

- Some will be created (e.g. big data platform, territorial digital twins, or publicly driven open platforms for BIM and other digital services, beyond the few existing initiatives)
- Some already existing ones will evolve in the context of digitalisation (e.g. adding digital rule checking tools to existing construction rules portals, or adding BIM processes to existing public procurement platforms)
- Finally, for both existing and new services, the purpose of the European platform will be to properly connect them, to provide a **single entry point** to all public digital services related to the European construction sector

Table 5: types of services to be included in the perimeter of public platforms at National and European Level

Services	National platforms	European platform
Publicly driven open platform for BIM and other digital services	X	X
Access to digitalized public services (e.g. building permit)	X	
Access to construction rules	X	X
Access to digitalisation standards		X

Access to public data	X	X
Big data platform, large scale data sharing		X
Educational content and tools	X	X
Sharing of best practices and innovation (esp. related to environmental performance and digitalisation)	X	X
Connection with Public procurement platforms	X	X
Connection with other existing public platforms (e.g. LEVELs)	X	X

8.4 Focus on public data platforms

This section develops the subject of public data platforms, which are a subset of public digital platforms. Many types of public data are of interest for the construction sector, such as:

- Territorial data with legal value: cadastre data, urban planning rules and maps, constraints related to natural or industrial risks…
- Other geographic data: topography, land use, pollution, biodiversity, soils, climate
- Infrastructure networks data
- Data regarding construction projects (e.g. building permit data) or the built environment in general (e.g. statistical data about the building stock)
- 3D territorial data, that an increasing number of public authorities are providing through dedicated portals, including the perspective of 3D territorial digital twins.

In the field of geographic data, the regulatory and standardisation framework at European level is set by the INSPIRE directive.

The role of public authorities regarding data availability is not limited to public data. They can also adopt broader public strategies to enable access to data of general/public interest, including data that may be produced by private operators (e.g. energy consumption data). This broader vision of public interest data in considered here.

Rather than an in-depth analysis of each kind of data, this objective of this section is to provide examples in which an improved access to data can create value for the construction sector, and highlight guidelines to support this improved access.

8.4.1 Territorial data and territorial digital twins

Public authorities are progressively opening their data. Pushed in particular by the INSPIRE directive, this movement is motivated by the desire to provide access to a better knowledge of the territory (public and natural spaces, heritage, equipment, roads, urban cartography, socio-demographic information, etc.), to increase the transparency of public action (budgets, expenditures, elections, grants, deliberations, costs of services, public safety, etc.), to develop services, support the local economy and foster innovation, and to share and improve exchanges within the communities and between different public actors.

This opening of urban and territorial data is an important criterion for the evolution of cities into "smart cities". But these data, coming from disparate data sources, must be assembled into meaningful urban models to be fully exploitable by applications (e.g. decision-making).

Amongst territorial data, those from cadastres and land registers are key in construction projects, for both new and existing buildings. As highlighted in deliverable D5.1, retrieval of such data should be made easier.

An increasing number of cities are providing 3D territorial data through open portals. In Estonia, the e-construction platform is an example of national-scale 3D territorial digital twin.

Furthermore, complementing GIS and 3D data, real-time data, such as traffic data, outside temperature, or air pollution, participate to the building of territorial Digital Twins. The use of proprietary infrastructures currently limit access to - and sharing of - this data. But recent developments have been made to harmonize the design and use of urban platforms, for instance thanks to the open source FIWARE initiative (see §3.4.4 above concerning the integration of IoT data into digital twins). As already mentioned above, the emergence of territorial digital twins:

- Relies strongly on the use of open standards and other guidelines of this framework, as it requires a cross-domain, multi-scale and multi-sources integration that no single proprietary platform could provide
- Might play an important role in the management of the environmental transition of territories, and of climate change action.

Recommendations:

- Develop territorial data platforms throughout the EU member countries and make the data open, within the limits of GDPR compliance (e.g. regarding the identity of parcel owners).
- Harmonize the way to access territorial data portals and retrieve data by relying on data exchange standards
- Organize sharing of best practices concerning the development of territorial digital twins at city or national scale, to better assess the benefits of such approaches

References:

- INSPIRE directive
- Initiatives to develop territorial digital twins, with the example of the national-scale e-construction platform in Estonia, and numerous city-scale initiatives (e.g. Helsinki).

8.4.2 Large public infrastructures

Important benefits can be expected from an improved management of large public infrastructures' data along their lifecycle. One important issue is to provide an efficient and controlled access to relevant data to the numerous stakeholders involved throughout this lifecycle. Part of the data should also be completely opened. Easy cross-border access to the data is of special importance for large projects associated with European-scale procurement procedures.

In France, the national research project MINnD (standing for Modelling of interoperable information for sustainable infrastructures) is dedicated to the structuring, controlling and sharing of infrastructures' data.

Improved data management and availability will allow greater control of the public works during their entire lifcycle (monitoring the state of physical infrastructures for the safety of citizens, improving simplification, speed, timeliness and accuracy of maintenance interventions, and more generally improving the effectiveness of public expenditure).

In Italy, the National Computer Archive of Public Works (AINOP) was recently set up by the Ministry of Infrastructure and Transport. It is based on the interoperability of the data produced by the administrations and other stakeholders involved in the works, and the unique identification of each infrastructure.

Such data platform should be able to connect with the tools used by the market, through the use of standardized formats and data exchange (e.g. data transmission trough standardised APIs).

Guidelines:

- Progressively harmonize the structuration of infrastructures' data, as well as their management throughout the lifecycle, in compliance with the core guidelines of this framework (see in particular §3.4 above for guidelines about asset lifecycle information management)
- Develop public platforms to grant a harmonized and controlled access to public infrastructures' data

References:

- National Computer Archive of Public Works[73] (AINOP) of the Ministry of Infrastructure and Transport (Italy)
- In France, the national research project MINnD[74]

8.4.3 Underground networks and other underground data

Damage to underground networks is a still serious issue for the construction sector, incurring safety hazards, and representing important direct and indirect costs.

Data availability is of crucial importance to improve this situation. Countries all have dedicated services for authorized access to underground network data in the context of a project. Restricted access is indeed required for several reasons, mainly security issues in relation with the criticality of the networks, and competition between network operators. Construction stakeholders are faced with poor data quality and accuracy, difficulty to integrate different sources due to heterogenous formats (often raster images), and slow procedures to obtain the data.

Among the different initiatives to improve these services, we can cite the KLIP project in the Belgium region of Flanders, together with the KLIC project in the Netherlands. Focus is put on the quality of the data, the harmonization of data formats in order to facilitate the integration of different sources, and the rapid access to the data through a digital portal. Data quality improved dramatically, and access time was reduced to less to 1 or 2 days, compared to c. 2 weeks in many countries.

Generalization of such best practices would benefit the construction sector. Related services should

[73] http://ainop.mit.gov.it/

[74] https://www.minnd.fr/en/

be integrated with other territorial data services, and territorial digital twins. The question of underground networks can also be extended to other underground data (e.g. capitalisation and access to soil survey data, which tend to gain importance in the context of urban densification).

Guidelines:

- Based on best practices, extend the efforts to harmonize underground networks and other underground data, in compliance with the INSPIRE directive, and with the core principles of this framework
- Support the initiatives aiming at improving digital access (quality, accuracy, access time) to underground networks and other underground data

References:

- KLIP and KLIC project in Belgium/Flanders and the Netherlands, which achieved to provide improved digital access to harmonized data about underground networks in the context of construction projects
- INSPIRE directive