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SPHERE

BIM DIGITAL TWIN PLATFORM

WP2 – ICT Platform Requirements and KPIs Definitions

D2.1 Needs and Opportunities Definition Report for Renovation based on IDDS Framework

SPHERE: Service Platform to Host and sharE REsidential data, has received funding from the European Commission H2020 Programme under Grant Agreement No. 820805

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V.0.1	19/12/2018	EKO	Deliverable Content / Outline
V.0.2	28/02/2018	EKO, OPY, COMSA	Updated TOC, incl. Acronyms, written draft parts
V0.3	11/03/2019	EKO, OPY, COMSA	Updated TOC, written draft parts
V0.4	04/04/2019	EKO, OPY, COMSA	Updated TOC, written draft parts
V0.5	11/04/2019	EKO, OPY, COMSA	Updated TOC, written draft parts
V0.6	07/06/2019	EKO, OPY, COMSA	Updated TOC, written draft parts
V0.7	24/06/2019	EKO, OPY, COMSA, ALL	Partial Draft Completed with sections up to Chapter 7
V0.8	04/07/2019	EKO, OPY, COMSA, ALL	Updated sections in chapter 7 and 8
V0.9	13/08/2019	COMSA	Updated Acronyms. Filled Section 5.9
V1.0	03/09/2019	EKO, OPY, COMSA, BASF, IDP	Full Review of text with drafts up to and including Chapter 7 for review by project partners
V1.1	24/10/2019	EKO, OPY, COMSA, BASF, IDP, COMET, VTT	Completion of deliverable for external review
V1.2	31/10/2019	EKO, OPY, COMSA, BASF, IDP, COMET, VTT	Final version for submission after external review
V1.3	12/11/2019	COMSA	Updated the list of acronyms
V1.4	10/12/2019	EKO	Integration of market positioning of SPHERE platform in Chapter 9
V1.5	08/01/2020	EKO	Integration of nZEB regulatory information in Chapter 9
V1.6	20/01/2020	EKO, OPY, COMSA, BASF, IDP, COMET, VTT	Amendment of information about numbers of interviewees in workshops
V1.7	10/02/2020	EKO	Updating of Executive Summary

Project	
Project Acronym	SPHERE
Project Title	Service Platform to Host and SharE REsidential data
Grant Agreement number	820805
Call identifier	H2020-NMBP-EEB-2018
Topic identifier	LC-EEB-06-2018-20 ICT enabled, sustainable and affordable residential building construction, design to end of life (IA 50%)
Funding Scheme	Research and Innovation Action
Project duration	48 months (From November 1st, 2018)
Coordinator	IDP – Eduard Loscos / Mikel Borràs
Website	http://sphere-project.eu/
Deliverable	
Deliverable No.	2.1
Deliverable title	Needs and Opportunities Definition Report for Renovation based on IDDS Framework
Description	Description of work generate a general IDDS framework for the development of the renovation solutions for building residential projects covering: i) *Potential and needs of improvements in the construction and renovation*. Focus will be given to the core objectives of the SPHERE methodology that aim to deliver the impact of the project. Opportunities delivered by the SPHERE concept and how the digital twin can enable the needs will be addressed**,** such as improved sustainability, shortened project life span , improved information exchange among stakeholders and social acceptance, improved project management, results monitoring and improved holistic benefits to the end users which will be the exploitable results of the project. *ii) Identification of Process Scenarios utilizing the Digital Twin.* Based on the identified opportunities and how the digital twin concept can address them, workflow scenarios on the process needs and the role of the SPHERE platform services will be identified. This will be carried out in collaboration with the administrative and technical acceptance analyses carried out in the task, ensuring the delivery of useable and scalable workflow scenarios. The relevant user types and actors will be identified, in close collaboration with the stakeholder and advisory board members, end user and demo support partners of the project consortium, to provide the usability and replicability of the workflows. iii) *Assessment of Barriers and need for Change Management.* Known barriers for the implementation of digitized ICT solutions in the renovation domain will be identified, as an essential aspect of the IDDS approach. Regulatory and technical compliance will be assessed. Behavioural and operational change requirements will be identified and solutions will be proposed. Emerging technologies in the sector which will be integrated into the digital twin approach, and the adoption and acceptance of the process stakeholders will be analysed. Social acceptance needs and their monitoring and collaboration methodology will be identified.
WP No.	WP 2
Related task	T2.3 (dependency)
Lead Beneficiary	Organisation

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1 Executive Summary

The SPHERE's projects overarching goal is to advance digital tools to build new and improve existing buildings' across their entire life-cycle. Better energy design improved and reduced construction cost, better operational performance, and ease of management, and better overall energy performance fit with a low carbon future. The novelty of SPHERE project is the demonstration and validation of one of the world's first Building Digital Twin platform's with cross-cutting tools for architects, engineers, construction managers, and building facility managers, naming a few, working with both real new building and retrofitting construction cases.

SPHERE as a special innovation project assembles and integrates different information streams needed to make these improvements happen, and bring together close to 20 existing software technologies, advancing them from laboratory or small pilots to large scale demonstrations, on the way for real use by companies. Another socio-technical innovation that SPHERE tries to accomplish is to bring as many actors in the life cycle of a building together through the Digital Twin approach, so they increase collaboration and create co-benefits. For example, for building facility managers to bring relevant operational energy use insights to building designers for making buildings use less energy. Done by advancing the idea of a fully systematic, collaborative and integrated framework for setting up and managing a building construction or renovation projects called Integrated Design and Delivery Services (IDDS).

The purpose of this report - *Needs and Opportunities Definition Report for Renovation based on IDDS Framework* - is to to deliver an understanding for the digitalisation potential in the Architecture Engineering Construction Owner & Operation (AECOO) sector at three levels: i) the potential and needs of improvements in construction and renovation, iii) and an assessment of barriers and needs for change management in the AECOO sector, iii) the identification of the SPHERE Digital Twin positioning and related requirements to address these barriers. The bring this understanding the report contains a wide-ranging literature review, scans of the construction sector in various countries, and workshops and interviews carried out with AECOO experts. The result is a deep understanding of existing barriers and potential solutions in the AECOO sector to improve performance in the delivery of newbuilds and renovation through implementing digital transformation. Specific solutions to be taken on-board for the SPHERE project are identified, and broad requirements for the platform are described. These include a workflow of the SPHERE renovation and new build pilots and their workflows to integrate the digital solutions, who will be the potential users of the SPHERE platform, what emerging technology requirements should be taken on board, what regulatory requirements and standards need to be aligned with to ensure a state-of-the-art Platform, and the start of the operational and change management requirements identification.

The report helps the SPHERE consortium to position itself in achieving a common understanding of both the key concepts for digitisation in the AECOO sector, the challenges and the related requirements to solve them. The insights will be further used across the project to ensure that the developments are on track for solving the 21st century AECOO sector challenges. The results are also helpful for other service providers and larger companies in the AECOO sector, to deepen their understanding of problems to be solved and ideas on how to solve them. As well as industry and umbrella associations such as the European Construction Technology Platform (ECTP), to inform on-going strategizing, setting of sector level targets, and long-term planning.

2 Introduction

2.1 Purpose

The works carried out in this report serve to define the high level requirements for the Sphere platform. The work serves nine different purposes based on the project Description of the Action (DoA) related to sections in this report (also see Figure 1 below):

1. To generate a baseline understanding of collaborative practices and their benefits that follow from Integrated Design and Delivery services (IDDS) and Integrated Project Delivery (IPD) **(section 4.1 and 4.2**) (Subtask 2.1.1)

2. To create a baseline understanding of Building Information Modelling (BIM) and Digital Twins (DT) and how these digital tools and associated practices can help to bring about collaborative IDDS based practices in the renovation and construction industry **(sections 4.3 and 4.4**) (Subtask 2.1.1)

3. To understand current barriers in the renovation and construction industry (2.1.1) including specific barriers for digitized ICT solutions, what the related needs for improvement are, how they are provided for by collaborative IDDS practices, and how these as a result improve sustainability, shortened project life span, improved information exchange (**chapter 5 and chapter 6)** (Subtasks 2.1.1 and 2.1.3)

4. To examine the opportunities to be delivered by the SPHERE platform and how the Digital Twin and its opportunity solutions can fill these needs (**chapter 6**). (Subtask 2.1.2)

5. To assess where the opportunities to barriers to be addressed by the SPHERE platform fit within workflow scenarios for the SPHERE platform, including their associated digital process needs/requirements, as a package of SPHERE platform services (**sections 8.2 and section 9.2**). (Subtask 2.1.2)

6. To identify what emerging technologies are needed to bring about these opportunities in the workflows that need to be integrated in the Digital Twin approach (**section 9.3).** (Subtask 2.1.3)

7. To identify the combination of users and actors and their potential interactions in the SPHERE platform to bring about these opportunities, in relation to their needs and benefits (**section 8.3 & 9.4**). (Subtask 2.1.2)

8. To identify how the digitized ICT solutions fit with regulatory frameworks and what requirement to align with state-of-the art technical capabilities and compliance per country (**sections 9.5**). (Subtask 2.1.3)

9. To identify the behavioural and operational change requirements, and the social acceptance and collaboration requirements, for different users and actors that are needed to work with the proposed digitized ICT solutions, also in relation to filling technical capability gaps (**section 9.6**). (Subtask 2.1.3)

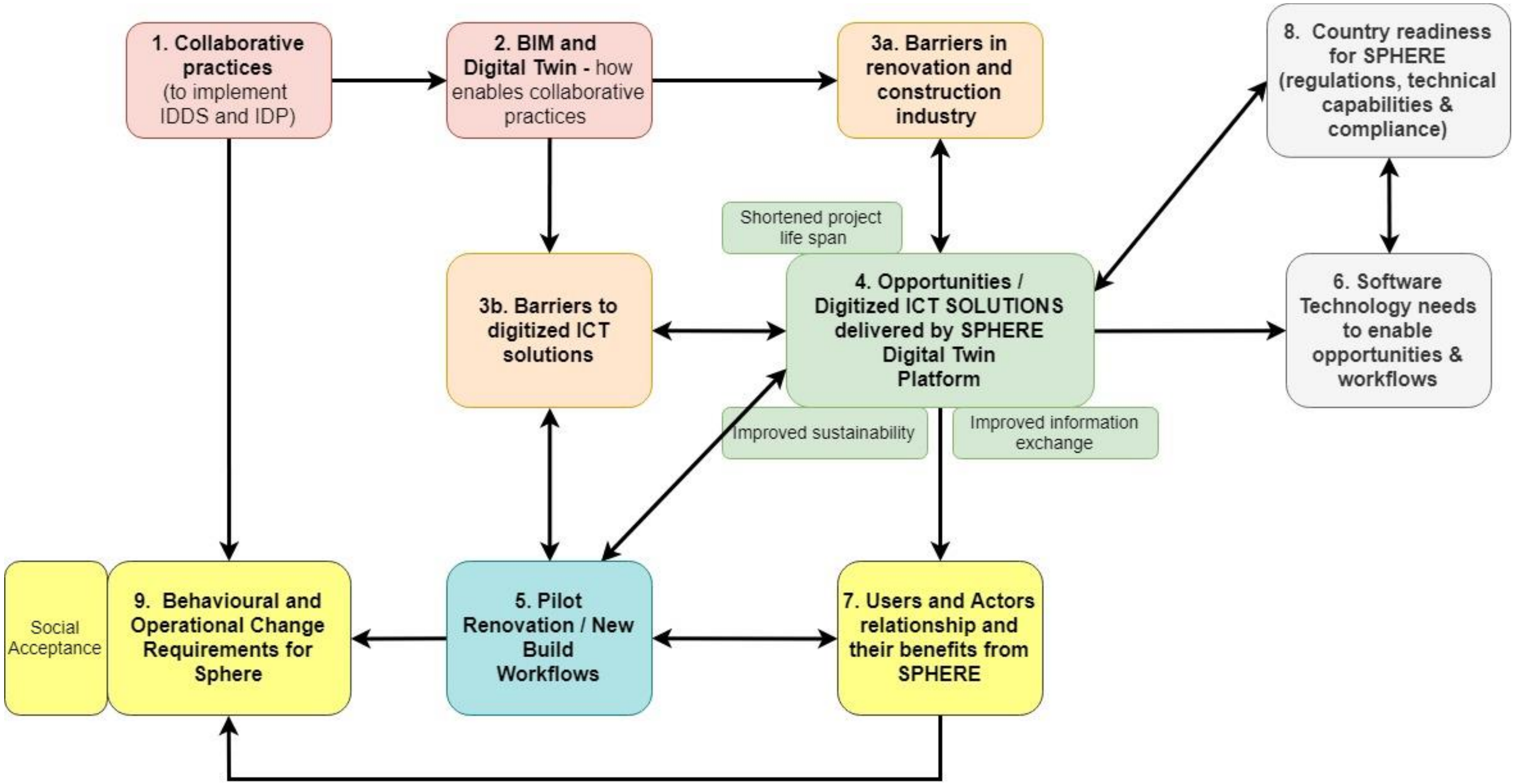

Figure 1. Overview of purposes of the Report as defined in DoA

2.2 Target group

The target group of the report is first of all, the Sphere consortium, composed of 19 partners. Other target groups, as identified in the communication and dissemination strategy and the exploitation plan include:

- Professionals (designers, ICT installers, energy advisors)
- Construction and engineering companies
- Energy service companies (ESCOs/ESC)
- Manufacturers and developers (ICT, BMS, equipment, HVAC)
- Government, municipalities and policy makers (standardization bodies)
- End-users and General Public
- Industry / Umbrella associations
- Academia, scientific community

2.3 Contributions of partners

Table 1. Partner Responsibilities in Task 2.1

Tasks carried out	Chapter	Involved Partner(s)
Writing of introduction	2	EKO, COMET, VRM, IDP, R2M
Definition of methodology and writing of methodology	3	EKO, COMET, OPY
Key concept definition identification (IDDS, IPD, IPI, BIM, DT) and relation to identified collaborative practices	4	EKO, OPY, IDP
Country Scans of Barriers and Opportunities and Regulatory systems and Technical Capabilities	5 & 8.5	EKO, OPY, COMSA, NEX, CREE, DE5, R2M, COMET
Workshops for Barriers and Solutions in Renovation and Construction practices	6	EKO, CAV, VTT, DE5, ASC, BASF, COMSA, OPY, COMET, NEX, VRM, R2M
Framework for operationalisation of IDDS using digital twins, including workflow, users, actors, and determining relevant barriers and pains to address	7	EKO, OPY
Definition of SPHERE Barriers to be addressed	8.1	ALL
Definition of SPHERE workflows with Digital solutions	8.2	ALL
Description of technology requirements needed to operationalise workflows	8.3	NEX, VRM, EKO
Defined Requirements from users and actors in collaboration practices, their roles and acceptance needs	8.4	OPY, COMET
Assessment of Regulatory linkages to proposed Sphere Solutions and technical capabilities for countries to absorb SPHERE solutions	8.5	EKO, OPY, COMSA
Definition of Operational and Change Management Requirements from current practices to introduce SPHERE Solutions	8.6	EKO, COMET
Writing of Achievements and Conclusions	9	EKO
Delivery of list of Acronyms and Glossary of Definitions	10	COMSA

2.4 Baseline

The deliverable provides the starting evaluation for the project to identify the needs and requirements in delivering the SPHERE ICT Platform, serving to optimise the design, construction and in-use performance of residential buildings, focusing on both new-built and renovation works. As a start of the works to understand the baseline two activities were carried out. First, existing platforms were screened as outlined in Table 2 below. Second, state-of-the-art knowledge developed in other H2020 projects focusing on ICT Platform activities for BIM, Digital Twins and IDDS collaborative approaches were analysed (Table 3 below), so as to understand the current baseline and develop synergies and knowledge transfer from existing works.

The evaluation of existing commercial cloud software platforms found that these focus on:

- Creating **interoperability of BIM data** use across platforms and stakeholders, so as to allow for improved connections across the entire project supply chains (incl. KONSTRU, BIMCHAIN)
- Creating **improved data collection tools and quality standards for BIM** utilisation as part of life cycle asset management (incl. GLIDERBIM, eRDS Clouds, CAFM Explorer)
- Creating **collaborative environments that allow for exchanging information and knowledge** between stakeholders within a project such as e-mails, documents, and data-files with our without BIM functionality (incl. BIM360, VIEWPOINT, PROCORE, NEWFORMA)
- Creating **digital BIM respresentations that can be interlinked with various simulations** for evaluating the quality of the building when in use such as energy, indoor environmental quality, sunlight (incl. IESVE)

The drawback of most of these tools is that they are too costly and/or focus on large building projects to work for smaller building projects and renovation works. As such eight EU funded projects are currently ongoing as listed in Table 3, that focus on enhancing such functionalities for purposes of smaller newbuild and/or renovation works (CBIM, ENCORE, BIM4EEB, BIMERR, BIM-SPEED, BIM4REN, P2ENDURE). These build upon nine earlier projects that looked at delivering specific software tools to understand real-life building complexities to measure performance of renovation and newbuild projects, yet did not specifically leverage BIM technologies (incl. HIT2GAP, MOEEBIUS, NewTREND, BUILT2SPEC, PEAKapp, HESMOS, BECA, PEBBLE).

SPHERE will monitor the outputs of these projects and screen past projects deliverables' to assess learnings as part of the WP2.3 efforts to identify requirements. The information will be used to understand where the set requirements are already met or are being met in other projects so as to make sure efforts are not duplicated and synergies can be generated. Based on this identification process contact will be sought with the other currently on-going projects.

Table 2. Existing ICT Platforms that support residential newbuild and/or renovation

Platform Name	Developer	Website	Focus
IESVE	IES	LINK	Digital repsentation and visualisation of buildings with BIM combined with architecture drawing/sketching and simulation options (incl. thermal, IEQ, sunlight).
KONSTRU	Konstru	LINK	Provides interoperability to view, edit, clean and synchronize model data between BIM tools (incl. Revit, Excel, ETABS, Grasshopper, SAP2000, Tekla, RAM and Dynamo) covering full BIM elements (not only geometry) in a data effective manner (1/10th data storage need versus a Revit model), with a powerful 3D model viewer, and share data between collaborators in an online cloud environment.
BIMCHAIN	Bimchain	LINK	Utilisation of Blockchain for securing BIM executing plans and BIM data exchange using a smart contracting approach to contractual and legal processes.
CAFM Explorer	Idox plc	LINK	Digital facility management software to increase operational efficiency and timesavings.
GLIDERBIM	Glider Technology	LINK	Life cycle asset management software to assist with information collection through design, construction and operation for BIM level 2 delivery.

eRDS Cloud	eRDS	LINK	Interoperability software for COBie building component data that is fully integrated with BIM, BMS and BIM-FM and can also interlink with 2D drawings for refrubishments to generate a comprehensive asset database under COBie compliant standards.
PGPLANT MW	Process Genius	LINK	Commercial company offering Digital Twin services for Manufacturing facilities with real-time process integration & visualisation for plant management and control and maintenance.
PROCORE	Procore Technologies	LINK	Platform for data, planning and finance integration for construction projects covering communications and knowledge sharing between general contractors, owners, real estate developers and subcontractors.
BIM360 Coordinate	Autodesk	LINK	Data centric cloud based management solution for BIM coordination so that project teams gain anytime, anywhere, access to project information for multi-disciplinary collaboration and coordination.
NEWFORMA	Newforma	LINK	Project email and file management software for architects, engineers, contractors and owners.
VIEWPOINT	viewpoint	LINK	Cloud based document and information management solution for hsaring, controlling and collaborating on project documents with dispersed project teams in construction.

Table 3. Past and Current BIM, Digital Twin, and IDDS Related EU funded Projects

Project Name	Period	Website	Relationship to SPHERE
CBIM	2020-2024 (H2020)	LINK	CBIM looks at how digital twins can be managed in the cloud utilising BIM technologies (Marie Curie Training Network)
ENCORE	2019-2022 (H2020)	LINK	ENCORE boosts renovation by developing a BIM cloud solution for rapidly generating BIM models of existing buildings & automated work planning for construction crews
BIM4EEB	2019-2022 (H2020)	LINK	BIM4EEB is delivering a BIM toolkit that has semantinc interoperability between software and stakeholders, with active participation of end-users and best practices and guidelines for public administrators and private stakeholders.
BIMERR	2019-2022 (H2020)	LINK	BIMERR is building a semantic interoperable toolkit for 3rd party legacy ICT tools to seamlessly integrate and create information exchange among AEC stakeholders for BIM adoption.
BIM-SPEED	2018-2022 (H2020)	LINK	BIM-SPEED is developed a cloud BIM platform with standardised procedures for as-built data acquisition, modelling, simulation, implementation and maintenance of renovation.
BIM4REN	2018-2022 (H2020)	LINK	BIM4REN focuses on a one stop access platform for utilisation of state of the art BIM technologies and services.
P2ENDURE	2016-2020 (H2020)	LINK	P2ENDURE focuses on prefabricated plug and play systems for deep renovation of building envelopes and technical systems, integrating 3D printing, laser & thermal scanning with BIM.
Net-UBIEP	2017-2020	LINK	NET-UBIEP focuses on developing a standard BIM qualification model for professionals in the construction sector (covering a BIM training scheme and a BIM qualification and certification scheme) to improve the energy competences gap in the sector.
OptEEmAL	2015-2019 (H2020)	LINK	OptEEmAL developed a platform for providing an Integrated Project Delivery (IPD) approach for building and district retrofitting projects to reduce time delivery and uncertainties when compared to business-as-usual practices.
HIT2GAP	2015-2019 (H2020)	LINK	Hit2GAP focused on existing measurement and control tools for understanding the energy performance gap and hot to reduce it.
MOEEBIUS	2015-2019 (H2020)	LINK	MOEEBIUS focuses on advancing simulation tools to understand real-life building complexities to reduce the performance gap and optimising retrofitting based on OLCA and LCC performance.
NewTREND	2015-2018 (H2020)	LINK	NewTREND focuses on semantic web interoperability for data exchange at district level for designing buildings and districts for refurbishment.
BUILT2SPEC	2015-2018	LINK	Development of toolsets for self-inspection, 3D Modelling, management and quality checks.
PEAKapp	2016-2019 (H2020)	LINK	PEAKapp enables users to consume more renewable energy with lasting energy savings by the implementation of ICT to Human ecosystem.
HESMOS	2010-2013 (FP7)	LINK	HEMOS provides a holistic approach and simulation capabilities to close the gap between BIM and the building life cycle.
BECA (CIP)	2011-2013	LINK	BECA platform will improve energy consumption + cost effectiveness in social housings.
PEBBLE	2010-2013 (FP7)	LINK	PEBBLE focused ICT-based tools to support the operation of energy positive buildings (EPBs) and energy-smart buildings.

2.5 Relations to other activities

Task 2.1 is the starting point of the SPHERE platform works and does not rest upon earlier inputs. It provides a baseline for several other tasks as identified in Figure 2 and Table 4.

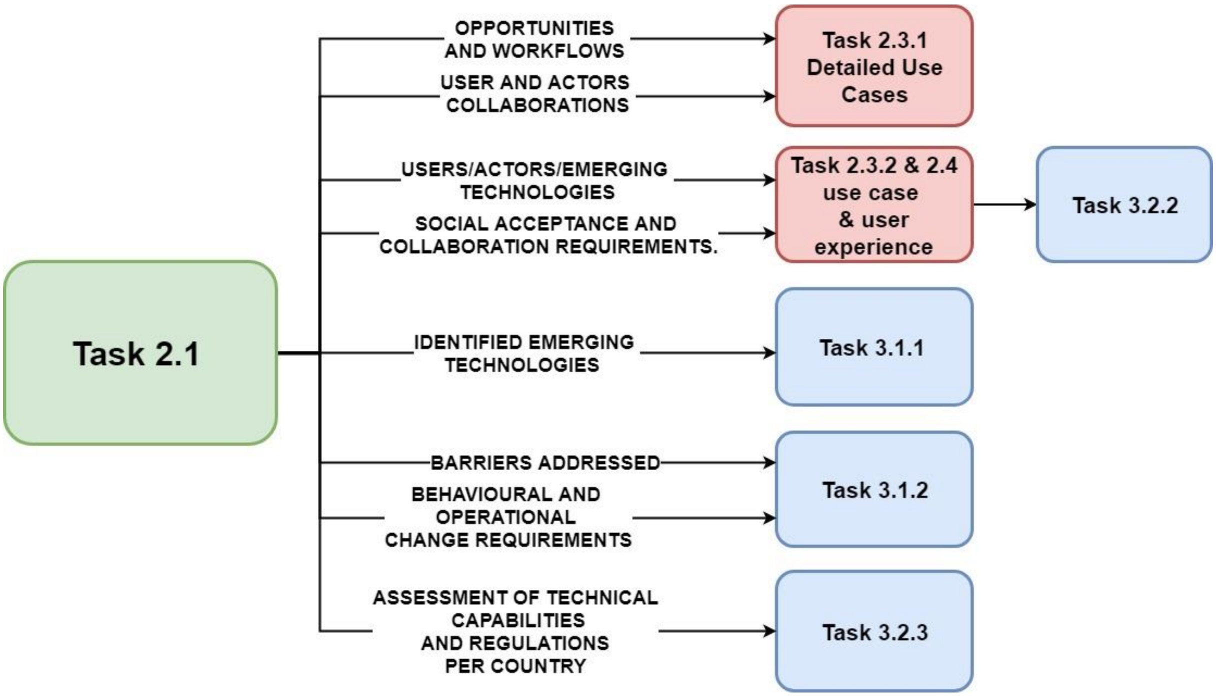

Figure 2. Relation to other Tasks as identified in SPHERE DoA

Table 4. Relationship deliverable 2.1 and follow-up tasks in the SPHERE project

Deliverable 2.1 Result	Sections	Follow-up task
Opportunities to be delivered by the SPHERE platform and related workflows	9.1, 9.2	**Task 2.3.1** to identify detailed use cases from the IDDS framework.
Identified users and actors and their collaborative practice requirements	8.3, 9.4	**Task 2.3.1** to identify their interaction and communication methods used between them in collaborative practices (which provides inputs for **task 3.2.2).**
Identification of users, actors, emerging technologies and digitzed ICT solutions as part of the workflow scenarios	9.3, 9.4	**Task 2.3.2** to identify the complete needs for the platform as part of identified user scenarios and use cases.
Users and actors and their social acceptance and collaboration requirements	9.4	**Task 2.3.2** to develop the user experience design of the platform.
Identified emerging technologies and digitized ICT solution scans for the Digital Twin approach	9.1, 9.3	**Task 3.1.1** to provide for digitalization process requirements for the SPHERE PaaS concept.
Description of barriers that are addressed in the SPHERE platform	9.1	**task 3.1.2** that adds detail to overcoming barriers for the SPHERE Paas concept.
Behavioural and operational change requirements	9.6	**Task 2.3.2** to identify the complete needs of the platform utilising a solutions workflow
Assessment of regulatory requirements and standards needed to be incorporated to be compliant with the state of the art	9.5	**Task 2.3.2** for the solutions workflows to be delivered and **Task 3.2.3** to provide for user-specific parameters for compliance and replicability of the Digital Twin capturing process

3 Methodologies Used

3.1 Literature Review

A literature review is carried out based on academic journal articles and past and current related H2020 projects to analyse Integrated Design and Delivery Solutions (IDDS), Integrated Project Delivery (IPD), Building Information Modelling (BIM) and Digital Twins (DT). The purpose is to examine and create a synthesis of collaborative practices that are required to implement IDDS and IPD, and examine how BIM and DT can serve to implement these practices. The consulted database for academic literature was Elsevier SCOPUS. Five database searches were carried out:

1. "Integrated AND Design AND Delivery AND Solutions" resulting in 908 entries;
2. "Integrated AND Project AND Delivery AND Construction" resulting in 822 entries;
3. "Building AND Information AND Modelling AND Review" with restriction of results from 2015 resulting in 757 entries;
4. "Digital AND Twin AND Construction" resulting in 73 entries;
5. "Digital AND Twin AND Buildings" resulting in 94 entries.

The abstracts were reviewed to identify their relevance for SPHERE, which after an additional snow balling approach resulted in the identification of 102 relevant articles about BIM, 30 articles about Digital Twins, 32 articles about IPD, and 29 articles about IDDS. A full reference list of the consulted articles can be found in Appendix H. In parallel to the industry literature 17 past and current state-of-the-art EU-funded FP7/H2020 projects focusing on developing tools for the built environment were consulted (see Table 4 in section 2.4). In Chapter 4 the results of IDDS, IPD, BIM and Digital Twins literature review can be found, in relationship to the SPHERE objectives and requirements in the context of new build and renovations of existing residential buildings, drawing upon the literature survey.

3.2 Country Scan: Regulations, Barriers and Solutions Methodology

The consortium partners carried out a series of extensive scans at a country level to identify the current status of the construction sector, barriers, needs or solutions and regulatory practices in relationship to collaboration using IDDS or IPD and BIM. A template was built to create a scan that can be compared across countries once all scans had been carried out consisting of the following sections:

- Current status of the Construction sector in terms of productivity and output.
- Practices in terms of typical, IPD and IDDS approaches in the countries construction sector.
- Applicable construction sector laws.
- Barriers to the implementation of IPD, IDDS and BIM in the construction sector.
- Private sector and Public Procurement based practices in the construction sector.
- Needs for change and solutions in the countries construction sector.

A total of 9 countries were identified based on the consortium's country of operation, given the need for extensive experience with practices in these countries in order to provide for the relevant information to the SPHERE project. The countries include Belgium, Germany, Spain, the Netherlands, Turkey, Austria, France, Italy, and the United Kingdom. The detailed scans can be found in Appendix B, the summary of results are available in Chapter 5 in relation to identified barriers and opportunities, with a summary in chapter 9 section 9.5 for regulatory needs and technical capabilities, in relationship to SPHERE Digital Twin Platform solutions.

The resulting country scans were analysed to evaluated barriers relating to the construction sector in a broad sense, and also in relation to the implementation of BIM and collaborative practices using IPD and IDDS. The evaluation led to a listing of barriers that were mentioned.

3.3 Workshops and Interviews

The consortium partners carried out a series of workshops and expert interviews, the demographics of which are shown in Table 5, to gain an understanding of construction and renovation sector practitioners. The workshops and expert interviews were facilitated using a prepared presentation that outlines key project concepts: IDDS, IPD, BIM and Digital Twins and a series of questions as outlined below. Also a facilitation guide was established that can be found in Appendix C that was created to prepare for workshops and interviews.

The series of general questions that were posed in the expert interviews and workshops included:

- What are the practices in your current approach to the delivery of a building project?
- What are the most common technical barriers that you face in delivery of a building project?
- What is your experience with and adoption level of BIM?
- What are the most significant advantages of BIM in your practice?
- What do you see as main challenges in implementing collaborative project delivery practices (IPD or IDDS)?
- What would be first needs to help you to start the shift towards more integrated project delivery?
- What are the software technologies / data and design management tools you currently use?
- What tools and software features are missing that would help in implementing a collaborative approach across partner companies that you work with?
- What is the current legal framework and procurement process you use for your building projects?
- What are regulatory and contractual rules that would help with collaborative working and responsibility sharing?

Specific further follow-up questions were asked depending on the organiser. In total seven workshops and interviews were held. The results in terms of barriers and solutions identified in the expert interviews and workshops for implementing IDDS, IPD, and BIM are presented in Chapter 6 and Chapter 7. The regulatory barriers and challenges are presented in Chapter 9 section 9.5. The listed barriers were evaluated similarly as in the country scans based on a listing approach. Duplicate barriers were eliminated to come to a unique list.

Table 5. Breakdown of roles and number of interviewees by partner, for selected partners.

Partner Acronym	Interview Job Role										Total
	Project manager	Building Owner	Design Team	Surveyor	MEP/civil engineer	Construction Manager	Construction Subcontractor	Maintenance Service company	BIM manager	Other	
VTT/CAV	1							2		3	6
R2M	2		1							1	4
COMS/OPY/COMET	1	1	2	2	1	1			1	2	11
EKO						1	2				3
BASF			2			4	2		1	2	10
NEANEX			1			1					2
CREE/EKO			1						1		2
DE5/EKO	1		1								2
TOTAL	**5**	**1**	**8**	**2**	**1**	**7**	**4**	**2**	**3**	**8**	**40**

4 Key Concepts: Digital Twins and BIM to facilitiate Collaborative IDDS and IPD practices

***DoA Objectives** : "Specifically, state of the art concepts based on lean and Integrated Design and Delivery solutions (IDDS) will be adapted and applied to the context of both retrofitting and new construction works solutions, enabled by the digital twin platform across all the lifecycles of the buildings. "*

***DoA Subtask 2.1.1 Opportunity Assessment for the Renovation Process**: Potential and needs of improvements in the construction and renovation will be identified. Focus will be given to the core objectives of the SPHERE methodology that aim to deliver the impact of the project. Opportunities delivered by the SPHERE concept and how the digital twin can enable the needs will be addressed, such as improved sustainability, shortened project life span, improved information exchange among stakeholders and social acceptance, improved project management, results monitoring and improved holistic benefits to the end users which will be the exploitable results of the project."*

4.1 Integrated Design and Delivery Solutions (IDDS)

According to the International Council for Research and Innovation in Building and Construction (CIB), Integrated Design and Delivery Solutions (IDDS) is defined as "*the use of collaborative work processes and enhanced skills, with integrated data, information and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build and operation, and across projects*."[1] IDDS has been developed to address key challenges associated with design, construction and commissioning sectors such as stalled productivity,[2] amount of waste generation, project delays and associated costs. The main idea is that increased communication and co-solutions across the design to construction to building use life cycle will solve these issues and improve the quality of the service delivered to the clients. IDDS thereby provides for a framework that brings people, industry processes and technologies together, with the aim to improve people's capabilities and the quality of work across the entire construction lifecycle from the earliest stage to the final stage i.e from commissioning to building decommissioning and materials recycling.[3]

The main definition of IDDS describes four main elements (see Figure 3) that are part of a project with an IDDS architecture[4]:

- Collaborative Processes across all project phases.
- Enhanced Skills.
- Integrated Information and Automation Systems.
- Knowledge Management.

Every element has different impacts on the three aspects of IDDS: processes, people and technology. The **collaborative processes across all project phases** element directly affects all main considerations of IDDS; people processes and technologies, since it indicates vertically integrated end-to-end processes throughout the project phases and enhanced collaboration among the stakeholders.[5] Ideally

[1] White Paper on IDDS Integrated Design & Delivery Solutions - CIB Publication 328 (2009)
[2] Utilizing BIM for Integrated design construction, commissioning, operation and maintenance
[3] Prins M, Owen R. Integrated design and delivery solutions. Archit Eng Des Manag. 2010;6(SPECIAL ISSUE):227–16.
[4] Owen R. Integrated Design & Delivery Solutions (IDDS). 2013.
[5] Owen, R. *et al*. Challenges for integrated design and delivery solutions. *Archit. Eng. Des. Manag.* 6, SPECIAL ISSUE (2010).

an information technology tool should support this cooperation and integration among the stakeholders, through seamless information sharing.[6]

The **Enhanced skills** element focuses on the collaborative capabilities of project teams including integration skills, developing coherent strategies for integration of work processes and having shared knowledge about work processes, in other words ability to work together in a multidisciplinary manner. Thus, it aims to add new values through introducing more social and collaborative skills to project team members. IDDS also foresees increasing the degree of integration through the supply chain or construction value chain using innovative digital and automated tools and systems and ensuring the integrity of the information flow and preventing the information loss. Basically, **Integrated Information and Automation Systems** aspect aims to introduce interoperability to ease the design fabrication processes and integration of information intensive work during the design thus increasing the overall efficiency.[6]

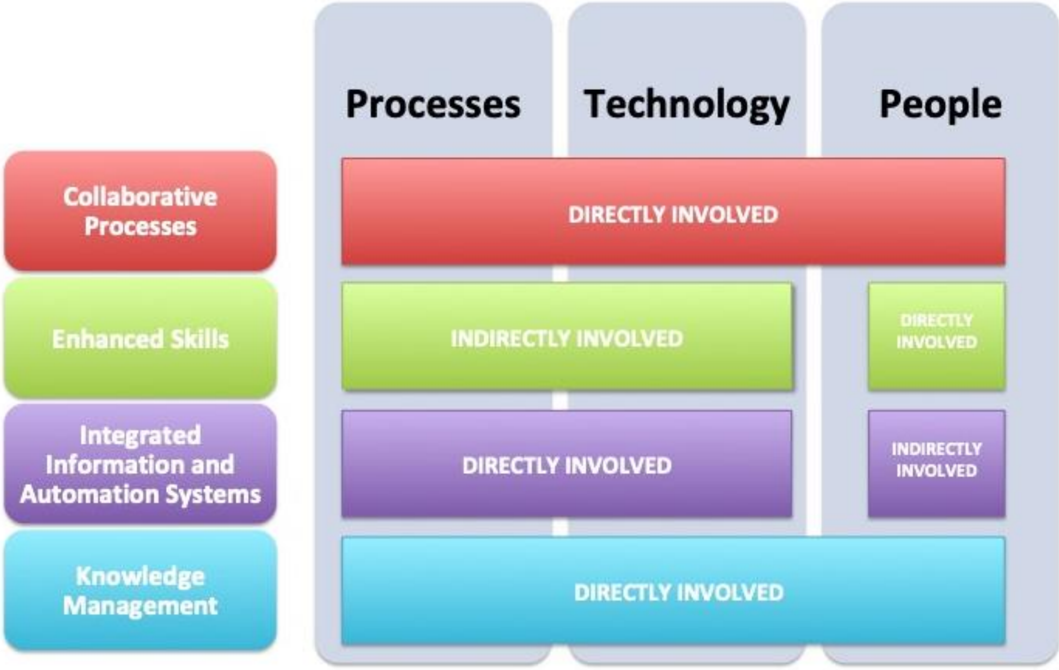

Figure 3. IDDS Elements and Pillars with their relationships. Adapted from CIB

Knowledge Management is concerned with the transmission and utilization of the knowledge. It ensures that the accumulation of knowledge obtained through external and internal stakeholders feedbacks throughout the life cycle is updated constantly and shared. Also information input from parties is encouraged in order to prevent obstructions of knowledge sharing between upstream or downstream partners in the name of the competitive advantage. The successful use of IDDS thereby involves changing practices in all project phases from conceptual planning of buildings to design, construction, commissioning, operation, retrofit and decommissioning. For each of these phases, key changes in the structure and culture of the project team across the different collaborating firms is needed to implement a successful IDDS based project. At this stage the implementation of IDDS is still in the research and development stage with limited case study examples.[7]

[6] Prins, M. & Owen, R. Integrated Design and Delivery Solutions. *Archit. Eng. Des. Manag.* 6**,** 4 (2010).
[7] Owen, Robert L., et al. "Research roadmap report: Integrated Design and Delivery Solutions (IDDS)." (2013).

4.1.1 IDDS based Collaborative Practices

Based on the consortium's experience with IDDS, and a review of IDDS practices contained in the literature, a series of collaborative practices required for IDDS implementation were deduced.

The eight collaborative IDDS practices defined in SPHERE are:

1. Align values in a kick-off meeting that are carried out throughout the project
2. Setup performance-based goals with all parties involved with a shared responsibility
3. Select a joint business model and contract structure with shared risk
4. Establish a shared project roadmap with collaborative group updating meetings
5. Establish open communication channels and practices across involved partners
6. Methodological discovery and implementation to reach the team goals
7. Sustaining the collaboration through an experienced facilitator
8. Construction and operation considerations to optimize results and ensure objectives

Partners here refers to all parties involved across the life cycle - from initial target setting to in use of the building - in a construction or renovation project. Below, a concise elaboration on the eight critical IDDS practices is provided as defined by the SPHERE consortium based on the consortium's expertise with IDDS and the literature.[8]

1. **Align Values:** Before delving into pre-design, the team members must agree in their alignment to the values that underlie the integrated project so as to develop confidence relationships that will be necessary to negotiate a contract and communicate effectively.

2. **Align Goals:** In an IDDS project, team members mutually define the desired outcomes and work together to set performance goals to reflect the integrated nature and open-ended potential of the project. Even conventional goals are different for each team member, integrated goals and conditions of satisfaction should be shared and project-centric, and should be gathered in project goal agreements.

3. **Select a Business Model and Contract Structure:** Risk management and financial terms ultimately determine how businesses and firms relate, aligning incentive structures by contractually linking two or more parties with an IPD contracting approach, sharing the financial risk and benefits under any of these ways:

    - Mechanism 1: Base Fee, with Contingent-on-Success Profits
    - Mechanism 2: Variable Costs, without a Cap
    - Mechanism 3: Limits on Change Orders

Key elements of the contract structure can be found in Appendix A. In brief the structure for sharing risks and rewards entails:

- Each party will only receive its share of profit if the project successfully meets the goals.
- Each party also agrees not to sue another for design errors, omissions, or delays (unless there is true negligence).
- Waiver agreements facilitate collaboration and cut costs.

[8] *CEC. 2015. Improving Green Building Construction in North America: Guide to Integrated Design and Delivery. Montreal, Canada: Commission for Environmental Cooperation. 84 pp ;* Singh, V., Design, I., Teams, D. & Bernard, A. Challenges for Integrated Design and Delivery Teams in AEC. in *10th Product Lifecycle Management for Society (PLM),* (2017). ; Rekola, M., Kojima, J. & Mäkeläinen, T. Towards integrated design and delivery solutions: Pinpointed challenges of process change. *Archit. Eng. Des. Manag.* 6**,** SPECIAL ISSUE (2010).

- Fiscal transparency (historical profits, overhead, and build-up of hourly rates) of the team increases trust between the owner, the design team and the construction teams.

4. **Establish a Shared Project Roadmap:** Once the team has settled on a business and contract model, it should develop a project roadmap for frequent and effective communication, identifying subteams for specific tasks, and assigning responsibility for tracking progress in relation to green performance goals, scheduling whole group meetings strategically to find synergies.

5. **Establish Cross Party Communication Channels and Practices:** While the team develops the project roadmap, communication strategies should be taken into account, as the fully co-location if possible, establish clear communication protocols, consider Web-based management tools or hosted intranets. The use of Building Information Modeling (BIM) saves time and money facilitating performance simulations that help to verify that the project is on track to meet green goals.

6. **Methodical Discovery and Implementation:** Once the project team has agreed on the previous points, it is ready to implement methodically the project process and follow through to project completion. Before engaging in schematic design, teams need to analyze interrelationships among project systems, analyze anticipated water and energy demands, perform early-design-phase simulations to predict actual loads, identify opportunities for design choices to reduce high-impact loads, and consider renewable resources.

7. **Sustaining the Collaboration through a Facilitator:** Considering a concerted effort is required to maintain the necessary high level of collaboration in an integrated team, a facilitator may be needed for the length of the project to sustain the collaboration and ensure that the team reaps the benefits of its earlier cost and time investments. Designers and builders come with various levels of skill and experience in collaborative work: ongoing coaching, facilitation, and support are essential to maintaining a high-functioning team. The bigger and less experienced the team, the more intensive and hands-on the facilitation has to be.

8. **Construction and Operation Considerations:** Ensuring that the values of the project are passed down into construction and operation without compromising green performance is one of the biggest challenges. Including the building operator in the design team to review roles and responsibilities helps ensure continuity. Coordinating the commissioning schedule with the construction schedule helps to efficiently verify performance targets. There is no final step in an IDDS project. Tracking performance and monitoring key performance indicators continues for the life cycle of the building. The building's green features and performance goals should be communicated to occupants to gain their support and buy-in.

4.2 Integrated Project Delivery (IPD) and IPD Contracting

As industry or construction projects and their requirements become more complex due to their size and the nature of the works involved, interaction between an increasing number of project teams from different disciplines is required. Integrated Project Delivery (IPD) is a collaborative practice that is close to but narrower in scope than IDDS. It can be utilised to manage and deliver projects that require high level of collaboration and communication.[9]

The main premise of IPD for construction is to setup effective collaboration between key industry actors; owner/buyer, designer and constructor stakeholders. IPD in construction and renovation involves a joint contract requiring architects, designers, general and key trade contractors to work together from the start of a project, making the best use of BIM as a collaborative tool.[10] By emphasising collaboration and contributions of knowledge at an early project stage and by utilization of new technologies, the quality of provided value increases throughout the project lifecycle. With a more effectively structure of trust based on collaborations, the success of the project becomes more important than the individual actor's success. In other words, the success of an individual participant is dependent on the other participants, which creates a tighter team and a higher degree of collaboration between the actors involved in the construction project. These teams are also sharing the risks and this supports value-based decision-making and utilization of full technological capabilities and support. Consequently, designing, building and operating processes for a facility can become more efficient and errors are reduced, which lowers the costs of construction or renovation projects if implemented well.

To summarize, Integrated Project Delivery (IPD) is a contract based approach, which creates an environment that enhances collaboration, innovation, and value, so as to optimise project results, increase project worth to the client, so as to reduce waste and maximize efficiency through all phases of design, fabrication and construction.

4.2.1 IPD based Collaborative Practices

Based on the consortium's experience with IPD, and a review of IPD practices contained in the literature, a series of collaborative practices required for IPD implementation were deduced.[11]

The five collaborative IPD practices defined in SPHERE are:

1. Setup a joint contract requiring architects, designers and key trade contractors to work together from the start in an Integrated Project Management and Delivery Team
2. Share risks and rewards and establish this in the contract based on the project's outcome
3. Jointly validate the project's goals and its performance across the project
4. Integrate the team's expertise throughout the project's process
5. Establish a constant flow of information and collaboration

Partners here refers to all parties involved - from initial target setting to in use of the building - in a construction or renovation project.

[9] Thomsen, C., Darrington, J. W., Dunne, D. & Lichtig, W. A. Managing Integrated Project Delivery. *Constr. Manag. Assoc. Am.* (2009).

[10] AIA (2007). "Integrated Project Delivery: A Guide". In: *American Institute of Architects*.

[11] Fish, A. IPD - The obstacles of Implementation. 60 pages (Kansas State University, 2011). ; Jones, B. Integrated project elivery (IPD) for maximizing design and construction considerations regarding sustainability. *Procedia Eng.* 95**,** Scescm (2014).

4.3 BIM and Collaborative Practices

Building Information Modeling (BIM) has been defined as a digital toolset used to digitally map a building or infrastructure facility for various purposes: visualization, scheduling, communication and collaboration between stakeholders throughout a building/facilities life cycle.[12] According to the Associated General Contractors of America (AGC), BIM is a data rich object oriented parametric digital representation of a building, which allows various users to extract and analyse the data to make decisions and improve the process of delivering the building.[13] Various levels of maturity of a BIM model have been identified based on their richness as shown in figure 4 below (Poljanšek 2017).

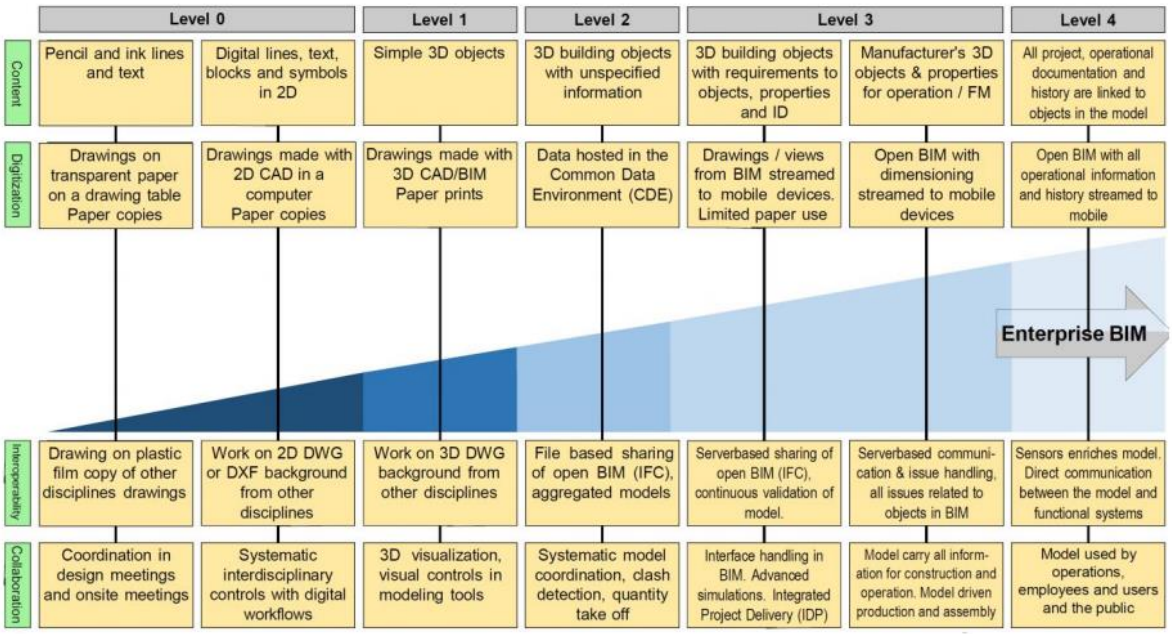

Figure 4. BIM levels of Maturity.
Source of Figure: Poljanšek (2017)

To establish a BIM data framework for a facility, the first step is to define the minimum BIM needs and related digital requirements. In ISO 19650, it is marked to draw up a EIR (Exchange Information Requirements) document, which defines the information that will be required by the model. It is important to have the contribution of all the stakeholders of the asset in defining the EIR. Then the object based modeling of the facility needs to be completed using an object-based modeling software tool similar to ArchiCAD, Revit, Tekla or Vico.[14] The resulting model can then be used in a multidisciplinary 'model-based' collaborative project where each party updates the model as necessary. The final possible stage of establishing a BIM model consists of the integration of the model with external databases to enrich it and allows further collaboration and interoperability of the data with third parties.

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[12] C.M. Eastman, C. Eastman, P. Teicholz, R. Sacks, BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractor, Wiley, Hoboken, NJ, 2011 (ISBN: 9780470541371).

[13] Succar, Bilal. "Building information modelling framework: A research and delivery foundation for industry stakeholders." *Automation in construction* 18.3 (2009): 357-375.

[14] Succar, Bilal, Willy Sher, and Anthony Williams. "Measuring BIM performance: Five metrics." *Architectural Engineering and Design Management* 8.2 (2012): 120-142.

The guidelines for developing and implementing a BIM plan are established in a BIM Execution Plan (BEP), redacted by the BIM Manager and applied in a project by the BIM Coordinator.[15] These figures are also responsibles to update the BEP eventually, to solve in a dynamic way interoperability conflicts or react to new opportunities. In a wider definition BIM has been defined as a holistic framework and not only a digital toolset, that covers processes, technologies, and regulations, so as to enable digitally supported management of the essential building design and project data throughout the building's life cycle.[16] As such it represents a paradigm shift in the process of building construction and delivery.

4.3.1 BIM facilitation of IDDS and IPD Collaborative Practices

The collaborative practices in Section 4.1, 4.2 and 4.3 were scrutinised by the SPHERE consortium from a BIM based perspective, on how BIM can assist to enable these practices. The results are established in Table 6 below.

Table 6. Facilitation of Collaborative Practices by using BIM in a project

Collaborative IDDS Practice	**BIM Facilitation**
1. Align Values in a kick-off meeting that are carried out throughout the project	Setup the expectation for using the BIM model and how it will facilitate exchange of information between parties in the project
2. Setup Performance based Goals with all parties involved with a shared responsibility	Using EIR (Exchange Information Requirements) BIM helps to identify critical requirements for the digitisation of the BIM model and can include performance goals for the BIM level of detail needed.
3. Select a joint business model and contract structure with shared risk	Potential improvement in the business model in terms of costs or performance thanks to more efficient information sharing and replicability of projects thanks to digitisation.
4. Establish a shared project roadmap with collaborative group updating meetings	The BIM Execution Plan defines periodic coordination meetings that serve to ensure the digital BIM model is developed in a steady and consistent manner.
5. Establish open communication channels and practices across involved partners	The BIM Execution Plan defines the interoperability process for a correct communication to establish the digitised BIM of the building between all the actors of the project, focusing especially on the tools utilised across all partners.
6. Methodological discovery and implementation to reach the team goals	Allows for more capabilities to assess different architectural and design options embedded in the building of interest.
7. Sustaining the collaboration through an experienced facilitator	BIM Coordinator, with supervision of BIM Manager, helps team collaboration, as marked in BIM Execution Plan
8. Construction and operation considerations to optimize results and ensure objectives	Ability to share and update the BIM digital model in near-real time to keep track of evolution in construction progress and compare with expected planning
Collaborative IPD Practice	**BIM Facilitation**
1. Setup a joint contract requiring architects, designers and key trade contractors to work together from the start in an Integrated Project Management and Delivery Team	The utilisation of digital BIM allows various actors in the project to have a common digital model of the building to ensure consistent delivery of the project with reduced errors from initial design to construction to operation. The contract can reflect the requirements and needs for this cooperation using BIM.
2. Share risks and rewards and establish this in the contract based on the project's outcome	A BIM model can help to establish a framework for mitigating particular risks related to project delivery and project quality/performance.
3. Jointly validate the project's goals and its performance across the project	A BIM model can help to assess whether particular goals are met in a more transparent and easy to communicate manner.
4. Integrate the teams expertise throughout the project's process	A BIM model can help as an integrator of different expertises by bringing together shared knowledge in a digital model

[15] Nisa Lau, S. E. *et al.* A Review of Application Building Information Modeling (BIM) during Pre-Construction Stage: Retrospective and Future Directions. *IOP Conf. Ser. Earth Environ. Sci.* 143**,** 1 (2018).

[16] Tarandi, V. A BIM Collaboration Lab for Improved through Life Support. *Procedia Econ. Financ.* 21**,** 15 (2015).

5. Establish a constant flow of information and collaboration	A BIM model can help to have a common platform for the exchange of information for collaboration purposes.

4.4 Digital Twins and Collaborative Practices

A Digital Twin (DT) is referred to as the digital representation of the mechanics or behaviour of a physical system. Using physical entities, high fidelity virtual models are created in digital platforms and these models can be used in various ways including: real-time data acquisition and storing, simulating the behavior of the physical object, and iterative real-life optimization of operations. A DT can be used as a 'test-bed' to simulate possible changes such as technological improvements virtually, prior to their implementation, referred to as a Digital Twin Prototype (DTP). It can also be used for on-going operational tracking and improving the performance of a physical system, referred to as a Digital Twin Instance (DTI). And finally, it can be used for comparison between different Digital Twins and their performance, referred to as a Digital Twin Aggregate (DTA). With Industry 4.0 and increasing digitalization, the digital twin concept has attracted attention from different industries, especially from the manufacturing industry.

Developments in monitoring sensors, the Internet of Things (IoT), improved digital data management, and cloud computing have increased the feasibility to develop digital twins in the construction industry. Applications include the deployment of sensors within building structures for material state or energy measurement with IoT communications technology to support real-time data acquisition for facility management activities. In other words, any relevant change of state in the physical state is detected by the sensors and triggers a flow of data that also changes the state of the DT representing aspects of the building correspondingly. [17]

It is important to consider that a BIM model is different from a DT, but a BIM model must be adapted to be used as DT, for example adapting the LOD (Level Of Detail) of the model. This "correction" is managed by the Digital Twin Manager. The Digital Twin Manager assures that the model and the external database works correctly and all the users have access to the DT platform. All changes (Example: new users, substitution of a equipment, etc.) to the DT are controlled by the DT Manager. Note that the DT manager needs to collaborate closely with the BIM manager and that the relationship between the two roles needs to be elaborated more closely.

4.4.1 Digital Twin facilitation of IDDS, IPD and IPI Collaborative Practices

The collaborative practices in Section 4.1, 4.2 and 4.3 were scrutinised by the SPHERE consortium from a Digital Twin based perspective, on how Digital Twins of existing buildings - DTI's - and planned for buildings - DTP's - can assist to enable these practices. Results can be found in Table 7 below.

Table 7. Facilitation of Collaborative Practices by using Digital Twins.

Collaborative IDDS Practice	Digital Twin Facilitation
1. Align Values in a kick-off meeting that are carried out throughout the project	The Digital Twin allows to set innovative values and goals in terms of how the project is developed and handed over to the owner/managers
2. Setup Performance based goals with all parties involved with a shared responsibility	The use of sensors in a Digital Twin enables all parties to consider more precise goals and how these can be evaluated
3. Select a joint business model and contract structure with shared risk	The Digital Twin provides additional opportunities for business models such as energy performance contracting, and also enables earlier detection of risks in terms of deviance from original plans

[17] Dawkins, Oliver, Adam Dennett, and Andrew Hudson-Smith. "Living with a digital twin: Operational management and engagement using IoT and Mixed Realities at UCL's Here East Campus on the Queen Elizabeth Olympic Park." (2018).

4. Establish a shared project roadmap with collaborative group updating meetings	The Digital Twin development and use can be featured in the project roadmap in terms of milestones and delivery, with periodic tracking in group meetings.
5. Establish open communication channels and practices across involved partners	The Digital Twin forms a common platform to facilitate communication about a project, by bringing together a wide variety of data streams and utilising analytics to assess building and project performance.
6. Methodological discovery and implementation to reach the team goals	The Digital Twin can help to explore different scenarios in a flexible manner, such as through generative design and energy simulations for different design options, which enables methodological discovery.
7. Sustaining the collaboration through an experienced facilitator	The Digital Twin can be utilised by a facilitator to understand in a faster way the latest status of a project if maintained well, helping with understanding where collaboration is going well and where it is underperforming.
8. Construction and Operation considerations to optimize results and ensure objectives	As Digital Twin Prototype (DTP) of a Digital Twin helps teams to evaluate solutions in a predictive manner using analytics and simulations.
Collaborative IPD Practice	**Digital Twin Facilitation**
1. Setup a joint contract requiring architects, designers and key trade contractors to work together from the start in an Integrated Project Management and Delivery Team	Provides a means to verify performance in a more reliable manner for contracting purposes to validate whether the targets and goals in the contract are delivered. Also enables better and more integrated collaboration via semi-automated communication of works delivered.
2. Share risks and rewards and establish this in the contract based on the project's outcome	The Digital Twin helps, using sensors to detect Asset Performances which can be used to mitigiate risks such as related to energy or indoor environmental quality performance needs.
3. Jointly validate the project's goals and its performance across the project	Allows for near real-time validation through the Digital Twin information stream to assess whether project goals are met and performance is as required.
4. Integrate the teams expertise throughout the project's process	Enables the integration of different expertises by providing a common platform where multiple parties can collaborate together based on complementary expertises.
5. Establish a constant flow of information and collaboration	DT, as a Digital Twin Instance and a Digital Twin Proptotype enhance collaboration between actors, to realize simulations and evaluate performances using the same tool.

5 Country Scans of Barriers

DoA: Subtask 2.1.3 Assessment of Barriers and need for Change Management: *Known barriers for the implementation of digitized ICT solutions in the renovation domain will be identified, as an essential aspect of the IDDS approach.*

A total of 9 country scans were carried out for Belgium, Germany, Spain, Netherlands, Turkey, Austria, France, Italy, and the United Kingdom from January to August 2019. Detailed results of the scans can be found in Appendix B. The scans included an assessment of barriers in the residential construction sector for the delivery of newbuild and residential renovation, to assess whether these can be potentially addressed by the SPHERE platform through the collaborative IDDS approach, the use of BIM, and the implementation of Digital Twins. A total of 32 unique barriers were identified as listed in Table 7 below. The barriers were also analysed structurally by associating them with categories of barriers. First an ontology of barriers was generated by the consortium (see Appendix F). Barriers are categorised in the ontology into five main types covering financial, technical, process & behavioural, political and regulatory, and awareness barriers. Subsequently, this ontology was used to classify the established barriers. Finally a second round of assessment was done to identify the applicability of the established barriers to each of the partner countries.

Key barriers identified for improving the productivity of the construction sector with more collaborative, lean processes from the country scans include barriers to:

- **Collaborative processes** were found limited due to a large number of different tools and documents in use that are not interoperable across actors in a construction/renovation project, weak linkages between certain key actors, difficulties in sharing and communicating information on a timely basis, and insufficient feedbacks between different life cycle phases such as in use information being fed back to design phases.
- **Data availability and quality** includes lack of availability of BIM models for older buildings, significant efforts needed to setup a BIM model.
- **Technological availability** includes limited access to real-time BIM workflow tools, plug-and play sensors for capturing data, and trend-based analytics of building use and degradation.
- **Regulations and standards** were found to be missing in terms of the requirements needed for project implementation and what technology suppliers should provide.
- **Weak sector innovation** with too rapid innovation for adoption and penetration in the market, and a general lack of emphasis on innovation in the sector to disseminate and foster uptake of new technologies.
- **Implementation Capacity & Skill availability** with many countries having difficulty in recruiting adequately skilled personnel for BIM implementation in projects, insufficient training and education available for digitisation in several countries, and there is a culture of mistrust in using BIM in many countries.
- **Financing capability and high costs** as developing BIM models of existing models for renovation costs too much, clients are not ready for higher costs, and contract durations for maintenance and operation of existing buildings are too short to warrant investments.
- **Contractual barriers** were found to include the lack of clarity on data ownership and associated legal risks, and the compatibility of BIM digisation and collaboration possibilities to more traditional contracting.

Table 8. Listing of Barriers from Construction Sector Country Scans for Residential Newbuild and Renovations

No.	Barrier	Barrier Category	Observed in countries
1	No real time collaboration between stakeholders in a project	Process & behavioural	ES,TR, FR
2	Lack of BIM software standardization to enhance effective communication and collaborative methods.	Political and regulatory	UK
3	No access to real-time workflow production tools	Technical barriers	ES, FR
4	No availability of plug and play sensors and Near Field Communication (NFC) technology	Technical barriers	ES, FR
5	No availability of pattern / trend-based advanced analytics	Technical barriers	ES, FR
6	Insufficient surveying and inspection tools are in use	Process & behavioural	ES, FR
7	Unavailability of BIM models previous to 1990	Technical barriers	ES
8	Significant data collection is required	Technical barriers	ES
9	Difficulty in recruiting trained personnel with a highly technical degree, engineers, project managers, etc.	Process & behavioural	BE, TR, AT, IT, UK
10	Lack of educational programmes towards digitalisation	Process & behavioural	UK
11	The availability of digital tools to improve processes outstrips adoption rates and applied innovation.	Awareness, Process	ES, FR
12	General lack of emphasis on R&D and innovation	Awareness barrier	ES, IT, UK
13	Widespread risk aversion and internal processes for innovation	Process & behavioural	ES, FR, UK
14	Weak linkage between technology suppliers and customers brings lack of standards	Politics & Regulatory	ES, FR, DE
15	Reluctance to modernise: Stagnant working practices might limit new technology uptake	Behavioural barrier	FI, AT, ES, IT, DE, UK
16	BIM practices do not meet the current tools and theory	Technical barriers	FI, ES, FR, DE, UK
17	Miscommunication, lack of collaboration among the project actors	Process & behavioural	FI, AT, IT, ES
18	Separate documents and tools, problems with integration of data and processes between actors	Technical barriers	FI, AT, IT
19	Design quality: clients are not prepared for higher cost	Financial barrier	FI, ES, UK
20	Unskilled staff for BIM, culture of mistrust	Technical barrier	FI, AT, FI, IT, TR, DE, FR
21	Lack of qualified employees (e.g. bricklayers, carpenters, installation controllers, roofers) as a consequence of the crisis	Technical barrier	NL, UK
22	BIM models require too much computing power at construction site	Technical barrier	FI, ES, FR
23	Resources limited/not compulsory to carry out ventilation / daylight simulations	Financial barrier	IT
24	No availability of effective GANTT actualization, not well communicated to contractors who hardly interpret the results	Process and behavioural	IT
25	Lack of building data information from previous works / history of the buildings	Process and behavioural	IT
26	Not known what should be monitored for the in use phase and how it relates to the design phase	Technical barrier	IT
27	Lack of understanding of lean thinking, resistance to the use of its fundamental techniques	Process & behavioural	UK
28	High initial investment needed for tools, equipment, training and wages/incentives to drive demand	Financial barrier	UK
29	Shortage of expertise and access to in-house training.	Technical barrier	UK
30	Ambiguity in data ownership and legal risks. Doubts about compatibility of BIM / contract formats.	Process & behavioural	UK
31	Scale: Strong negative correlation between the size of a project and the use of BIM	Financial & Technical	UK
32	Duration of maintenance contracts of buildings limited to a short-time duration (<5 years)	Financial barrier	ES

6 Identified Barriers from Workshops/Interviews

DoA: Subtask 2.1.3 Assessment of Barriers and need for Change Management: *Known barriers for the implementation of digitized ICT solutions in the renovation domain will be identified, as an essential aspect of the IDDS approach.*

To deepen the understanding of barriers and solutions for the implementation of renovations and newbuilds a series of in-depth workshops and interviews were carried out with 40 actors from different sectors in the construction industry, as described in section 3.2. The approach followed the materials as outlined in Appendix C. A total of ten sets of interviews or workshops were held covering the entire spectrum of the renovation life cycle, designers, architects, engineerings, construction companies, and material/compoment suppliers, with detailed descriptions of the results provided in Appendix D. The results provided for an identification of 47 barriers as listed in Table 9 below. The barriers were also analysed structurally by associating them with categories, similar to the procedure in Chapter 5 utilising the developed ontology of barriers (see Appendix F).

Key barriers identified for improving the productivity of the construction sector with more collaborative, lean processes from the country scans include barriers to:

- **Collaborative processes** due to barriers caused by miscommunication and limitations to facilitate collaboration, the utilisation of different documents and tools by different actors.
- **Data availability and quality** is hindered by BIM object databases not being integrated across the product manufacturing supply chain and the data generated therein, the absence of digital data of existing buildings for renovation, the limited maintenance of BIM data on the construction site, limitations in finding BIM objects that are adequate for utilisation in absence of easily searchable high quality libraries.
- **Technological availability** barriers include the absence of tools for updating BIM on the construction site in an easy manner because they are too slow to be usable or not fit for the on-site user interface (smartphones).
- **Regulations and standards** were found to be too limited at present to incentivise collaborative working practices, especially in terms of contract implementation, and the absence of maintenance protocols that are aligned with digitisation and BIM.
- **Weak sector innovation** barriers include a limited updating of working practices to incorporate new technologies, and a lack of overall know-how and high educational needs.
- **Implementation Capacity & Skill availability** is constrained due to limited BIM skills and available personnel in several countries, lack of know-how in the industry about BIM, the absence of evidence on benefits resulting in a mistrust of new technologies
- **Financing capability and high costs** requires improvement on the front of high financial costs of utilising BIM in project at present, with limited resource for smaller projects to commission particular works like simulations, and insufficient clarity on the higher advantages of BIM and Digital Twins softwares over more standard tools on the market.

Table 9. Listing of Barriers identified from workshops and interviews

No.	Barrier	Barrier Category
1	Working practices are too stagnant and limit new technology uptake.	Process & behavioural
2	BIM practices do not meet current tools and theory.	Process & behavioural
3	Miscommunication and potential lack of collaboration among the project actors.	Process & behavioural
4	Stakeholders work with separate documents and tools causing problems with data/works integration	Process & behavioural
5	Design quality – clients are not prepared for higher cost of using BIM	Financial
6	Often staff is not skilled enough to use BIM and there is a culture of mistrust of such technologies	Technical
7	BIM models require too much computing power at construction site	Technical
8	Resources limited for commissioning particular works such as ventilation / daylight simulations	Financial
9	Not known what should be monitored during the use phase to adequately improve the design phase	Process & behavioural
10	The absence of available documentation of the building that is to be renovated/refurbishment	Technical
11	The disposal of removed materials during renovation is difficult as these materials are not valuable, there is no/insufficient value pipeline for building wastes	Financial
12	Limited regulations and contractual rules are in place to incentivise collaborative working practices	Political and regulatory
13	A lot of tools are used per construction site. Merging data and getting all stakeholders to understand interfaces is a major issue.	Technical
14	Inconsistency between different project stage works such as architectural and mechanical drawings.	Technical
15	Lack of know how in the industry about BIM	Awareness
16	Numerous software tools are used and this makes the process of adopting BIM more complicated	Process & behavioural
17	Losing time in construction through the bulk of softwares that need to be used and tasks to be done	Financial
18	Not every actor is competent with complicated interfaces of large construction management software	Technical
19	Missing tools for the construction manager to easily handle the BIM model on the construction site, resulting in a lack of updates of the BIM model.	Technical
20	Selection of building materials during construction is done independently + outside the BIM model by the construction manager)	Technical
21	BIM objects are not or rarely used, because of the lacking unity of the attributes	Technical
22	Building operation data is often not requested and there are no standards	Process & behavioural
23	Evaluation of cost-benefit equations often takes place before connecting appropriate data	Process & behavioural
24	Difficulties in transferring IFC within Revit. Requires substantial Know-how.	Technical
25	Designers don't get enough information back from contractors to complement the BIM model	Process & behavioural
26	BIM objects are not or rarely used, because they are not neutral (search via google)	Technical
27	Project design and planning with current HOAI life cycle phases do not work with BIM	Process & behavioural
28	Products and BIM objects are searched via google. Search Enginge Optimization is critical	Technical

29	Maintenance of the data on the construction site often does not happen and iis still critical	Process & behavioural
30	Designers for public infrastructure projects are not yet ready	Process & behavioural
31	BIM object databases are far from digital supply chain (digital delivery notes, truck tracking ...)	Technical
32	Insufficient communication between manufacturers / factory and construction site.	Process & behavioural
33	Misunderstandings arise between parties when agreeing on a project in BIM, resulting in mutual distrust	Process & behavioural
34	BIM object libraries are still under construction, and this leads the designer to simplify the project to products that are available in	Technical
35	The BIM>4D dimensions are just beginning to emerge. The most advanced is 5D. The 7D, which links the building to its life cycle, is the	Technical
36	Construction managers of contractors are very reluctant to incorporate BIM into their daily work, because today it represents more of an additional cost than a benefit	Financial
37	There is a great lack of specialized personnel to handle BIM and take advantage of it.	Process & behavioural
38	The current cost of the BIM tool is only amortized for large projects.	Financial
39	Currently, virtually no one introduces maintenance protocols to build equipment and technical systems on BIM, and without it, 7D cannot be executed.	Process & behavioural
40	The ability to import and export files from/to BIM has not yet overcome all the technical barriers.	Technical
41	In rehabilitation projects, working in BIM requires an additional previous task of scanning and digitizing the pre-existences, that if you want to do properly, it has a very high cost	Technical and Financial
42	BIM in the residential sector of single-familiar dwellings is not economically justified, except for multi-family buildings with some technical complexity.	Financial
43	The feasibility of using BIM on construction sites is subject to capacity limitations of resources available.	Financial
44	The performance of existing simulation tools compatible with BIM (Digital Twin) does not offer more attractiveness than others that already exist on the market, even if they are not compatible with BIM.	Technical
45	The cost of projecting a building of outstanding architecture in BIM can be very high and is only available to great experts in management of BIM tools.	Financial
46	In Spain, BIM training in Universities and Schools of Architecture and Engineering is very recent, even not mandatory, which means that there is a limited supply of BIM experts in Spain.	Technical

7 Identified Solutions from Workshops/Interviews and by Partners

The country scans plus workshops and interviews also include an understanding of opportunities provided to improve the efficiency and productivity in the construction sector. Opportunities raised in country scans and workshops were analysed and integrated to provide insights in how they could address the identified barriers. Partners also screened the barriers and integrated these with potential solutions. Particular attention was paid to the utilisation of BIM, Digital Twins, and the collaborative practices as found in Chapter 4. Subsequently, the potential solutions were linked to anticipated impacts, resulting in an understanding in Table 10 below of how barriers can be addressed and what the benefits are.

Key solutions at a general level that came out of the country scans include the following:

- **Collaborative processes** can be improved by utilising near-real time communiation protocols with triggering of events and notifications such as information updates, analytical results, and tracking of planned progress using the Digital Twin environment. Further improvements include the utilisation of collaboration tools between on-site construction and office environments, the use of a communication standard, and making the Digital Twin available as a common data pool between actors.
- **Data availability and quality** can be improved by utilising a common information architecture to orchestrate information exchange between applications focusing on interoperability. The utilisation of versioning of the Digital Twin based on new baselines and additional improvements. The improvement of data maintenance both on the construction site and during the in use phase in a standardised manner. And the creation of partial models for specific purposes on the construction site with different model views.
- **Technological availability** can be improved by improving the usability of digital tools and how they are utilised in workflows, and by bringing a wide variety of tools that can be directly used or integrated via APIs or data protocols within SPHERE together.
- **Regulations and standards** can be improved by providing protocols for the communication of building operational data for Digital Twins, as well as maintenance data.
- **Weak sector innovation** can be improved by increasing the ease at which with limited efforts insights can be provided in short cycle simulation tools, as well as by creating linkages between different tools that are common practice and new innovation tools under the SPHERE platform.
- **Implementation Capacity & Skill availability** can be improved by having available best practices and BIM modelling standards within the platform that make the implementation easier for BIM and Digital Twin practicioners. Also by explicating the implementation of BIM and data requirements for different use cases the implementation needs can be made more transparent.
- **Financing capability and high costs** can be improved by enabling early calculations of cost and benefits with a high level of detail through simulations offering insights into design decisions, and by bringing evidence from the SPHERE pilots from utilising BIM and Digital Twins of buildings.

Table 10 offers more detail on these solutions as discussed above including specific technical aspects around data exchanges, specific standards, and specific tools in the SPHERE platform.

Table 10. Listing of Potential Solutions to Barriers and Expected Benefits

No.	Barrier	Potential Solutions
1	No real time collaboration between stakeholders in a project	Collaboration of all project information in real time, using web-based markup tools like Zutec
		BIMBOTS can trigger stakeholders event driven (meaning, they are triggered when new information for them is available). When design changes (for example in an energy simulation) the stakeholder can be notified to bring real-time collaboration to a higher level.
		Collaboration tool (Flink2Go - Ascora) in site construction and the office
		Stakeholders using a single platform (SPHERE) instead of different ones. Platform itslelf is a potential solution. Different users: professionals, non-professionals, different levels of collaboration need to be taken into account.
		Using standardised processes and clearly defined tools which are web-based to make sure that every actor has access to the same data.
		1. Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications. Hence, applications don't need to be cloud-based, nor does the IT-landscape need to contain a fixed set of applications. 2. Make sure people can access their primary information within their main tool. If they want extra information they should be able to go to one central place (sphere). 3. Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams. 4. Offer different views on data for different stakeholders. A technical user requires different information than a non technical user (owner, tenant,...)
2	Weak linkage between technology suppliers and customers brings lack of standards	Digital Twin Standardisation Body-Organisation
		Start discussion about standards, and ultimately define collaboration standard.
		Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications. Hence, applications don't need to be cloud-based, nor does the IT-landscape need to contain a fixed set of applications.
3	Miscommunication and potential lack of collaboration among the project actors.	Adoption of kanban approaches and tools
		SPHERE offers a digitization platform that can prevent this.
		Having regular notifications and reminders, meetings or call to actions to the actors within the platform. Communication tools should be provided inside the platform.
		Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams. Make use of standarised communication system like BCF
4	Not known what should be monitored for the in use phase and how it relates to the design phase	SPHERE platform offers a suite of complementary tools for both phases, BIMBOTS, HTM for both, IoT sensors should be factored into design phase and implemented/monitored in operational phase.
		Look at historical data and current calculations and how they can feed analytically into design
		Define the Use Cases independent of any existing application.
		Deliver a process to monitor information in a "building maintenance book" [FASCICOLO DEL FABBRICATO] that contains the history of the building (concrete used in a good day with a good temperature)
		The starting point to shift towards more integrated project delivery as pointed out in the workshop, should be integrated design. Already superposed projects will accelerate construction start and minimize problems: the problem they face most often is inconsistency between different projects such as the architectural and mechanical drawings. As built projects can be monitored with the design and construction teams if there is a superposed base document on BIM. For the contractor team it is important to establish a memory for the project. How and why design decisions were taken should be accessible to the team building them.
5	A lot of tools are used per construction site. Merging data and getting all stakeholders to understand interfaces is a major issue.	This is a challenge. SPHERE should allow these stakeholders using their own tools! Sphere platform offers APIs for accessing relevant information from different data sources. Don't use the data procedure from different end users, Use the outcomes and results for own purposes and share with a broader audience. METALAYER for the data at least (support with open data exchange). Make sure that people can use their own tools where they work well. Think about if a METALAYER needed for displaying the information/knowledge provided by the tools for integration.

	Actors in projects work with separate documents and tools causing problems with data/works integration	1. Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications. Hence, applications don't need to be cloud-based, nor does the IT-landscape need to contain a fixed set of applications. ==> Define proper Interface Agreements 2. Make sure people can access their primary information within their main tool. If they want extra information they should be able to go to one central place (sphere)
		The tool must be an add on to established softwares or be able to import from them. Double work should be avoided and it is almost certain that major players will be doing their workplan on Primavera, this should sync with it. Even if it is a Revit plugin or BIM component it should be part of these as well.
6	Selection of building materials during construction is done independently + outside the BIM model by the construction manager)	Fit for purpose front end must make it easy to enter deviations from the design in the SPHERE platform.
		Provide technical Specs of materials to be compliant with. Updating of model according to construction process should be validated by DT manager, validating the final choice of materials.
		The Central Asset register (in sphere) should be classified to an external Standard/Classification/OTL (eg. using the BsDD). Why external > you do not want to overload the platform with tons of classifications (very regional). Based on the classification and the project specific meta-data of an object, suppliers should offer valid solutions. These should be validated within the 3D model.
7	Evaluation of cost-benefit equations often takes place before connecting appropriate data	WP4 develops simulation tools for early calculating benefits of design decisions.
		SPHERE simulation tools require specific necessary data in order to be run
		Determine a proper IA (Interface Agreement) between the Sphere platform and the Simulation tools from WP4
8	Maintenance of the data on the construction site often does not happen and is still critical	Automate as many maintenance data processes as possible and enforce the application of guidelines for data maintenance. Tie the data exchange in a process - (BIM Execution PLAN) - Formal procedure in IFC data exchange (Model VIew Definition Process)
		WP5 develops a diagnostics module (not sure what this refers to - not a specific deliverable (VRM) - needs to be clarified). VRM: Refurbify can be utilised for on-site works/process management and data maintenance
		Need to have a procedure how to connect things to IFC, easiest idea may be to have a GUI that has a connection, and a certain way/process on how the information exchange is handled regarding maintenance (Not only for maintenance also for IoT Sensors).
		Define the minimal required data (and format/Information architecture) you need from On-site to be able to deliver a propoer Digital Twin. Selected On-site tools should hence comply to those requirements.
9	Designers don't get enough information back from contractors to complement the BIM model	Focus on framework-led organisations wherein the contractor is known at the deisgn stage. In many cases contractors will be appointed post-design, or at least towards the end of the process
		1.Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams. 2. Make use of standarised communication system like BCF. 3. Contractors should be able to select the correct specific objects based on a classication of a generic object and the according meta-data.
10	Project design and planning with current HOAI life cycle phases (German system) do not work with BIM	Higher planning cost at the beginning accepted by the investors for more cost security during the whole project as a motivation to use BIM. HOAI system is already in the process of changing because of that matter.
11	BIM object databases are far from digital supply chain (digital delivery notes, truck tracking ...)	Maybe SPHERE could develope a sub-module linked with Construction Management sub-module where materials from bill of quantities are checked by the Construction Manager once they are received at the Construction Site.
		Sphere should contain the necessary data to feed the logistic process and receive/store certain results. There are tools available which manage logistics in a LEAN way > propergate. Sphere should not develop that themselves
12	Insufficient communication between manufacturers / factory and construction site.	SPHERE allows early calculation of KPIs. Implementation decision (either in factory or on site) must be fed into the SPHERE platform. BIMBOTS can notify relevant stakeholders.
		One central place offering the project information in the applicable context of the user. Organise acceptance procedure based on objects in stead of drawings

13	Misunderstandings arise between parties when agreeing on a project in BIM, resulting in mutual distrust	SPHERE should offer a web-based environment such as BIM Collab
		Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams.
		The current and past versions of the project shall be kept in the system along with the work schedule, while reporting works completed and managing payments.
14	Unavailability of BIM models previous to 1990	Look at what tools can be used without BIM models - what kind of information needs to have from the BIM model to carry out the calculations - calculations can often be done on more generic parameters
		Need a tool that analyses the quality of the BIM model (quality check outside of the core of the SPHERE platform) and its representation to understand what functionality can be provided related to which Tools. No tool/scope of anyone who can analyse the quality of the BIM model. Once SPHERE is running with DT built out of data, it could be integrated with an already existing tool that can analyse the quality of a BIM Model (Solitary Model Checker)
		> scan to BIM + semantic labeling > out of scope in my opinion > crap in = crap out > No data, No Twin
15	Lack of building data information and documentation from previous works / history of the buildings for the building to be renovated/refurbished	Adoption of mandatory schema, each building should have a list of minimum documentation including as built info
		If you dont have a BIM model you can still make a 3D generalised representation with sizes of the spaces - build an option to generate a space model. However, for retrofitting the structure you still need the geometry of some components (pillars, slabs etc.). We may need a system for different types of renovations and different data requirements associated with these. What is the case and what are the data needs.
		Incorporate the guidelines (see Finland example) related to the LoD levels for the rules on how the BIM model is checked - for example architecture, security/safety etc.. However, rules are different between every country and project. Key on elicitating for this what is the use of the DT.
		What is the required LOD for which Use Case? Depending on that matrix a owner can make the trade-off.
16	BIM objects are not or rarely used, because they are not neutral (search via google), and/or lacking unity of attributes	Provide attribute/unit guidelines to enable SPHERE use
		Design a code of work
		These depend as well on regional specifications (OTL/classifications). Depending on what you want to do, you need to add attributes. Ontology should allow this.
17	Products and BIM objects are searched via google. Search Enginge Optimization is critical	BIM Objects should be classified
18	Numerous software tools are used and this makes the process of adopting BIM more complicated	Creation of interface agreements and ontology, utilise open standards.
		Allow this. Focus on data interoperability. Follow IFC related standards in the models. Study ISO standards on semantics and how they are related (how to structure your data) based on construction.
		Providing an ideal process with specific tools and standards for each phase of the project and through the different actors.
		Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications.
19	No availability of plug and play sensors and Near Field Communication (NFC) technology	Not mentioned – this is changing rapidly
20	No availability of pattern / trend-based advanced analytics	Define KPIs and design dashboards for these KPIs.
21	Missing tools for the construction manager to easily handle the BIM	Adoption of tools like Zutec able to manage on site info
		Design robust, easy to use front end

	model on the construction site, resulting in a lack of updates of the BIM model.	Plenty of On-site tools exist > Make an IA and select the right tool based on the data-requirements for the DT use cases.
22	No availability of effective GANTT actualization, not well communicated to contractors who hardly interpret the results	There are plenty of planning tools out there > Sphere should integrate (feed and consume). Not more
		GANTT chart updating based on construction site development (critical path), with information updates provided by the construction manager or general contractor (depending on approach) in a simple way to parties in a way that can be interpreted/helpfully sent to contractors (e.g. plumber) to make sure construction activities happen on time
23	Insufficient surveying and inspection tools are in use	There is an awareness rather than an access issue. VRM will be working to improve it's inspection tool within the project.
		Incorporate in diagnostics module of WP5?
24	Inconsistency between different project stage works such as architectural and mechanical drawings.	Utilise model view checkers
		Known what the information means for the architectural view and the mechanical view and if they are talking about the same things.
		Tools for clash detections to avoid inconsistencies.
		Utilise baselines with version control
25	BIM models require too much computing power at construction site (you don't have the same tools at the construction site then at the office - computers at the construction site donthave good computing power if there are any) - time for opening models takes too long execution of the models - time that construction executives/professional can wait	Need to create partial models for different purposes to provide the models rapidly on the construction site. Solution for 3D models, split the building into levels (every level has its own view and its own information)
		Calculate at server, and offer thin client front end at construction site
		Cloud implementation > no problem
26	The performance of existing simulation tools compatible with BIM (Digital Twin) does not offer more attractiveness than others that already exist on the market, even if they are not compatible with BIM.	Understand needs and existing market competitors, what we do different/better than other systems
		Focus on fast, short cycle simulation tools. Also show part of the model in a nice manner (part to access the model, use the viewer or visualisation to show different things in one place, show the temperature, show the energy consumption in different spaces, show the sensor data live, etc. then we do more than many systems)
		Create linkages to other tools that can display information, add ways to exchange information with different places, can be within SPHERE yet also we can consider easy exports and imports to other softwares and it can come in the same project in a different model (If we can show the differences and explain it). Develop procedures to implement such exchanges.
		If using the Sphere data can lower the transaction costs it will be more attractive.
27	BIM object libraries are still under construction, and this leads the designer to simplify the project to products that are available in libraries, or requires manual labour to create new objects (project cost overrun)	None mentioned
28		Use of web-based tool such as IDP's

	The BIM>4D dimensions are just beginning to emerge. The most advanced is 5D. The 7D, which links the building to its life cycle, is the necessary tool for the development of IPD contracts and the IDDS itself.	Neanex manages the lifecycle of objects > I do not understand the Barrier perfectly... Update information in a "building maintenance book" [FASCICOLO DEL FABBRICATO] that contains the history of the building (concrete used in a good day with a good temperature)
29	The ability to import and export files from/to BIM has not yet overcome all the technical barriers.	IDP has already developed several plug-ins for REVIT too Explore the use of plug-ins from BIM softwares. Neanex already utilise a few plugins. Needs to evolve based on particular requirements. Requires an analysis on what information is needed, certain model view definition. Use as much as possble open data standards
30	Losing time in the construction process through the bulk of softwares that need to be used and tasks to be done	Can SPHERE make this more efficient? Design easy workflows with higher levels of automation (i.e. the end user can skip many tasks). The number of applications a project member needs to apply should be limited. Doing something specific will take place in a specific tool. Accessing information should be easy within sphere
31	Lack of know how in the industry about BIM	Organise workshop, symposium and events to promote the adoption of BIM and its benefits
32	The availability of digital tools to improve processes outstrips adoption rates and applied innovation.	Focus on usability and (semi-automatic) workflows.
33	BIM practices do not meet current tools and theory.	No solutions mentioned – outside of SPHERE scope
34	Not every actor is competent with complicated interfaces of large construction management software	Offer free courses/workshops of the construction management software Avoid complicated interfaces. Promote usability The platform should be agile with integrations and scalable (start small and grow into it). Tools must be user friendly, provide intuitive use along with user specific interfaces. Something web based and accessible, like dropbox, with different access levels for different user groups and interfaces focused on the tasks these groups would handle will be practical.
35	The feasibility of using BIM on construction sites is subject to capacity limitations of resources available.	No solutions mentioned – outside of SPHERE scope
36	There is a great lack of specialized personnel to handle BIM and take advantage of it. Insufficient skilled staff for BIM, culture of mistrust	Raise the salary of the BIM experts, improve the job employment (must be mandatory to hire BIM experts) etc
37	Difficulties in transferring IFC within Revit. Requires substantial Know-how.	I believe that's a challenge for Autodesk... – outside of SPHERE scope
38	Difficulty in recruiting trained personnel with a highly technical degree, engineers, project managers, etc. . Lack	No solutions mentioned – outside of SPHERE scope

	of qualified employees (e.g. bricklayers, carpenters, installation controllers, roofers) as a consequence of the crisis	
39	Lack of educational programmes towards digitalisation. Shortage of expertise and access to in-house training. In Spain, BIM training in Universities and Schools of Architecture and Engineering is very recent, even not mandatory, which means that there is a limited supply of BIM experts in Spain.	There should be organised in each country educational programmes and courses from a team of experts (not necessarily of the same home country)
40	Designers for public infrastructure projects are not yet ready for BIM	Regulations are to be extended in due time – outside of SPHERE scope
41	Significant data collection is required to operationalise BIM	This is changing rapidly too, maybe? Pointclouds are much more economic now than years ago – outside of SPHERE scope
42	Resources limited for commissioning particular works such as ventilation / daylight simulations	No solutions mentioned – outside of SPHERE scope
43	High initial investment needed for tools, equipment, training and wages/incentives to drive demand	Promote the adoption of BIM through discounts and tax reliefs on tools, equipments etc and organise free courses to train the professionals
44	Design quality – clients are not prepared for higher cost of using BIM	Increase the awareness of the clients on the benefits
		Higher planning cost reflects lower costs in the construction phase.
45	The disposal of removed materials during renovation is difficult as these materials are not deemed valuable, there is no/insufficient value pipeline for building wastes	This should be included in the result for the circular economy KPIs.
46	BIM in the residential sector of single-familiar dwellings is not economically justified, except for multi-family buildings with some technical complexity. The current cost of the BIM tool is only amortized for large projects. There is a	incentivate the use of BIM in the residential sector using tax reliefs for the owners
		May be able to demonstrate the benefit where there is a programme of modular buildings, some of the barriers will be lessened by using the platform as the starting point is from each place each time, and then the changes can be tracked and benefits can be made visible.

	strong negative correlation between the size of a project and the use of BIM. The cost of projecting a building of outstanding architecture in BIM can be very high and is only available to great experts in management of BIM tools.	Part of the BIM cost can be amortised using a standardised building system and planning process.
47	Construction managers of contractors are very reluctant to incorporate BIM into their daily work, because today it represents more of an additional cost than a benefit	Analyse benefits from utilising BIM within SPHERE pilots
		Higher planning cost at the beginning for more cost security during the whole project as a motivation to use BIM. Showing benefits.
		What are the Use Case they do want to pay for > maybe they are easy to implement?
48	In rehabilitation projects, working in BIM requires an additional previous task of scanning and digitizing the pre-existences, that if you want to do properly, it has a very high cost	Incentivate the use of data capture techniques to speed up the data gathering
		> define the required LOD for the different Sphere Use cases and let the Owner make a trade off
49	Ambiguity in data ownership and legal risks. Doubts about compatibility of BIM / contract formats.	Read-only/Editting rights issued for data and/or SPHERE users
50	Limited regulations and contractual rules are in place to incentivise collaborative working practices	SPHERE provides collaborative environment, maybe resembling BIM Collab? It's the client who decides how to work
51	Lack of BIM software standardization to enhance effective communication and collaborative methods.	Make this explicit and try to define a solution (e.g. propose a new standard). – outside of SPHERE scope
52	There is a lack of knowledge and standards in the use of BIM and lean construction practices across terms, methodologies and technologies	Do we make a distinction on user expertise required for using the SPHERE platform? Do we want to have the platform implemented in a lean way, bring in some of the lean thinking in the development
		Make this explicit and try to define a solution (e.g. propose a new standard). Make a proposal from SPHERE side on how the drawing is done technically (follow IFC as much as possible what standards building SMART is developing). Note also practices on following the guidelines then need to be included in the SPHERE platform.
		Utilise well defined processes to build the software, integrate best-practices. There is not a standardised way of modelling, a difference in BIM modelling between countries. How do you deal with the variability or genericness. (example: different drawing of outer wall, different connections for beams connected to walls etc.) Different countries have different guidelines, some do not have guidelines at all.
		The SPHERE Platform should provide standardised guidelines showing one defined and accurate process.
		There is a risk in creating yet another guidline/standard next to the existing ones
53	Building operation data is often not requested and there are no standards	Make this explicit and try to define a solution (e.g. propose a new standard).

54	Currently, virtually no one introduces maintenance protocols to build equipment and technical systems on IM, and without it, 7D cannot be executed.	This should be included in the ontoloy
		Update information in a "building maintenance book" [FASCICOLO DEL FABBRICATO] that contains the history of the building (concrete used in a good day with a good temperature)
55	General lack of emphasis on R&D and innovation	No solution mentioned - outside of SPHERE scope
56	Widespread risk aversion and internal processes for innovation	No solution mentioned - outside of SPHERE scope
57	Reluctance to modernise: Stagnant working practices might limit new technology uptake	organise events to highlight the benefits that the adoption of new technology can bring and workshops to introduce the technology to the users. workshops to highlight the benefits that lean methodology can bring
58	Lack of understanding of lean thinking, resistance to the use of its fundamental techniques	organise events to highlight the benefits that the adoption of new technology can bring and workshops to introduce the technology to the users. workshops to highlight the benefits that lean methodology can bring
59	Working practices are too stagnant and limit new technology uptake.	organise events to highlight the benefits that the adoption of new technology can bring and workshops to introduce the technology to the users. workshops to highlight the benefits that lean methodology can bring

8 Methods for assessing barriers to be addressed by SPHERE Digital Twin Digitized ICT Solutions

8.1 Relevant Barriers and Solutions selection for SPHERE

*DoA Subtask 2.1.1 Opportunity Assessment for the Renovation Process: Potential and needs of improvements in the construction and renovation will be identified. Focus will be given to the core objectives of the SPHERE methodology that aim to deliver the impact of the project. Opportunities delivered by the SPHERE concept and how the digital twin can enable the needs will be addressed**, such as** improved sustainability, **s**hortened project life span **, i**mproved information exchange among stakeholders and social acceptance**, improved project management, results monitoring and improved holistic benefits to the end users which will be the exploitable results of the project.***

A total of 60 barriers were identified in Chapter 5 and Chapter 6 that restrict the uptake of BIM methodologies and collaborative IDDS and IPD practices. In relation also 118 related opportunities were established that could help to address these barriers. SPHERE will not be able to solve all these barriers and will need to focus on those barriers that can be addressed through the **Building-centred Digital Twin Environment,** and the **seamless and efficient updating and synchronisation of the SPHERE Digital Twin platform to be using Integrated Design and Delivery Solutions**, as per the general objectives of the project.

To evaluate the scope of the barriers that are within the SPHERE objectives a methodology was incorporated to rank each barrier in terms of their importance for addressing that barrier under SPHERE. Any duplicate barrier provided across Chapter 5 and Chapter 6 was first removed, resulting in a total of 60 unique barriers that were identified. Subsequently, the ranking was carried out using a simple 1-2-3 scoring with the following criteria, 1 – highly relevant, 2- maybe relevant, and 3 – not relevant. The ranking was done on a google spreadsheet independently by each partner and subsequently averaged with scores that received a majority scoring of 1 selected for addressing the barrier in SPHERE.

After the barriers were selected the potential solutions to take on-board in the project are also identified. To this end a two step procedure was followed. First on top of initially identified solutions a collective re-thinking of potential solutions was carried out where each partner added potential solutions to the google spreadsheet for *to be addressed* barriers. Subsequently, the identified solutions were discussed in-depth on four iterative work-package teleconferences with the partners to provide for a final identification. The result of the process can be found in section 9.1. Note that solutions include the collaborative practices identified in Chapter 4 on IDDS and IPD and their relationship to BIM and Digital Twins, so as to ensure integration of collaborative practices within the SPHERE platform.

Finally, after the selected barriers and solutions were identified their potential impacts were evaluated by the project partners in relation to the anticipated impacts of SPHERE following the project proposal. These benefits as outlined under Task 2.1 in the DoA include improved sustainability, shortened project life span**,** improved information exchange among stakeholders and social acceptance**,** improved project management, results monitoring and improved holistic benefits to the end users. The results is a detailed understanding of the solution approach in SPHERE and anticipated qualitatively identified benefits.

8.2 Workflow and Process Identification for Digital Twins

DoA Subtask 2.1.2 Identification of Process Scenarios utilizing the Digital Twin: *Based on the identified opportunities and how the digital twin concept can address them, workflow scenarios on the process needs and the role of the SPHERE platform services will be identified. This will be carried out in collaboration with the administrative and technical acceptance analyses carried out in the task, ensuring the delivery of useable and scalable workflow scenarios.*

In the previous chapters the core SPHERE concepts and the barriers and solutions to improve collaborative and BIM based practices were identified for construction and renovation projects. The results were presented form a general perspective, without specifying where in a renovation or construction project they need to be integrated.

To make the tackling of *to be selected* barriers and related solutions more effective (following the selection carried out by following the procedure outlined in section 8.1) they need to be related to digitized ICT solutions to be provided in SPHERE. To do so the barriers and solutions are aligned with the required workflows of the SPHERE pilots. To this end specific workflows were generated of all activities in the renovation and new construction pilots in the project: the modular wooden construction in Austria by CREE, the energy performance contracted based new construction in the Netherlands by TNO, the renovation of an existing concrete structure in Italy by DE5, and the replacement of a HVAC system in an existing buiding in Finland by Caverion. The workflows were put together by consortium partner Ekodenge and reviewed together with the pilot partners.

The method to build the workflows was based on first identifying the UK Royal Institute of of British Architects RIBA construction sector phases, similar to the ISO 2263:2008 Building lifecycle stages.[18] The identified phases include: 0) Strategic definition, 1) Preparation and Brief, 2) Concept Design, 3) Technical Design, 4) Construction, 5) Handover and closeout, 6) In Use. RIBA also specified a developed design phase, but as this additional design iteration is not common across countries it was left out.

Subsequently, a draft set of activities defined by actors in a renovation and construction project for each pilot were specified based on the expertise of the Ekodenge Architecture team. A structural approach was developed by taking activity names under the ontology of AEC sector activities under the Uniclass 2015 ontology developed by the UK Construction Project Information Committee (CPIC).[19] The ontology lists 905 different activities that can take place in the construction or renovation of a building defined under 20 groupings and 135 sub-groupings. The ontology also lists 32 different actors, which was extended to 37 Actors under the SPHERE project to incorporate IDDS structures by adding project team, construction surveyor, energy auditor, geographical surveyor, and land surveyor as separate actors.

As a third step the workflows were reviewed in a workshop setting with each pilot partner to iterate and improve the set of suggested activities and related actors to fit with the actual pilot. New actors and their relationships were specified, new activities were added and not relevant ones removed. Also individual barriers were specified that related to particular activities. An example of a final workflow without barriers and solutions can be found in Figure 5 below. The detailed final workflows are added in Appendix E.

Finally, after this process the workflows were used to assess and incorporate the specific barriers and solutions to be addressed in the SPHERE project with the procedure outlined in Section 8.1. The

[18] Royal Institute of British Architects. RIBA plan of work 2013. RIBA London. 2013;6(2):1–27.
[19] UK BIM Alliance, CDBB. Information Management according to BS EN ISO 19650 - Guidance Part 1: Concepts [Internet]. 2019. Available from: https://www.ukbimalliance.org/stories/information-management-according-to-bs-en-iso-19650/

identification carried out by EKO was reviewed in two teleconference workshops, one with the technology partners, and one with the pilot partners in the project. The final set of workflows delivered from WP2.1 in this report will be utilised in WP2.3 to develop particular use cases.

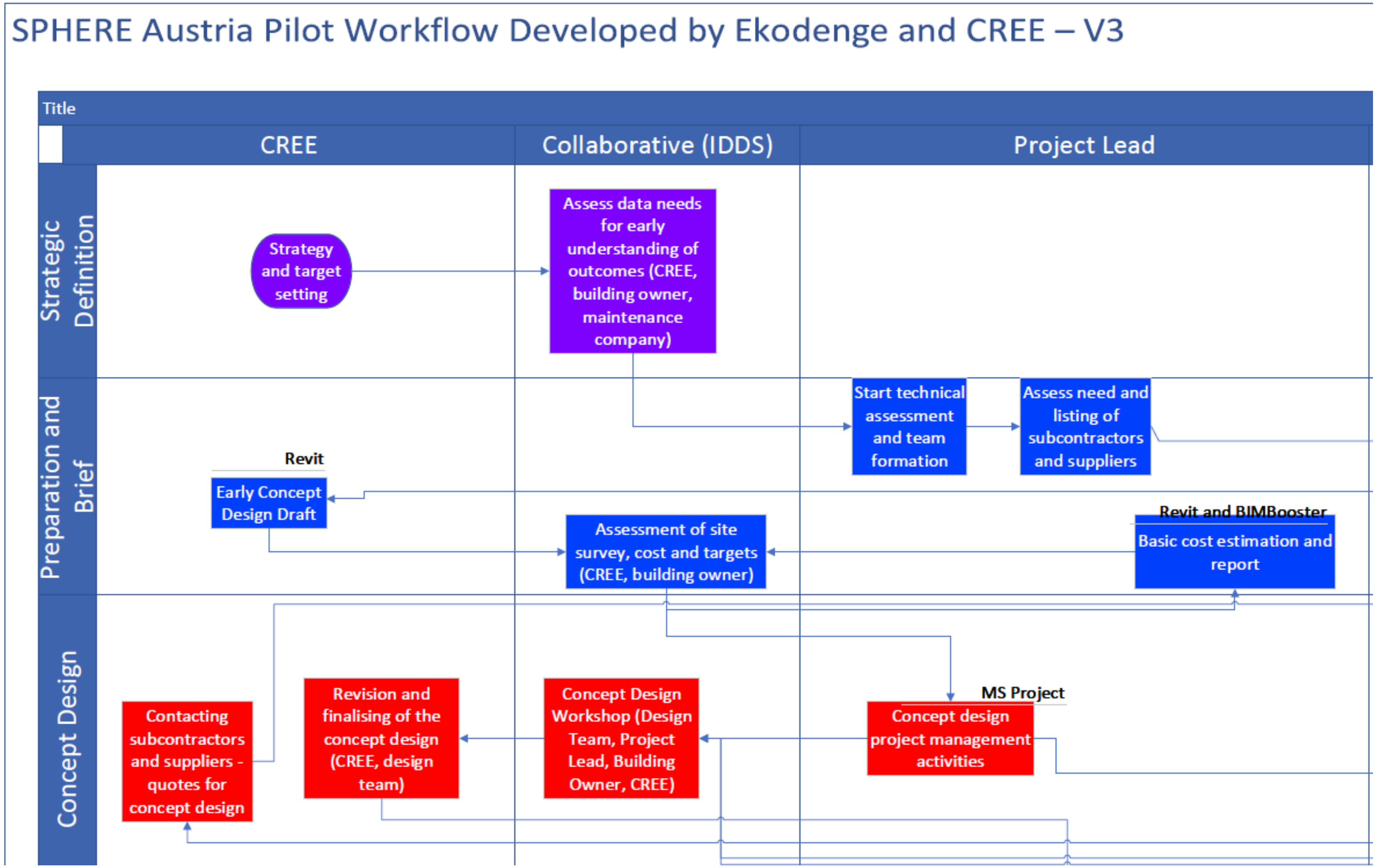


Figure 5. Example of Part of Pilot workflow developed in the SPHERE project

8.3 Users and Actors Identification

***DoA Subtask 2.1.2 Identification of Process Scenarios utilizing the Digital Twin:** The relevant user types and actors will be identified, in close collaboration with the stakeholder and advisory board members, end user and demo support partners of the project consortium, to provide the usability and replicability of the workflows.*

The role of traditional end users in the context of the AEC industry in general and the SPHERE platform specifically is well understood. Designers, contractors, architects and so forth require digital data and exchange in order to make their work easier, more productive, and more cost effective. The utilisation of platforms for the AEC during the in use phase has been found to be innovative and novel, however, requiring a rethink of how actors that relate to the use phase of buildings could be interlinked with digital services as users. To this end a separate piece of work was carried out in D2.1 to establish the potential role of use phase actors.

To this end a *user analysis methodology* was developed to assess the renovation process from the perspective of building owners, building managers, maintenance and renovation companies, and occupants. The efforts will support the design of the SPHERE platform, to make it of interest not only to companies carrying out the renovation, but also to bridge the gap between those that decide upon the investment or specify the renovation works themselves, as to benefit from decision support and the development of Digital Twins. The findings from this *user analysis methodology* will enable us to challenge assumptions, highlight commonalities and inspire decisions regarding platform function and design. The first step was to define what users and actors are for implementing the methodology, which resulted in the following definitions:

- **Users:** those who will be the end users of the SPHERE platform, they might not have agency to act but will be in receipt of the platform should it be implemented.
- **Actors:** those who have agency to invest and implement SPHERE platform use in renovation decisions, not necessarily those who will directly use the platform.

The developed *user analysis methodology* was then deployed which consists of the following three steps:

1. **Grey literature scan to evaluate occupancy-ownership archetypes:** the initial identification of typical relationships in building occupancy and ownership were evaluated for each country by searching the grey literature. These resulted in four occupancy-ownership archetypes that could be evaluated to understand if these relationships are effectuated across countries. Statistics and recent reports were used to determine the level of use of each relationship in respective countries.

   The five archetypes of occupancy-ownership in residential buildings were identified as:
   - **Community owned with a Building Manager Relation** (Administrador de Fincas)
   - **Large Property Developer Relation** (Inmobiliaria Patrimonialista)
   - **Neighbourhood Association Relation**
   - **Freehold-Leasehold Relation**
   - **Social Housing Relation**

   Further details of the relationships within these archetypes between each actor can be seen in the diagrams in appendix G.

2. **Assessment of applicability of Archetypes to Countries**: In order to identify the users and actors of interest the archetypical relationships of ownership in residential buildings were studied for 9 countries to have a broad coverage of potential configurations across Europe. The relationships were ranked as Common/Uncommon/No for each country respectively. The results of this analysis can be found in appendix F.

3. **Assessment of Agency for each Actor to determine potential role as a SPHERE User**: A social-economic incentive methodology was then used, based on the so-called Stakeholder Salience Model that has been developed in management science[20], to identify potential users from the actors in each archetypical residential renovation decision. The actors were assessed for the following categories;
    - **Process Stage** (signalling needs, preparing brief, investing and implementation): the stage of the decision process that the actor is likely to be involved in
    - **Ability to invest** (yes/no): the agency of the actor to invest in renovation works
    - **Ability to implement change** (low/medium/high): the agency of the actor implement renovation works
    - **Incentive to act** (low/medium/high): how likely the actor is to implement renovation works
    - **Intended Outcome**: The outcome desired by the actor from a renovation action
    - **Potential benefit from SPHERE**: how the SPHERE platform would benefit the actor in the decision-making process and beyond.
    - **Likely User** (low/medium/high): based on the above analysis if the actor is likely to be an end user of the SPHERE platform

The results of the Methodology that result in the definitions of Actors for in use buildings to drive and implement renovations, and the relevant users among these actors for SPHERE, are summarised in the results section 9.4 also covering operational and change management requirements. The identification process will feed into D2.5 on User Centred design following out of T2.4.

[20] Mainardes EW, Alves H, Raposo M. A model for stakeholder classification and stakeholder relationships. Manag Decis. 2012;50(10):1861–79.

9 SPHERE Platform Vision and Market Positioning

9.1 Scope of to be addressed barriers and solutions

***DoA Subtask 2.1.1 Opportunity Assessment for the Renovation Process**: Potential and needs of improvements in the construction and renovation will be identified. Focus will be given to the core objectives of the SPHERE methodology that aim to deliver the impact of the project. Opportunities delivered by the SPHERE concept and how the digital twin can enable the needs will be addressed, such as improved sustainability, shortened project life span , improved information exchange among stakeholders and social acceptance, improved project management, results monitoring and improved holistic benefits to the end users which will be the exploitable results of the project.*

The assessment of barriers and solutions in Chapters 5 to 7 resulted in 59 unique barriers and 128 proposed solutions to address these barriers. After the full identification was made the ranking procedure, described in section 8.1, was conducted by all 20 partners in the consortium, so as to obtain the most relevant barriers that can be addressed partially or fully by SPHERE through the emerging solutions. The resulting set of 15 barriers and related solutions, as depicted in table 11 below, provides a blueprint for the project in general, with specific ideas to be taken on board in various work packages as identified in the table. These should serve to lead to several benefits from using the SPHERE platform as identified in the table including: improvements in project management and information exchange between companies, monitoring of results, social acceptability, uptake of BIM practices, and financial sustainability of projects.

To summarise the results in table 11, the solutions cover **collaboration process improvements** such as the offering of a suite of tools to cover both building in use and building design phases and making these more interconnected with feedback. The utilisation of procedures, tools and data for updating of data on the construction site in an as automated manner as possible with standardised communication protocols. And the setup of a notification and reminder system for events, data updates, and call to action of actors integrated with communication tools. In terms of **data availability and data quality** the solutions cover the integration of model view checkers to avoid inconsistencies and data clashes, working with versioning control and set baselines for the Digital Twin to avoid errors. The utilisation of common information architecture to orchestrate information exchange between applications and making SPHERE highly interoperable. As well as integrating a building maintenance databook within the Digital Twin that logs any changes and the history of the building. The **technological incorporation and quality** can be improved delivering early insights through fast short cycle simulations with rapid feedback, visual insights based on breaking down info for different spaces in the building using the Digital Twin, increasing linkages across tools, both those brought into the SPHERE platform and third party tools, by utilising plug-ins to make existing BIM softwares accessible for SPHERE users, and by using open standards. The **financial cost and requirements** can be improved through solutions where minimum needs are defined, by reducing transaction costs in communication and for transferring data making the digitisation proposition more attractive, and by automating a number of processes to save labour costs. It will also to bring evidence on the benefits from particular digitisation services within SPHERE to understand returns from the cost of developing BIM and digitisation. When it comes to **regulatory structures and standards** the SPHERE platform suggested solutions include a workflow process with standard guidelines and interoperability to define an accurate process across all life cycle phases, lifting existing standards and protocols into a dynamic version in the platform.

Table 11. Listing of Highly Ranked Barriers and Solutions for Construction Sector to be Addressed by SPHERE

No.	Type	Barrier	Potential Solutions to be Considered	Related WPs to study solution	Benefits
1	Collaboration Processes	Not known what should be monitored for the in use phase and how it relates to the design phase	Define use cases independent of any existing application.	WP2, WP3	Improved information exchange improved results monitoring
			Look at historical data and current calculations and how they can feed analytically into design	WP4, WP5	
			Offer a suite of complementary tools for both phases ; BIMBOTS, HTM for both, IoT sensors should be factored into design phase and implemented/monitored in operational phase	WP4, WP5	
			Deliver a process to monitor information in a "building maintenance book" [FASCICOLO DEL FABBRICATO] that contains the history of the building (concrete used in a good day with a good temperature)	WP2-WP6	
			The starting point to shift towards more integrated project delivery as pointed out in the workshop, should be integrated design. Already superposed projects will accelerate construction start and minimize problems: the problem they face most often is inconsistency between different projects such as the architectural and mechanical drawings. As built projects can be monitored with the design and construction teams if there is a superposed base document on BIM. For the contractor team it is important to establish a memory for the project. How and why design decisions were taken should be accessible to the team building them.	WP3	
2	Collaboration Processes	Updating the data on the construction site often does not happen and is still critical	Need to have a procedure how to connect things to IFC, easiest idea may be to have a GUI that has a connection, and a certain way/process on how the information exchange is handled regarding maintenance (Not only for maintenance also for IoT Sensors).	WP3, WP5	Improved information exchange
			The Refurbify tool within SPHERE can be utilised for on-site works/process management and data maintenance	WP5	
			Automate as many maintenance data processes as possible and enforce the application of guidelines for data maintenance. Tie the data exchange in a process - (BIM Execution PLAN) - Formal procedure in IFC data exchange (Model VIew Definition Process)	WP3, WP5	
			Define the minimal required data (and format/Information architecture) you need from On-site to be able to deliver a propoer Digital Twin. Selected On-site tools should hence comply to those requirements.	WP3, WP5	
3			Adoption of kanban approaches and tools	WP2, WP3	

	Collaboration Processes	Miscommunication and potential lack of collaboration among the project actors.	Having regular notifications and reminders, meetings or call to actions to the actors within the platform. Communication tools should be provided inside the platform.	WP2, WP3	Improved information exchange, improved project management,
			Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams.	WP2, WP3	
			Make use of standarised communication system like BCF	WP2, WP3	
4	Technology availability / Collaboration Process	Numerous software tools are used and this makes the process of adopting BIM more complicated	Providing an ideal process with specific tools and standars for each phase of the project and through the different actors.	WP3, WP4, WP5	Improved information exchange
			Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications.	WP3	
			Focus on data interoperability. Follow IFC related standards in the models. Study ISO standards on semantics and how they are related (how to structure your data) based on construction.	WP3	
			Creation of interface agreements and ontology, utilise open standards.	WP3	
5	Technology Quality	The ability to import and export files from/to BIM has not yet overcome all the technical barriers.	Explore the use of plug-ins from BIM softwares. Neanex and IDP already utilise a few plugins. Needs to evolve based on particular requirements. Requires an analysis on what information is needed, certain model view definition.	WP3, WP4, WP5	Improved information exchange
			Use as much as possble open data standards	WP3, WP4, WP5	
6	Financial capability & high cost	BIM in the residential sector of single-familiar dwellings is not economically justified, except for multi-family buildings with some technical complexity.	Part of the BIM cost can be amortised using a standardised building system and planning process.	N/A	Improved social acceptability
			Demonstrate the benefit where there is a programme of modular buildings, some of the barriers will be lessened by using the platform as the starting point is from each place each time, and then the changes can be tracked and benefits can be made visible.	WP6	
7	Regulatory Structures & Standards	There is a lack of knowledge and standards in the use of BIM and lean construction practices across terms, methodologies and technologies	The SPHERE Platform should provide standardised guidelines and interoperability showing one defined and accurate process. Make this explicit and try to define a solution. Make a proposal from SPHERE side on how the drawing is done technically (follow IFC as much as possible what standards buildingSMART is developing). Note also practices on following the guidelines need to then be included in the SPHERE platform. Note: there is a risk in creating yet another guidline/standard next to the existing ones.	WP2 (What) WP3 (How), WP4 (Where), WP5 (Where)	Improved uptake of BIM practices

			Utilise well defined processes to build the software, integrate best-practices. There is not a standardised way of modelling, a difference in BIM modelling between countries. How do you deal with the variability or genericness (example: different drawing of outer wall, different connections for beams connected to walls etc.) Different countries have different guidelines, some do not have guidelines at all.	WP2 (What) WP3 (How), WP4 (Where), WP5 (Where)	
8	Technology Quality	Inconsistency between different project stage works such as architectural and mechanical drawings.	Utilise model view checkers, utilise tools for clash detections to avoid inconsistencies.	WP3, WP4, WP5	Improved results monitoring
			Known what the information means for the architectural view and the mechanical view and if they are talking about the same things.	WP3, WP4, WP5	
			Work with baselines within the process, consider versioning in the models that are updated at each stage into a new baseline (design, construction, renovation, in use)	WP3	
9	Financial capability & high cost	Construction managers of contractors are very reluctant to incorporate BIM into their daily work, because today it represents more of an additional cost than a benefit	Higher planning cost at the beginning for more cost security during the whole project as a motivation to use BIM. Showing benefits from utilising BIM based on SPHERE pilots	WP6	Improved project management
			Adoption of mandatory schema for BIM incorporation for particular uses	N/A	
			What are the Use Case they do want to pay for > maybe they are easy to implement.	WP2 (WP3)	
10	Technology Quality	The performance of existing simulation tools compatible with BIM (Digital Twin) does not offer more attractiveness than others that already exist on the market, even if they are not compatible with BIM.	Understand needs and existing market competitors (R2M?), what we do different/better than other systems	WP7	Improved financial sustainability
			Focus on fast, short cycle simulation tools. Also show part of the model in a nice manner (part to access the model, use the viewer or visualisation to show different things in one place, show the temperature, show the energy consumption in different spaces, show the sensor data live, etc. then we do more than many systems)	WP4, WP5	
			Create linkages to other tools that can display information, add ways to exchange information with different places, can be within SPHERE yet also we can consider easy exports and imports to other softwares and it can come in the same project in a different model (If we can show the differences and explain it). Develop procedures to implement such exchanges.	WP3	
			If using the Sphere data can lower the transaction costs (time/labour/data transfer cost effort in entering and transferring data) it will be more attractive. Use a minimum information input requirement to do a simulation. Allow for automated information input that utilises a sparse/lean BIM package of information	WP3, WP4, WP5, WP6	
11	Collaboration Processes	No real time collaboration between stakeholders in a project	Stakeholders collaboration is enhanced by using a new platform (SPHERE), a best of breed platform. Platform itself is a potential solution. Different users: professionals, non-professionals, different levels of collaboration need to be taken into account.	WP2 to WP6	Improved information exchange,
			Using standardised processes and clearly defined tools which are web-based to make sure that every actor has access to the same data.	WP2 to WP6	

			Use aCollaboration tool (Flink2Go - Ascora) in site construction and the office	WP2 to WP6	improved results monitoring, shortened project lifespan
			BIMBOTS can trigger stakeholders event driven (meaning, they are triggered when new information for them is available). When design changes (for example in an energy simulation) the stakeholder can be notified to bring real-time collaboration to a higher level. Look at the operation of the BIMBOTS, are they in the TNO server how would that work.	WP2 to WP6	
			Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications.Hence, applications don't need to be cloud-based, nor does the IT-landscape need to contain a fixed set of applications.	WP2 to WP6	
			Make sure people can access their primary information within their main tool. If they want extra information they should be able to go to one central place (sphere)	WP2 to WP6	
			Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams.	WP2 to WP6	
			Offer different views on data for different stakeholders. A technical user requires different information than a non technical user (owner, tenant,...)	WP2 to WP6	
12	Collaboration Processes	A lot of tools are used per construction site. Merging data and getting all stakeholders to understand interfaces is a major issue. Actors in projects work with separate documents and tools causing problems with data/works integration	Allow stakeholders using their own tools. Sphere platform offers APIs for accessing relevant information from different data sources. Don't use the data procedure from different end users, Use the outcomes and results for own purposes and share with a broader audience. METALAYER for the data at least (support with open data exchange). Make sure that people can use their own tools where they work well. Think about if a METALAYER needed for displaying the information/knowledge provided by the tools for integration.	WP3, WP6	Improved information exchange
			1. Apply a common Information architecture (ontology & standards) to orchestrate information exchange between different applications.Hence, applications don't need to be cloud-based, nor does the IT-landscape need to contain a fixed set of applications. ==> Define proper Interface Agreements 2. Make sure people can access their primary information within their main tool. If they want extra information they should be able to go to one central place (sphere)	WP3, WP6	
			The tool must be an add on to established softwares or be able to import from them. Double work should be avoided and it is almost certain that major players will be doing their workplan on Primavera, this should sync with it. Even if it is a Revit plugin or BIM component it should be part of these as well.		
13	Collaboration Processes	Designers don't get enough information back from contractors to complement the BIM model	Focus on framework-led organisations wherein the contractor is known at the design stage. In many cases contractors will be appointed post-design, or at least towards the end of the process	N/A	Improved information exchange
			1.Make sure to differentiate between collaboration on live data within a team (eg. design team) and collaboration on baselines between teams.	WP3, WP4, WP5	
			2. Make use of standarised communication system like BCF.	WP3, WP4, WP5	

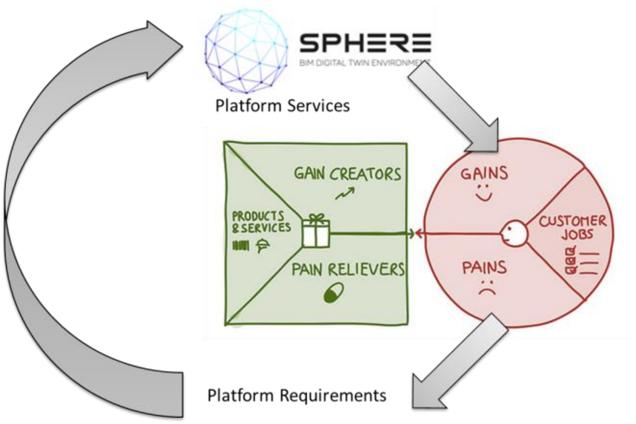
			3. Contractors should be able to select the correct specific objects based on a classification of a generic object and the according meta-data.	WP3, WP4, WP5	
14	DATA --> Data Availability	Lack of building data information and documentation from previous works / history of the buildings for the building to be renovated/refurbished	Adoption of mandatory schema, each building should have a list of minimum documentation including as built info	N/A	Improved information exchange
			If you dont have a BIM model you can still make a 3D generalised representation with sizes of the spaces - build an option to generate a space model. However, for retrofitting the structure you still need the geometry of some components (pillars, slabs etc.). We may need a system for different types of renovations and different data requirements associated with these. What is the case and what are the data needs.	WP2, WP3, WP4, WP5	
			Incorporate the guidelines (see Finland example) related to the LoD levels for the rules on how the BIM model is checked - for example architecture, security/safety etc.. However, rules are different between every country and project. Key on elicitating for this what is the use of the DT.	WP2, WP3	
			What is the required LOD for which Use Case? Depending on that matrix a owner can make the trade-off.	WP2, WP3	
15	Technology availability	Missing tools for the construction manager to easily handle the BIM model on the construction site, resulting in a lack of updates of the BIM model.	Plenty of On-site tools exist > Make an IA and select the right tool based on the data-requirements for the DT use cases (adoption of tools like Zutec able to manage on site info).	WP3, WP6	Improved results monitoring
			Design robust, easy to use front end	WP3, WP6	

9.2 Solutions IT requirements identification from SPHERE Workflow Scenarios

DoA Subtask 2.1.2 Identification of Process Scenarios utilizing the Digital Twin: *Based on the identified opportunities and how the digital twin concept can address them, workflow scenarios on the process needs and the role of the SPHERE platform services will be identified.*

The Sphere platform aims to address the known challenges and barriers in the digitalisation of the construction process with the support from the Digital Twin framework. The platform is intended to provide a set of sound business services. The known barriers and challenges are assessed as customer pains, utilising a value proposition analysis framework where the platform provides pain relievers for end users. Due to the complex nature of the construction and renovation process with multiple potential end users, the functional requirement identification study is carried out with two primary sets of parameters, namely the life cycle phases and user types.

Figure 6. SPHERE platform requirements development process



The life cycle phases that were incorporated in the workflows are based on the RIBA specifications from the UK, and cover: 0) strategic definition, 1) preparation and brief, 2) concept design, 3) detailed technical design, 4) construction, 5) handover and close out, and 6) building in use phase. **The user types** that were incorporated in the workflows include: the Pilot partner, the project lead, surveyors, the design/architecture team, the construction lead/team, the commissioning team, the building owner, the building automation delivery team, and the maintenance team.

As a follow-up to Task 2.1, in Task 2.3 of the project the sets of functional requirements will be specified in detail following this structure. The process of the requirement specifications has been started and follows a three step procedure:

Step 1 - business as usual needs specifications: The renovation and construction processes have been identified in Task 2.1 as carried out in the recent practices for the SPHERE pilots, where known shortcomings and barriers are identified. The results of these workflow scenarios can be found in Appendix E for each of the SPHERE pilots, based on the methodology described in section 8.2.

Based on the execution of this step a number of beneficial modules and submodules for the SPHERE platform were identified. The table 11 summarises these modules in relation to the identified barriers from section 9.1, to provide further information on how they can be overcome within SPHERE.

Step 2 - identification of needs for collaborative practices: Based on the workflow processes and needs for improvement, the potential benefits that can be provided by integrated and collaborative practices are identified with works to be carried out in Task 2.3, as shown in Figure 7 below. These practices, due to the nature of the collaborative works, are usually found to be not roles of specific users, but multiple actors. This leads the workflow to be studied with the new typology of Collaborative User Role, providing a more centralised and multi user action set. An example is the collaborative design review works or the feedback practices among multiple actors at a single workshop.

Step 3 - requirement Identification: It is observed that lack of sound data and process management capabilities is one of the core reasons of not being able to carry out collaborative practices, thus avoiding the potential benefits deep collaboration is expected to deliver. Based on the business as usual and potential improved collaborative practices, as such the requirements of the Sphere platform will be identified in Task 2.3

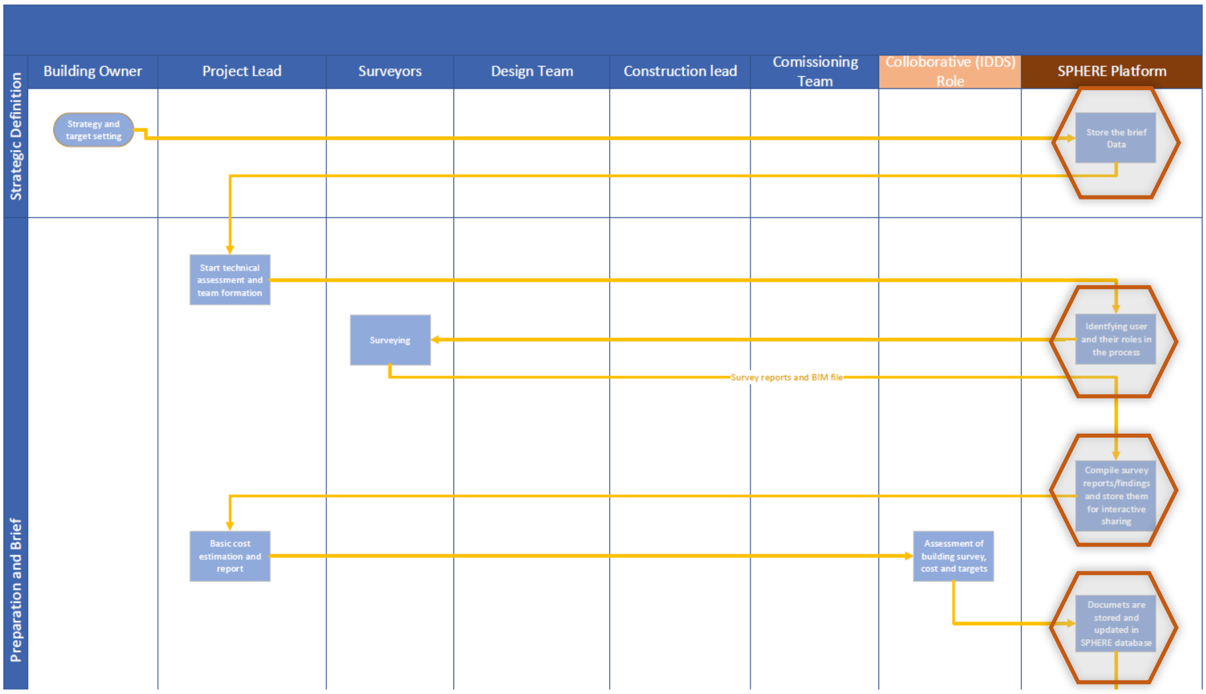


Figure 7. Workflow example with collaborative processes and SPHERE platform

Table 12. High level services of SPHERE Platform addressing the identified barriers

No.	Type	Barrier	Potential supportive service Modules of SPHERE Platform
1	Collaboration Process	Not known what should be monitored for the in use phase and how it relates to the design phase	- Complete life cycle process management - Identification and monitoring of predefined and reusable KPIs in the whole life cycle
2	Collaboration Process	Updating data on the construction site often does not happen and is still critical	- Collaborative data environment, with platform user and role specification - Predefined rules and supportive documents for the data acqusition, processing and handling process
3	Collaboration Process	Miscommunication and potential lack of collaboration among the project actors.	- Collaborative message, issue and informaiton exchange services
4	Technology availability	Numerous software tools are used and this makes the process of adopting BIM more complicated	- Workflow and process management of the SPHERE platform, guiding the users for related tools with the required set of data from the platform database
5	Technology Quality	The ability to import and export files from/to BIM has not yet overcome all the technical barriers.	- Collaborative data environment
6	Financial capability & high cost	BIM in the residential sector of single-familiar dwellings is not economically justified, except for multi-family buildings with some technical complexity.	- Serve as a platform / software service, rather that a monolithic Software investment, with benefit based usage
7	Regulatory Structures & Standards	There is a lack of knowledge and standards in the use of BIM and lean construction practices across terms, methodologies and technologies	- Built in standards for process management
8	Technology Quality	Inconsistency between different project stage works such as architectural and mechanical drawings.	- Collaborative data and process management
9	Financial capability & high cost	Construction managers of contractors are very reluctant to incorporate BIM into their daily work, because today it represents more of an additional cost than a benefit	- Serve as a platform / software service, rather that a monolithic Software investment, with benefit based usage
10	Technology Quality	The performance of existing simulation tools compatible with BIM (Digital Twin) does not offer more attractiveness than others that already exist on the market, even if they are not compatible with BIM.	- Needs further analyses
11	Collaboration Process	No real time collaboration between stakeholders in a project	- Collaborative data and process management
12	Collaboration Process	A lot of tools are used per construction site. Merging data and getting all stakeholders to understand interfaces is a major issue. Actors in projects work with separate documents and tools causing problems with data/works integration	- Mobile interfaces of platform for data acquisition and management
13	Collaboration Process	Designers don't get enough information back from contractors to complement the BIM model	- Implementation and compliance checks to the digital twin data management needs
14	Data Availability	Lack of building data information and documentation from previous works / history of the buildings for the building to be renovated/refurbished	- Needs further analyses on available data and their acquisition
15	Technology availability	Missing tools for the construction manager to easily handle the BIM model on the construction site, resulting in a lack of updates of the BIM model.	- Collaborative BIM Data management services

9.3 Technology requirements for the Digital Twin

Subtask 2.1.3 Assessment of Barriers and need for Change Management: *Emerging technologies in the sector which will be integrated into the digital twin approach.*

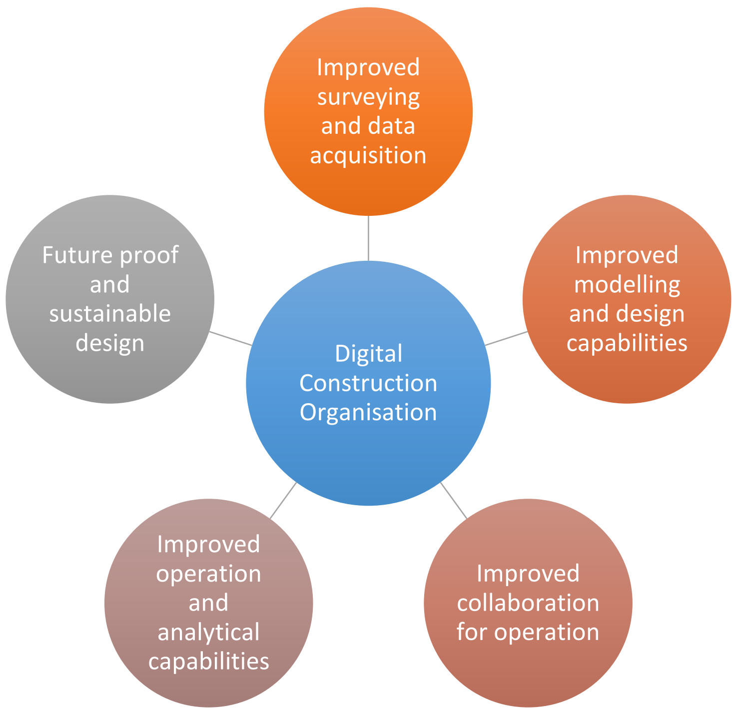
Construction labour productivity has not been able to keep pace with the overall economic productivity. The industry has not yet embraced new digital technologies that need up-front investment, even if the long-term benefits are significant. R&D spending in construction runs well behind that of other industries: less than 1 percent of revenues, versus 3.5 to 4.5 percent for the auto and aerospace sectors. This is also true for spending on information technology, which accounts for less than 1 percent of revenues for construction, even though a number of new software solutions have been developed for the industry.[21]

The digitisation transition can best be addressed by an approach that serves both the demands for the current status in the sector and its immediate needs, and emerging requirements to ensure future practices can be incorporated. With this awareness, the Digital Twins methodology is studied in SPHERE project, not as a final ambition, but as an enabler and reliable backbone for the realisation of the digitisation transition. Although Digital Twin standards in the construction sector and built environment are yet to be globally identified, collaborative innovation projects such as SPHERE are increasingly providing a framework and exemplary demonstration for the benefits of the approach.

The development of the SPHERE Digital Twin will be strengthened by incorporating emerging software and hardware technologies. To this end emerging trends in technologies were evaluated that if they can be related and connected to SPHERE will enhance the Digital Twin capabilities.

Based on desk research of innovative companies in the AECO sector and both grey and academic literature, five technology trend pillars for the AECO sector emerged, which are critical in how they will shape the sector in the next decades. In the next pages each of these pillars, as displayed in Figure 8 on the right, are discussed. Within this context disruptive emerging technologies that will drive the digitisation transition forward are presented below, all of which are directly related to the life cycle needs of the value chain.

Figure 8. Pillars of the digitised AECO sector



[21] McKinsey&Company, Organisation for Economic Co-Operation and Development, https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future

Digitisation Pillar 1: Improved surveying and data acquisition

Higher-definition surveying and geolocation: New techniques that integrate high-definition photography, 3-D laser scanning, and geographic information systems, enabled by recent improvements in drone and unmanned-aerial-vehicle (UAV) technology, can dramatically improve accuracy and speed.

Lidar: Light-detection-and-ranging (lidar) technology is much faster than conventional technologies and provides high-quality 3-D images that can be integrated with project-planning tools and BIM.

Data Consolidation: Used in conjunction with ground-penetrating radar, magnetometers, and other equipment, lidar can generate above-ground and underground 3-D images of project sites. Advanced survey techniques are complemented by geographic information systems that allow maps, images, distance measurements, and GPS positions to be overlaid. This information can then be uploaded to other analytical and visualization systems for use in project planning and construction. Expected Benefits Include: i) Conducting structural inspections without the need for human labour, ii) Quickly deliver and maintain living digital twins

Product Example:
The Matterport Pro2 3D Camera captures 2D photography and 3D data from job sites, and automatically stitches them into a complete, immersive 3D model of a real-world job site. Each 360º sweep takes less than 20 seconds. Scans are automatically registered and stitched into a textured mesh in hours.[22]

Digitisation Pillar 2: Improved modelling and design capabilities:

Holistic Design with the Digital Twin and 5-D BIM : considers a project's cost and schedule in addition to the standard spatial design parameters in 3-D. It also includes details such as geometry, specifications, aesthetics, thermal, and acoustic properties. A 5-D BIM platform allows owners and contractors to identify, analyze, and record the impact of changes on project costs and scheduling.

Virtual Reality (VR) and Augmented Reality (AR) Solutions: The use of digital twin and 5-D BIM technology will be further enhanced through augmented-reality technology via wearable devices. For example, a wearable, self-contained device with a see-through, holographic display and advanced sensors can map the physical environment. Companies are developing BIM-like design and construction solutions for these platforms. In this "mixed reality" environment, users can pin holograms to physical objects and interact with data using gesture, gaze, and voice commands. Expected Benefits include: i) Use AI and ML to give decision makers new insights into data, ii) Visualize data in mixed reality, iii) Combining 5-D BIM and augmented-reality devices will transform construction, maintenance, and operations.

Digitisation Pillar 3: Improved collaboration for construction processes

Digital-collaboration and field-mobility solutions : Central-planning teams and on-site construction teams in need to connect and share information about progress in real time. Cloud-based, mobile-enabled field-supervision platforms that integrates project planning, engineering, physical control, budgeting, and document management for large projects are emerging. Several large project developers have already successfully digitized their project-management work flows.

[22] https://matterport.com/en-gb/

Crew-mobility solutions: Supported with mobile devices, sensors and wearable technologies are expected to have a similar catalytic effect on productivity. This will allow the industry to carry out everything from work- and change-order management, time and material tracking, dispatching, scheduling, productivity measurement, and incident reporting.

Products: The digital-collaboration and mobility-solutions segment has attracted close to 60 percent of all venture funding in the construction-technology sector. One start-up has developed apps for tablets and smartphones that allow changes in construction blueprints and plans to be relayed in real time to on-site crews; site photos can be hyperlinked to construction plans.

Figure 9. Examples of digitial collaboration solutions

Design management	Scheduling	Materials management	Crew tracking
• Visualize drawings and 3-D models on-site, using mobile platforms • Update blueprints in the field with markups, annotations, and hyperlinks	• Create, assign, and prioritize tasks in real time • Track progress online • Immediately push work plan and schedule to all workers • Issue mobile notifications to all subcontractors	• Identify, track, and locate materials, spools, and equipment across the entire supply chain, stores, and work front	• Provide real-time status updates on total crew deployed across work fronts, number of active working hours, entry into unauthorized areas, and so on
Quality control	**Contract management**	**Performance management**	**Document management**
• Offer remote site inspection using pictures and tags shared through app • Update and track live punch lists across projects to expedite project closure	• Update and track contract-compli-ance checklists • Maintain standardized communication checklists • Provide updated record of all client and contractor communications	• Monitor progress and performance across teams and work areas • Provide automated dashboards created from field data • Offer staffing updates and past reports generated on handheld devices	• Upload and distribute documents for reviewing, editing, and recording all decisions • Allow universal project search across any phase

Digitisation Pillar 4: Improved operation and analytical capabilities

Sensors and wireless technologies: enable equipment and assets to become “intelligent” by connecting them with one another. On a construction site, the Internet of Things would allow construction machinery, equipment, materials, structures, and even formwork to “talk” to a central data platform to capture critical performance parameters.

Continuous Data Acquisition: From field devices, mobile interfaces and experts’ systems, insights gained through the adoption of advanced analytics in construction projects can help to improve efficiency, timelines, and risk management.

Predictive analytics and data mining capabilities: Utilise the acquired information for simulations and forecasts, providing impacts to prevent equipment breakdowns on-site and allow optimise the logistics and mitigation of events in a timely and cost effective manner. Expected areas where this trend will have an impact include: i) Equipment monitoring and repair, ii) Inventory management and ordering, iii) Quality assessment, iv) Energy efficiency, v) Safety.

Digitisation Pillar 5: Future proof and sustainable design

New building materials: Such as self-healing concrete, aerogels, and nanomaterials, as well as innovative construction approaches, such as 3-D printing and preassembled modules, can lower costs and speed up construction while improving quality and safety. Building materials represent a $1 trillion global industry; materials usually account for more than half the total cost of projects. Traditional materials such as concrete, cement, and asphalt make up most of this demand. But new and better construction materials are also required.

Off Site Construction: Assembling lighter, easier-to-handle materials off-site can improve project efficiency, address on-site space constraints, and create the conditions for crews to improve their skills.

This trend is best driven by the digitalised design and construction, where the digital catalogues of products are used for the precise field implementation.

Expected Impact of these trends include i) Green and sustainable construction, ii) Cost efficiency, iii) Waste reduction at site, iv) Supply-chain agility, v) Off-site construction

9.4 SPHERE positioning requirements within the technology trends

The SPHERE project has been structured with a vision on and awareness of the mentioned emerging technologies and practices. Yet, it is the purpose of the WP2, starting with this identification of barriers, solutions, and initial requirement analyses document, to define the incorporation of emerging technologies in further detail. Such that the SPHERE platform, with an already existing background on Digital Twin and construction and renovation process related, data driven solutions, will evolve into a life cycle management support service set for the AECO sector. Table 13 outlines the high-level relation between the digitisation pillars, SPHERE proposition for their incorporation forming a set of platform technology capability requirements, and the related modules where these technology capabilities are to be implemented.

Table 13. SPHERE positioning within the Digitisation Pillars in the AECO sector

Digitisation Pillars	SPHERE Technology Capabilities	Related Modules and WPs
Improved surveying and data acquisition	A common and interoperable data environment. Innovative BIM and Digital twin data management capabilities	Data Management module; WP3 for standards and architecture
Improved modelling and design capabilities	Energy modelling, sustainability assessment, visualisation and other support capabilities	Design Support Module; WP4 for Energy Modelling
Improved collaboration for operation	Common data Environment. Pilot cases for testing of construction processes	WP5 For integrated tools and data management; WP6 for Construction/Renovation Piloting
Improved operation and analytical capabilities	IoT and data connectivity. Acquisition and management of data for operation	Operation and Maintenance Module; WP5 For integrated tools and data management
Future proof and sustainable design	Sustainable design and operation practices. KPIs and metrics for assessment. Inventories for green materials and compliance checks	WP5 For Sustainability assessment tools; WP6 Pilots for validation of performance and impact

How SPHERE stands out in relation to other manufacturers of BIM software, is that these focus primarily on design software and this workflow does not match with real-life projects that span from design to implementation and handover. Most of the BIM review platforms currently available on the market such as clash detection or markup software cannot make the information accessible in other software for other life cycles stages used by other stakeholders involved in a construction or renovation project. Among the BIM tools some of the the most dominant vendors in the market for architectural projects are:

- **ArchiCAD:** ArchiCAD is a full-fledged tool and the oldest available in the market. It comes with a large library. The platform is compatible with budgeting and energy calculation software and others.
- **Bentley Architecture** : Bentley Systems' BIM solution supports IFC format and is part of a large platform that encompasses specific software for structure, installation and modeling of complex elements.
- **Revit Architecture**: Revit, an Autodesk Software, is one of the most popular and widely used in the market due to the fact that it comes from the same vendor as AutoCad. The tool can read the files generated by Revit Structure and installations (Revit MEP), which facilitates the coordination and compatibilization of the complementary ones.
- **Vectorworks Architect**: Nemetschek Group's Vectorworks is highly compatible with the IFC format for file exchange with other BIM tools. It is a simpler and cheaper platform, which makes it possible to design in the traditional way, like a conventional CAD program.

Life Cycle Perspective of SPHERE Platform

The novelty and positioning of the SPHERE platform is to provide a vendor agnostic solution, not in competition with the spectrum of full-fledged design platforms, but to **serve as a life cycle and workflow oriented range of services.** Definitions of the BIM dimensions vary, yet, they are most commonly defined as follows:

- 2D/3D: Digital Modelling
- 4D: Measurements, Scheduling and Planning
- 5D: Cost estimation, Budgets and Quantity Takeoffs
- 6D: Energy Analysis, Efficiency Studies, and Sustainability
- 7D: Facility Management and Operations

Among the mentioned scope of services, the facility management and operation stage of the life cycle provides a complementary and holistic perspective**. SPHERE aims to position itself as a cloud based life cycle service provier**. Having the opportunity to link BIM architecture software with an application for Facility Management gives us the following advantages:

- Create real-time bi-directional links between the BIM model and FM applications in the cloud
- Connect data in the design, construction, management and maintenance phases of the building
- Manage rooms, zones and spaces
- Synchronize the contained properties (families) of the BIM model with FM teams
- Create maintenance plans for operations teams
- Perform tracking on scheduled activities and warranty requirements
- Publish views of the BIM model to the FM application allowing anyone in the project team to visualize and manage the information model

9.5 Digital Twins as an Enabler for Market Solutions

A recent market study carried out by Blanco et.al[23] has revealed the positioning of recent technologies and services in the construction sector. A range of grouped so called constellations ahve been observed, emerging around established use cases, which serve as indicators of what technologies are gaining the most traction and where their impact can be expected to rapidly increase in the near future. Today, the most prominent constellations include 3-D printing, modularization, and robotics; digital twin technology; artificial intelligence (AI) and analytics; and supply chain optimization and marketplaces.

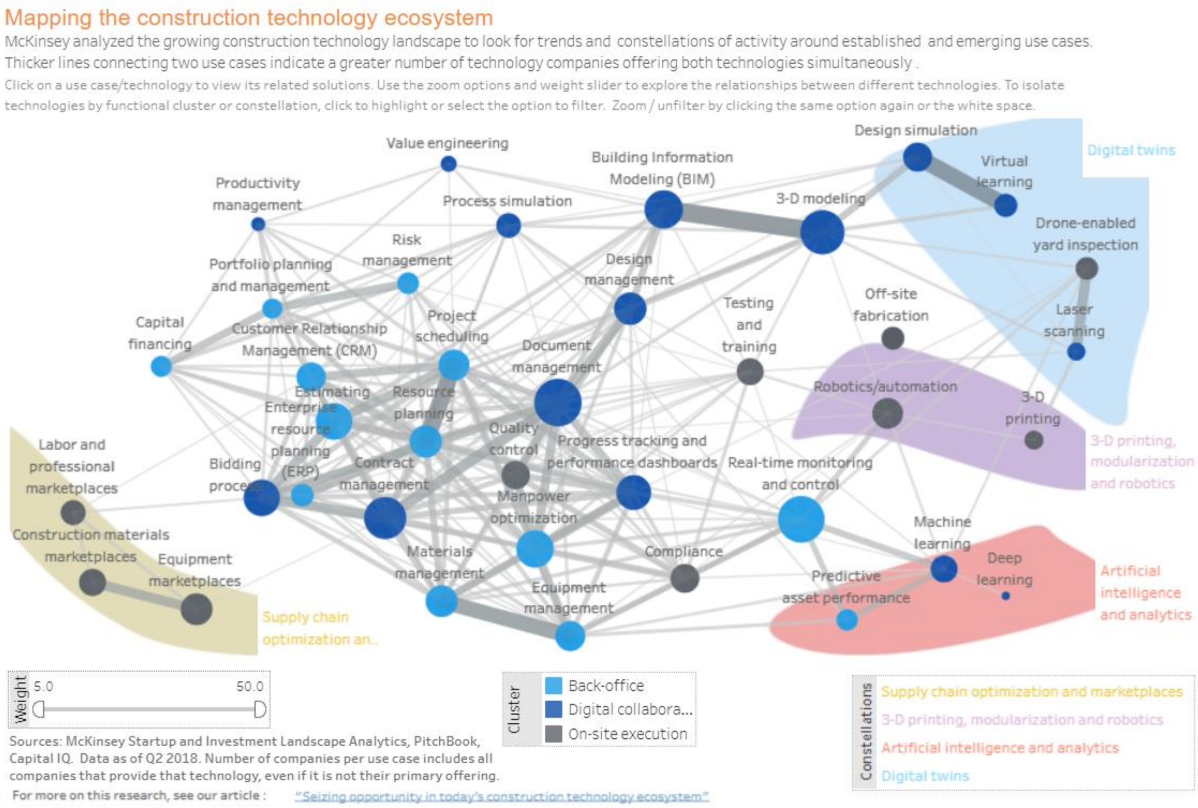


Figure: Mapping of the construction Ecosystem, McKinsey & Company[15]

Digital twin technology appears as the cluster that benefits from the BIM and Modelling technologies, as well as being linked and potentially collaborative to the 3D manufacturing, robotics and Analytics related solutions. **This market analyses directly relates to the mositioning of the SPHERE solution as the collaborative data management backend supporter as well as the analytics services enabler role.**

In the sector, productivity gains are directly driven by transparency and proactive problem resolution. Digital twin platforms and reality-capture solutions enable stakeholders to minimize rework in the field by allowing a dynamic view of the project and real-time comparison of progress to design blueprints—and the ability to adapt those blueprints as the work progresses and inevitably results in changes.

[23] Blanco et.al, Seizing opportunity in today's construction technology ecosystem, 09.2018, McKinsey & Company, online : https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/seizing-opportunity-in-todays-construction-technology-ecosystem#

10 Sphere Platform Requirements

10.1 Requirements of users and actors with their roles and benefits

Subtask 2.1.2 Identification of Process Scenarios utilizing the Digital Twin: *The relevant user types and actors will be identified, in close collaboration with the stakeholder and advisory board members, end user and demo support partners of the project consortium, to provide the usability and replicability of the workflows.*

The consortium carried out a mapping of potential SPHERE users based on looking at actors beyond traditional AECO sector software users in ten countries focusing on renovation works in existing buildings. Such actors include building managers, individual property owners, subcontractors, renters, large property owners, housing associations and so forth, next to the more traditional software users like architects, engineers, energy experts and construction experts. The commonality of these actors and their relationships in different housing occupancy structures were studied resulting in five different owning-renting-building relationships as outlined in more detail in Appendix F.

The most common of the five relations found across countries, as displayed in Table 14 below, is either social housing with government or public-private owned and managed housing, or community owned housing with a community group, where usually a building manager takes care of maintaining the building. A second model that is found in half of the scanned countries is that of a large private property developer which owns and maintains the building and its dwelling(s). More specialised and uncommon models include neighbourhood associations which maintain multiple buildings, and freehold-leasehold relations of ownership with their incentive structures. The SPHERE platform will therefore be most impactful if it can serve actors within commnity owned and social housing structures that have a government managed structure.

The mapping resulted in a number of anticipated roles that actors within these relations hold and an understanding of whether they will be a likely user, based on the assessment of agency as described in section 8.3. The evaluation found that given the highest ability to invest, implement change and act in terms of renovations, likely SPHERE platform users include building managers, subcontractors, and public building owners. In case of private property also private owners are likely to have an interest in using the Sphere platform (see Table 14).

Table 14. Results of identified Actors and Users in owning-rental-building relations

ARCHTYPICAL RELATIONSHIP	COMMONALITY ACROSS COUNTRIES	ACTORS	LIKELY SPHERE PLATFORM USER
Community owned with a Building Manager Relation (Administrador de Fincas)	9/10	Building Managers	High
		Individual Owners	Low
		Subcontractors for Building Service & Maintenance	Medium
		Subcontractor for Building Renovation Works	Medum
		Renters	Low
Large Private property Developer Relation (Immobiliaria Patrimonialista)	5/10	Building Owner	High
		Internal Building Facility Manager	High
		External Building Facility Manager	Medium
		Subcontractors for Building Renovation Works	Medium
Neighbourhood Association Relation	2/10	Individual Flat Owners	Low
		Neighbourhood Association	High
		Subcontractors for Building Renovation Works	High
		Subcontractors for Building Service & Maintenance	High

Freehold-Leasehold Relation	2/10	Freeholder	High
		Leaseholder	High
		Subcontractors for Building Renovation Works	High
		Subcontractor for Building Renovation Works	High
Social Housing Relation	9/10	Government Comission acting as Building Owner	High
		Internal Building Facility Manager	Medium
		Subcontractors for Building Service & Maintenance	Low
		Subcontractors for Building Renovation Works	Low

After identifying the likely users, specific outcomes and potential benefits from SPHERE for the users were established. A summary of these can be found in Table 15 below. The main outcome for building facility managers was found in creating a one access place for most information, and making it easier to control the building in a smooth and cost savings manner. This is expected to result in less effort required to commission renovations, making early improvement assessments possible, providing rapid overall knowledge of the state of the building, and allow for assistance in renovations for monitoring purposes.

Subcontractors are anticipated to obtain as an outcome a more reliable control in work processes and also to reduce their errors. The benefits from using SPHERE would thereby be from the start to have a better work plan of what needs to be done, to have access to multiple tools in an easy to access online inventory, to result in early correction of errors and better dynamic design and implementation, as well as monitoring improvements. This results in reduced completion time and cost as labour is utilised more efficiently, and thereby a likely more attractive market proposition and client base.

Public governmental building owners and private owners are anticipated to obtain as an outcome easier access to documents and information in one place, and improved efficacy of budget investments as well as cost savings. Their benefits from using SPHERE would be improved ease in commissioning renovation works and delivery of insights across the real estate portfolio for management purposes.

Table 15. Overview of outcomes and benefits from SPHERE for different users

Potential User	Intended outcomes	Potential Benefits from SPHERE
Building Facility Manager	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data).
		Early assessment of improvement measures possible
		Overall knowledge of the state of the building for daily management tasks. Digital twin provide advantage for the implementation of routine maintenance tasks.
	Information in one place. As-built models, energy, water and electricity consumptions.	Constant monitoring and easy access to documents
	Time savings > more efficient work process (their income = typically a fixed fee)	Assessment of improvement measures, traceable improvement activities
Subcontractors for renovation works	Have a precise and reliable control of the state of the building, which will be available	Have a clear plan of what is needed to be done. Better scope of the renovation works.
		Predefined proposals (materials, technologies, solutions, ...) for renovation activities.

	when reforms and updates are necessary. When working for a fixed price > less bad surprises	Easy access to rich inventory of the materials and dynamic design tools, facilitated data flow
		Dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents
		Reduced project completion time, reduced costs due to the efficient use of labour and resources. Easy and transparent cost assessment and establishing a mutual trust with the client
		Maintenance status in model, current values and history data for energy consumption, temperature and other sensors.
		SPHERE recognized organization could have larger client base/attract more clients
Public (Government) owner)	Key figures available, up-to-date information and models from building.	Easier to commission renovation works (use of digital twin BIM data)
	budget investments and control quality. Savings in time & cost.	One place for materials, share with different stakeholders.
		Delivery of insights in real estate portfolio
Private Property Owner	More efficient buildings and lower energy costs	Easier and more reliable renovation implementation. Continous monitoring to decide future change, reduced construction time and costs. Scheduling the next rennovation
		Easier Commissioning. Less ad hoc repairs (pro-active). Easier selection & decision process
		Updated Energy Data and Simulations for Energy Certificates in New/Retrofitting buildings
Tenant	Operations system of the house	Monitor and control of connected appliances and Building Automations.
		Reduction of Energy Consumption by custom optimization of Explicit Demand Response, based on historical time series of the tenant energy demand, allowing better contracts with the ESCO.
		Access to innovative tools inside the Building Digital Twin Instance APPs marketplace.

10.2 Regulatory requirements and standards to be encapsulated in SPHERE

DoA Subtask 2.1.3 Assessment of Barriers and need for Change Management: *Regulatory and Technical compliance will be assessed.*

DoA Subtask 2.1.2 Identification of Process Scenarios utilizing the Digital Twin: *This will be carried out in collaboration with the administrative and technical acceptance analyses carried out in the task, ensuring the delivery of useable and scalable workflow scenarios*

The country scans carried out also included an assessment of standards and regulations that have been developed for the digitisation transition in the AECO sector within the ten countries that have been analaysed and the European Union. Also the regulatory environment and associated targets around the increasingly stringent performance needs of new and existing buildings has been assessed. The results of these analyses are summarised in three tables below that contain the following:

- **BIM procedural implementation standards**, listed in table 16, which provides insights in existing standards and protocols containing the processes required for implementing BIM for new and existing buildings. The main standards that have driven this process are EN ISO-19650 that provides for the main processes and steps needed to implement BIM for a project, and ISO-16739 that describes the Industry Foundation Class (IFC) as the main data exchange and schema system to capture BIM data. The majority of national standards have been derived from these.
- **Nearly zero energy building (nZEB) requirements**, listed in table 17, which provides insight into nZEB targets for a number of EU nations. A nZEB is defined within the Energy Performance of Buildings Directive (2010/31/EU) as a building which "has a very high-energy performance" where performance is defined as a transparent parameter determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with typical use and shall reflect the heating energy needs and cooling energy needs to maintain the envisaged temperature conditions of the building, and domestic hot water needs. Additionally a significant extent of the minimized energy required for the asset should be covered by an energy from renewable source, either on site or nearby. EPBD article 9(2010/31/EU) establishes that all new buildings must be nZEBs by 31 December 2020. As there are no concrete values stated in the definition of nZEBs in the EPBD, each country has different nZEB definitions and methodologoies due to the differences in member states' regulations, technological readiness level and climate, some examples are outlined in appendix J. Accordingly, to asses progress the European Commission has requested a cost optimal assessment of energy performance requirements, in relation to each countries methodology.
- **Energy Performance requirements**, listed in table 18, which provides insights in the building efficiency directives at the EU level and the implementation thereof at the national level that is in effect. A comprehensive overview per country is given in terms of required thermal insulation performance or U-values for windows, walls, roofs, doors and floors for new buildings, including regulatory updates of applicable laws in recent years. The national laws are based on the requirements in the European Union Energy Performance for Buildings (EPBD) directive(2010/31/EU).

- **BIM Objects and elements data**, listed in table 19**,** which provides insights in existing and emerging standards that describe data schemas, data requirements, and data dictionaries to allow a BIM compliant description of the many products for the AECO sector delivered by a wide variety of suppliers for the construction of buildings and its interior. The main standards include ISO 12006 which is a standard for the classification of construction works including general and object-oriented information, EN 17473 astandard that is under approval developed by CEN/TC 442 committee that provides for a product data template for products and systems used in construction works with linkage to IFC, and EN ISO 16757 which provides a standard to describe products of building service systems

The assessment gives a requirements grounding for the SPHERE platform on what standards and protocols to align with. Both for describing the building digitisation life cycle processes in the platform, for ensuring BIM objects and data schemas and templates are delivered with EU needs, and for aligning energy performance needs assessment scenarios in SPHERE simulations with existing laws and regulations. By incorporating the standards the SPHERE platform will be up-to-date with the state of the art .

Table 16. Existing International and national standards for the procedural implementation of BIM

	BIM standards	Description
EU	EN ISO-19650	Regarding the whole life cycle of the building, concepts and principles for information management considering building information modelling (BIM) are identified
	EN ISO-16739	The Industry Foundation Classes (IFC) which are used as an open international standard for BIM data for building life cycle are defined
	EN ISO-29481-1:2010	Specifies a methodology that connects the flow of business process with the specification of information required by this flow considering the information processes within whole life cycle for construction. Aims to facilitate integration between softwares and construction processes
	EN ISO-29481-2:2012	Identifies a methodology and format for collaboration acts between stakeholders in a construction project during all life cycle stages, promotes digital collaboration and information exchange practices
	EN ISO 23386	Describes the methodology to effectively work with interconnected dictionaries and establishes the rules in defining properties used in construction sector
BE	Belgisch BIM protocol	Describes a reference protocol to standardise the implementation of BIM in Belgian construction and renovation projects
DE	Stufenplan Fur BIM	In the scope of Planen Bauen 4.0, aims to identify the challenges and solutions of BIM adaptation and implementation among the stakeholders and setting up guidelines
	VDI 2552	Provides a national (German) approach to the implementatiton of BIM through building life cycle and aims to coordinate international and national contents to form standards
ES	Guias uBIM	First proposed within the framework of the EUBIM2013, uBIM acts as an adaptable guide for Spanish BIM users and coordinates all the stakeholders involved in preparation of BIM modeling
NL	Nationaal BIM Protocol	Aims to bring unity to BIM terminology, protocol offers a foundation for project specific BIM protocols and a checklist for the BIM-related aspects that must be arranged in the contract between the client and the contractor
TR	No national standard-	

AT	ÖNORM A - 6241-1	Specifies the technical implementation of data exchange and data storage for information on building construction and related spatial civil engineering constructions which are required during the life time cycle management of real estate property.
	ÖNORM A - 6241-2	Identifies the prerequsites for collaborative data models for buildings, regulates the technical implementation of multi-dimensional building data models and lays groundwork for a for a comprehensive, uniform, product-neutral, systematic data exchange based on IFC and bSDD
FR	Plan Transition Numérique dans le Bâtiment	Aims, beyond highlighting the interest of a BIM approach, to give the pragmatic elements of the actions to be carried out.
IT	UNI 11337	The technical standard is divided into 10 parts and represents the entire work flow of the BIM project which at the same time provides the general terminology, the criteria for the naming and classifying models for organizing and storage of technical data.
FI	YTV2012	Publication series consist of 13 series for the purpose of dentifying the BIM requirements such as requirements for structural, MEP design and management of BIM projects
	InfraModel	Offers an open method documentation for the exchange of infrastructure structure information
UK	BIM Level 2	Announced in 2011 as a part of UK Construction Strategy, BIM Level 2 involves domain specific models including collaborative 3D geometrical and non-graphical data
	BS ISO-19650	Provides the standards for managing information over the whole life cycle using BIM and additionally contains requirements of BIM Level 2
	PAS 1192-2	Withdrawn, Superseded by ISO-19650
	BS 1192-4:2014	Defines a methodology for the exchange of the structured data relating facilities, building and infrastructure
	BS 8536	Includes systematic approach to briefing for designers to consider the in use performance in order to minimise the costs (maintenance cost)
	CIC BIM Protocol	Comissioned as a part of UK Government BIM Strategy, protocol ensues additional obligations and rights for the employer and the contracted party and identifies building information models that are required to be produced by the project team and puts in place specific obligations, liabilities and associated limitations on the use of those models.

Table 17. Energy Requirements defined by EU Member States for nZEB Levels. Abbreviations used: primary energy (PE).

Country	Residential Buildings (kWh/m²/y or Energy Class)		Non-Residential Buildings (kWh/m²/y or Energy Class)	
	New	Existing	New	Existing
Austria	160	200	170	250
Belgium	45 (Brussels region) 30 (Flemish region) 60 (Walloon region)	~54	(95–2.5) *(V/S) (Brussels region) 40 (Flemish region) 60 (Walloon region)	~108
Bulgaria	~30–50	~40–60	~30–50	~40–60
Cyprus	100	100	125	125
Czech Republic	75%–80% PE	75%–80% PE	90% PE	90% PE
Germany	40% PE	55% PE	n/a	n/a
Denmark	20	20	25	25
Estonia	50 (detached house)	n/a n/a n/a n/a	100 (office buildings) 130 (hotels, restaurants) 120 (public buildings) 130 (shopping malls)	n/a n/a n/a n/a
	100 (apartment blocks)	n/a n/a n/a	90 (schools) 100 (day care centres) 270 (hospitals)	n/a n/a n/a
France	40–65	80 n/a	70 (offices without AC) 110 (offices with AC)	60% PE n/a
Croatia	33–41	n/a	n/a	n/a
Hungary	50–72	n/a	60–115	n/a
Ireland	45 (Energy load)	75–150	~60% PE	n/a
Italy	Class A1	Class A1	Class A1	Class A1
Latvia	95	95	95	95
Lithuania	Class A++	Class A++	Class A++	Class A++
Luxemburg	Class AAA	n/a	Class AAA	n/a
Malta	40	n/a	60	n/a
Netherlands	0	n/a	0	n/a
Poland	60–75	n/a	45–70–190	n/a
Romania	93–217	n/a	50–192	n/a
Spain	Class A	n/a	Class A	n/a
Sweden	30–75	n/a	30–105	n/a
Slovenia	45–50	70–90	70	100
Slovakia	32 (apartment buildings) 54 (family houses)	n/a n/a	60–96 (offices) 34 (schools)	n/a n/a
UK	~44	n/a	n/a	n/a

Table 18. Standards on the energy performance requirements for new buildings with updated values

	Building efficiency performance laws	Standard updated on	Description of latest updated values					
EU	Energy performance of buildings directive (EPBD) (2010/31/EU)	Not yet updated	Widened the scope of EU Directive 2002/91/EC, amended the future targets and introduced the Nearly Zero Energy Buildings (NZEB), cost optimal levels of energy performance in buildings, forms a basis for the national building efficiency policies					
EU	Energy efficiency directive (2012/27/EU)	Not yet updated	Establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020					
BE	Réglementation sur la Performance Energétique des Bâtiments (PEB Wallonia) 2012	2019	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			All Climate Zones (CZ)	1.1	0.24	0.24	2	0.24
BE	Energieprestatie en Binnenklimaat (EPB Flanders) 2012	2018	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			All Climate Zones (CZ)	1.1	0.24	0.24	2	0.24
DE	Energy Conservation Regulations (EnEV) 2012	2015	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			All Climate Zones (CZ)	1.3	0.28	0.35	1.8	0.35
ES	Código Técnico de la Edificación (2009)	2019	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			CZ α	3.2	0.8	0.55	5.7	0.8
			A	2.7	0.7	0.5	5.7	0.7
			B	2.3	0.56	0.44	5.7	0.56
			C	2.1	0.49	0.4	5.7	0.49
			D	1.8	0.41	0.35	5.7	0.41
			E	1.8	0.37	0.33	5.7	0.37
NL	Bouwbesluit 2012: Chapter 5	Not yet updated	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			All Climate Zones (CZ)	1.4	0.4	0.4	N/A	0.4
TR	Building Energy Performance Directive (2010)	2013	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			CZ 1	1.8	0.66	0.43	1.8	0.66
			CZ 2	1.8	0.57	0.38	1.8	0.57
			CZ 3	1.8	0.48	0.28	1.8	0.43
			CZ 4	1.8	0.38	0.23	1.8	0.38
			CZ 5	1.8	0.36	0.21	1.8	0.36
AT	OIB - Richtlinie 6, National Code	2019	**U-Values (W/m²K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			All Climate Zones (CZ)	1.4	0.35	0.2	1.4	0.4

FR	Réglementation Thermique 2012	Not yet updated	. Average U-value must be smaller or equal to 0.36 W/m2K . Ratio of global average linear thermal transmittance must be smaller or equal to 0.28 W/m2K					
IT	Italy National Building Energy Code n .192/2005 (values in effect from January 1, 2019 for public use and from January 1, 2021 for all other buildings	2019	**U-Values (W/m^2K)**	**Windows**	**Walls**	**Roof**	**Partition Wall**	**Floor**
			CZ A	3.00	0.43	0.35	0.80	0.44
			CZ B	3.00	0.43	0.35	0.80	0.44
			CZ C	2.20	0.34	0.33	0.80	0.38
			CZ D	1.80	0.29	0.26	0.80	0.29
			CZ E	1.40	0.26	0.22	0.80	0.26
			CZ F	1.10	0.24	0.20	0.80	0.24
FI	National Building Code of Finland 2012	2017	**U-Values (W/m^2K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			Warm and cooled cold spaces	1	0.17	0.09	1	0.09
			Semi-warm spaces	1.4	0.26	0.14	1.4	0.14
UK	Building Regulations (England and Wales) 2010	2016	**U-Values (W/m^2K)**	**Windows**	**Walls**	**Roof**	**Door**	**Floor**
			All Climate Zones (CZ)	2	0.3	0.2	2	0.25

Table 19. Standards providing BIM data dictionaries and methods for the description of building elements as BIM objects

	Standards	Description
EU	EN ISO-12006	Framework for the development of built environment classicifcation systems, also aims to relate how the object classes classified in BIM
	EN 17473	Standard under approval by developed by CEN/TC 442 commitee. Provides a common method for creating product data templates in alignment with Construction Products Regulation (CPR) and linking these data templates with IFC classes for data sharing in the construction and facility management industries
	ISO 16757	Enables the design and simulation of complex building service systems by allowing designers to import the electronic product catalogues provided by the manufacturers automatically into models of building services software applications
BE	No specific product/compoment element data classification standard or BIM object standard could be located	
DE	VDI 3805	Describes a manufacturer and IT system independent and unified data format for the exchange of product data for systems including data for drawing, sizing and bidding.
ES	GUBIMCLASS	Provides a system of classification of construction elements, developed based on international classification systems such as OMNICLASS, Uniformat and Uniclass 2015
NL	CB-NL Semantic standard	Is a digital dictionary/taxonomy based on the semantic definition of generic and re-usable concepts (types). These concepts apply to physical objects, functional spaces, and properties, which are related to each other. It is usable in the whole lifecycle and covers the building subsectors: utilities, housing, civil sector etcetera and has a important link to geo-information (GIS).
TR	No specific product/compoment element data classification standard or BIM object standard could be located	
AT	No specific product/compoment element data classification standard or BIM object standard could be located	
FR	XP P07-150	Published in 2014, XP P07-150 includes methodology for defining and managing construction product information for digital use and allow information exchange between industrial actors
IT	No specific product/compoment element data classification standard or BIM object standard could be located	
FI	InfraBIM classification	Provides BIM dictionary-classification for InfraBIM methodology such as geometries, structure types and functions etc.
UK	BS 8541	Provides an object library for AEC(Architecture, Engineering and Construction) applications
	BS EN ISO 16757-1:2019	Enables the design and simulation of complex building service systems by allowing designers to import the electronic product catalogues provided by the manufacturers automatically into models of building services software applications
	Uniclass 2015	Provides detailed classification structure for construction industry
Other	OMNICLASS(US)	Provides a standardized basis for classifying data used by AEC industry considering the whole life cycle of the construction project

10.3 Operational and Change Management Requirements

Subtask 2.1.3 Assessment of Barriers and need for Change Management: *Behavioural and operational change requirements will be identified and solutions will be proposed.*

The SPHERE Digital Twin solutions that have been identified require a number of significant changes to how different actors, such as those identified in section 9.4, operate and carry out their works for renovation and construction, and how they interface their works with the Digital Twin. The solutions that emerged from the workshops, country scans, and partner insight, made it clear that for the operation of the SPHERE Digital Twin workflow management is an essential element, and that the development of a step by step protocol on where, what and how different elements of the SPHERE platform can be utilised. And in relation what data flows and streams are needed. The protocol will provide for Digital Twin Operations and Communications management, as an oversight of the process, which can be facilitated by a new role in construction or renovation projects: the Digital Twin manager. The role of the Digital Twin manager requires further elaboration in SPHERE under WP2.3 within the workflow context and the workflow protocol, especially in relation to the BIM manager and how these two roles work together.

The development of this workflow protocol as an overall solution will help to facilitate different actors in their operational and change management from current work practices to new Digital Twin practices. It can be based on existing standards and protocols that are brought together, as described in section 9.5, and form a unified integrated protocol for Digital Twin delivery and management using BIM, covering how different actors and users interface with the Digital Twin as identified in section 9.4. Based on this a step by step understanding of setting up the Digital Twin emerges. It also interfaces with the technology requirements to deliver the Digital Twin as described in section 9.3 as enablers of this workflow in an efficient and cost effective manner with substantial capabilities.

The delivery of the workflow protocol is to be carried out for a first version in deliverable 2.3 so as to form a requirements blueprint for the SPHERE digital twin functionality. It will form an integration of various needs following from the user story and use case developments. As a first step an example of some of the workflows and related operational implementations for the Digitial Twin associated with the protocol can be found in Figure 10 on the next page. The numbers in the diagram correspond to specific barriers as identified in section 9.1 and how they are addressed by particular solutions as also identified. As can be seen the diagram integrates the relations between different processes, different actors and SPHERE users, and particular communications and data relations.

After a first version is created in deliverable 2.3 as an integration of the works under this task, the protocol can be furthered in WP3 and also be used to clarify the positioning of the tools in WP4 and WP5, and also be utilised for execution of Pilot works in a streamlined manner. It thereby will form an integral part of the SPHERE development and implementation works.

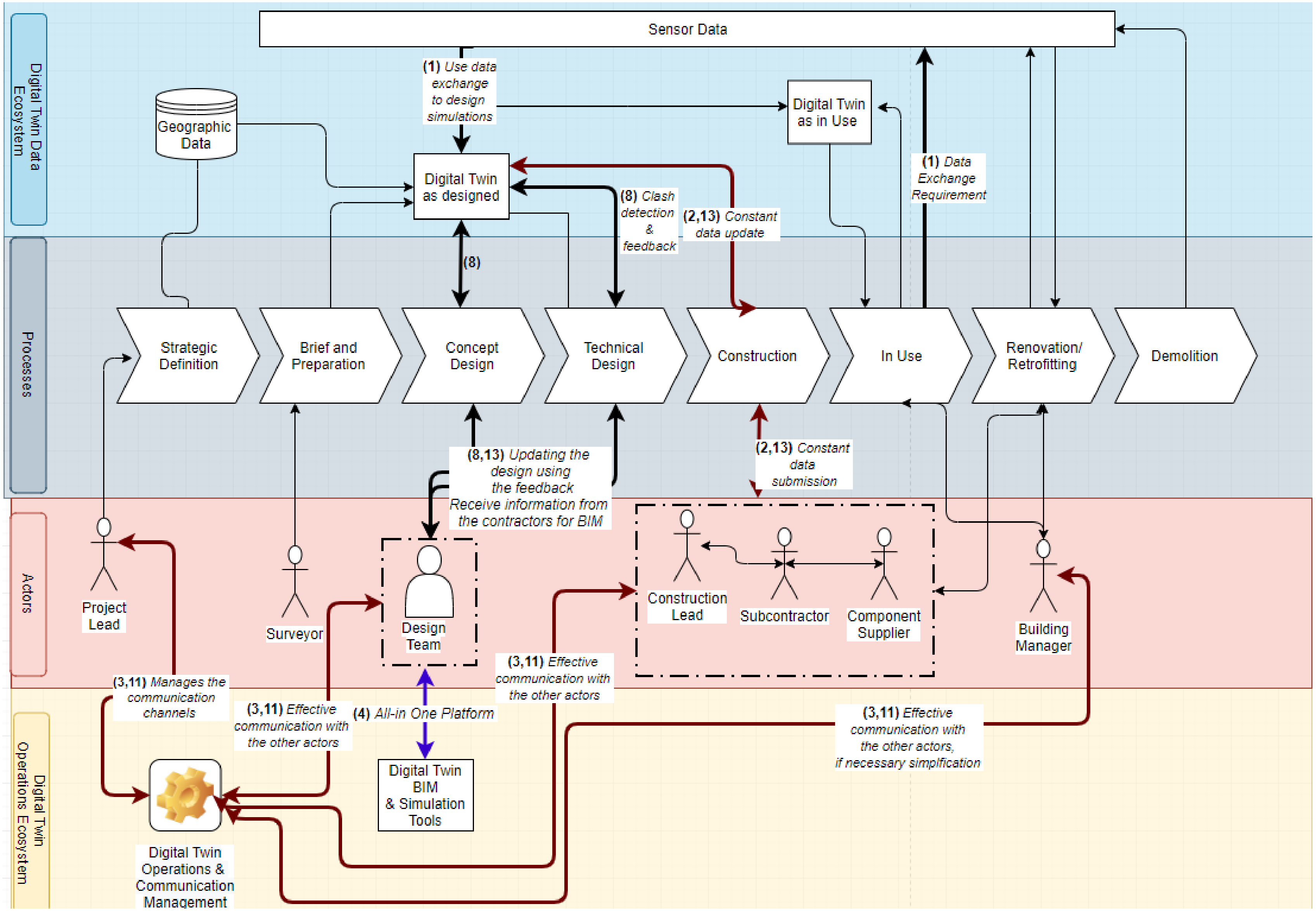


Figure 10. Simplified description of SPHERE workflow for operational and change management

11Conclusions

10.1 Summary of Achievements

The works in the deliverable 2.1 have generated a number of critical insights for the SPHERE project:

- First, a number of SPHERE collaborative practices have been identified that form a series of processes needed for the implementation of Integrated Design and Delivery Solutions (IDDS) and Integrated Project Delivery (IPD) with substantial background documentation as highlighted in Chapter 4. Subsequently, these practices have been linked to BIM and Digital Twin benefits on how these can facilitate and be interlinked with these practices for integration in SPHERE.
- Second, based on country scans and interviews and workshops a large number of barriers in the AECO sector and potential opportunities (named solutions) were identified for implementation in the SPHERE platform. A list of most relevant barriers to be addressed resulted in the main areas of improvement covering 15 barriers that the SPHERE platform will address, as described in section 9.1. In addition particular potential benefits that these solutions can bring were identified.
- Third, a number of base workflow scenarios, one for each pilot has been delivered that cover the staging of processes across all life cycle phases, from strategy and brief to the in use phase, as provided in section 8.2 and 9.2 including an understanding of which SPHERE IT sub-modules are helpful to incorporate for enabling particular solutions within these workflows.
- Fourth, relevant actors and SPHERE users were identified focusing on both traditional users and potential new users from a Digital Twin perspective, as summarised in section 9.4 covering a wide range of country situations.
- Fifth, specific administrative, regulatory and technical standards that form requirements for incorporation to align SPHERE with the state-of-the-art in the platform have been identified covering BIM processes, BIM product integration and Energy Performance requirements as per section 9.5.
- Sixth, emerging technologies that are appearing in the AECO sector have been identified and how particular instances of these will be integrated in the SPHERE Digital Twin Ecosystem as per section 9.3
- Finally, the operational and change management requirements identification process has been delivered and a first understanding of such changes has been identified in section 9.6.

10.2 Relation to Continued Developments in SPHERE

The detailed relations of the deliverable works in how it feeds to other tasks in the SPHERE project has been outlined in section 2.5. The main follow-up works will take place in task 2.3 where use cases and user stories will be developed taking into account the identified barriers and solutions in this deliverable. Specific follow-ups to particular barriers and solutions have been noted in section 9.1 for WP2 to WP6 so as to enable an uptake of the solution understanding across the project.

The works delivered on regulatory requirements and standards, technology requirements and particular IT solutions will form input in both task 2.3 and WP3 on the Digital Twin data architecture and implementation. In Task 2.3 a solutions workflow will be delivered based on user stories and use cases, as also described in more detail in section 10.3 below, which integrates these various aspects from a functionality perpective.

10.3 Other Conclusions and Lessons Learned

The main conclusion and lesson learnt from the work package works is that it will be highly beneficial to develop a workflow protocol for renovation and construction works. The protocol will be an overall solution by integrating all the sub-solutions as identified in this work-package. And it will both guide the development works and the pilot implementation in SPHERE. And after the project help to understand how SPHERE can assist and facilitate different actors in their operational and change management from current work practices to new Digital Twin practices on a step by step basis.

The workflow protocol should bring together a number of key elements from a functionality perspective: i) a life cycle phase description, ii) identification of aspects within the SPHERE digital twin data ecosystem and the SPHERE digital twin environment, iii) existing standards and protocols, iv) actors and SPHERE users as identified with specific roles in the process and how they interact with SPHERE, v) interfacing with different software technologies, vi) changes in operations that are needed from current practices, vii) specific solutions and how they are integrated within the workflow.

The protocol as to be developed in WP2.3 thereby forms a complete functional requirements specification that emerges from the works in this work-package once further developed. After a first version is created in deliverable 2.3 as an integration of the works under this task, the protocol can be furthered in WP3 and also be used to clarify the positioning of the tools in WP4 and WP5, and also be utilised for execution of Pilot works in a streamlined manner. It thereby will form an integral part of the SPHERE development and implementation works.

12 Acronyms

Table 20. Acronyms utilised in the SPHERE Project

1	**2D**	Second Dimension in BIM (plane)
2	**3D**	Third Dimension in BIM (volume)
3	**4D**	Fourth Dimension in BIM (Time, Scheduling, Planning)
4	**5D**	Fifth Dimension in BIM (Cost, Budget)
5	**6D**	Sixth Dimension in BIM (Sustainability)
5	**7D**	Seventh Dimension in BIM (Facilities Management, Life Cycle)
6	**8D**	Eighth Dimension in BIM (Safety & Security)
7	**9D**	Ninth Dimension in BIM (Lean Construction)
8	**AC**	Activities Table (CPIC Uniclass 2)
9	**ACE**	Architects Council of Europe
10	**ACFM**	Associació Catalana de Facility Management
11	**ACT**	American Council for Technology
12	**AD4**	Asset Data Dictionary Definition Document (Crossrail Limited)
13	**ADM**	Activity Definition Model
14	**ADMM**	Asset Data Management Manual (Highways Agency)
15	**ADQ**	Actual Digital Questions (from BIM Acronyms Dictionary)
16	**AEC**	Architecture, Engineering and Construction
17	**AECO**	Architecture, Engineering, Construction and Owner (or Owner-operated, or Operation)
18	**AEV**	Alternative Equivalent Value
19	**AGC**	Associated General Contractors (USA)
20	**AIA**	American Institute of Architects
21	**AIM**	Asset Information Model/Modelling
22	**AIMS**	Asset Information Management System (Crossrail Limited)
23	**AIR**	Asset Information Requirements
24	**ALM**	Asset Lifecycle Management
25	**ALM**	Application Lifecycle Management
26	**AM**	Asset Management
27	**AMF**	Asset Management Framework
28	**AMO**	Asset Management Office (Highways Agency)
29	**AMP**	Agreed Maximum Price

30	**AMR**	Automatic Meter Reading
31	**APCE**	Associació de Promotors i Constructors d'Edificis de Catalunya
32	**API**	Application Programming Interface
33	**APM**	Association for Project Management
34	**APPs**	Applications
35	**ASHRAE**	American Society of Heating Refrigerating and Air-Conditioning Engineers
36	**AR**	Augmented Reality
37	**AS**	Appraisal of Service
38	**ASP**	Application Service Provider
39	**ATTR**	Average Time to Repair (see MTTR)
40	**Avanti**	(UK Government sponsored to assist collaboration)
41	**B&ES**	Building and Engineering Services Association (formerly, till 2012, known as HVCA). (See BESA)
42	**BACS**	Building Automation and Control System
43	**BAS**	Building Automation System
44	**BCF**	BIM Collaboration Format
45	**BCHS**	Barcode Housing System
46	**bcXML**	Building and Construction eXtensible mark-up Language
47	**BDS**	Building Description System
48	**BEIF**	Built Environment Information Fabric
49	**BEIS**	Business, Energy and Industrial Strategy
50	**BEM**	Building Energy Management
51	**BEMS**	Building Energy Management System
52	**BEP**	BIM Execution Plan
53	**BEP**	Building Energy Performance
54	**BERR**	Business, Enterprise and Regulatory Reform
55	**BES**	Building Energy Simulation
56	**BESA**	Building Engineering Services Association (See B&ES)
57	**BIM**	Building Information Model/Modelling/Management
58	**BIM(M)**	Building Information Modelling and Management
59	**BIS**	Business, Innovation and Skills (See BEIS)
60	**BLIS**	Building Lifecycle Interoperable Software
61	**BLPU**	Basic Land and Property Unit

62	**BMS**	Building Management System
63	**BMS**	Battery Management System
64	**BOM**	Building Office Manager
65	**BOM’s**	Building Object Models
66	**BOOT**	Build-own-operate-transfer (See BOT)
67	**BOQ**	Bill of Quantities (See BOQ)
68	**BOT**	Build-Operate Transfer (See BOOT)
69	**BPEP**	BIM Project Execution Plan
70	**BPI**	Building Performance Indicator
71	**BPIC**	Building Project Information Committee
72	**BPMN**	Business Process Model and Notation
73	**BQ**	Bill of Quantities (See BOQ)
74	**BQBS**	Bill of Quantities (or BQ) Breakdown Structure
75	**BRE**	Building Research Establishment
76	**BREEAM**	Building Research Establishment Environmental Assessment Method
77	**BRep**	Boundary Representation
78	**BrIM**	Bridge Information Model
79	**BS**	British Standard
80	**BSA**	Building Smart Alliance
81	**BSD**	Building Systems Design
82	**bSDD**	buildingSMART Data Dictionary
83	**BSI**	British Standards Institute
84	**BSI**	Building Smart International
85	**BSIM**	Building Services Information Model (See BIM)
86	**BSRIA**	Building Services Research and Information Association
87	**CA**	Contract Administrator
88	**CAATEEB**	Col·legi de’Aparelladors, Arquitectes Tècnics i Enginyers d’Edificació de Catalunya
89	**CAD**	Computer-Aided Design
90	**CADD**	Computer-Aided Design and Drafting
91	**CAFM**	Computer-Aided Facility Management
92	**CAM**	Computer Aided Manufacture
93	**CAPex**	Capital Expenditure
94	**CAR**	Collection, Assessment and Response

95	**CASBEE**	Comprehensive Assessment System for Building Environmental Efficiency
96	**CATIA**	Computer Aided Three-dimensional Interactive Application
97	**CAWS**	Common Arrangement of Work Sections
98	**CBC**	Construction Blockchain Consortium
99	**CBS**	Cost Breakdown Structure
100	**CCIP**	Contractor Controller Insurance Program
101	**CCMS**	Construction Coordination Management Services
102	**CCOs**	Contract Change Orders
103	**CD**	Compact Disc
104	**CDE**	Common Data Environment
105	**CDF**	Common Data Format
106	**CDM**	Construction (Design and Management) Regulations
107	**CDPA**	Copyright, Designs and Patent Act
108	**CE**	Construction Excellence
109	**CEC**	Commission for Environmental Cooperation
110	**CECE**	Committee for European Construction Equipment
111	**CEN**	European Committee for Stantardisation
112	**CEO**	Chief Executive Officer
113	**CERL**	Construction Engineering Research Laboratory (USACE)
114	**CFC**	Chlorofluorocarbon
115	**CFD**	Computational Fluid Dynamics
116	**CFR**	Central Facilities Repository
117	**CFRP**	Carbon Fiber Reinforcement Polymer
118	**C/I**	Civils/Infrastructure
119	**CI**	Configuration Item
120	**CI**	Continuous Improvement (the same as CIP and CPI)
121	**CIAT**	Chartered Institute of Architectural Technologists
122	**CIB**	International Council for Research and Innovation in Building and Construction (Ant. Conseil International du Bâtiment)
123	**CIBSE**	Chartered Institution of Building Services Engineers
124	**CIC**	Construction Industry Council
125	**CIFE**	Center for Integrated Facility Engineering (Stanford University)
126	**CIM**	City Information Modelling

127	**CIOB**	The Chartered Institute of Building
128	**CIP**	Continuous Improvement Process
129	**CIR**	Contractor's Information Requirements
130	**CIS**	Construction Information Service
131	**CITE**	Construction Industry Trading Electronically
132	**CityGML**	City Geography Markup Language
133	**CL**	Construction Lean (see Lean Construction)
134	**CM**	Construction Manager
135	**CMa**	Construction Manager Advisor
136	**CMAA**	Construction Management Association of America
137	**CMAR**	Construction Management At Risk (the same as CMc)
138	**CMc**	Construction Manager as Constructor (the same as CMAR)
139	**CMDB**	Configuration Management Database
140	**CMM**	Capacity Maturity Model
141	**CMM**	Coordinate Measurement Machine
142	**CMMS**	Computerized Maintenance Management System
143	**CO**	Complexes Table (CPCI Uniclass 2)
144	**COAC**	Col·legi Oficial d'Arquitectes de Catalunya
145	**COBie**	Construction Operations Building information Exchange
146	**COEIC**	Col·legi Oficial d'Enginyers Industrials de Catalunya
147	**COINS**	Construction Industry Software
148	**COP**	Coefficient of Practice
149	**COP**	Coefficient of Performance
150	**COS**	Conditions of Satisfaction
151	**CPD**	Continuing Professional Development
152	**CPI**	Coordinated Project Information
153	**CPI**	Continuous Process Improvement (the same as CIP)
154	**CPIC**	Construction Project Information Committee (also named CPI)
155	**CPIX**	Construction Project Information Xchange
156	**CPMS**	Capital Planning and Management System
157	**CPR**	Construction Progress Reporting
158	**CPS**	Cyber Physical Systems
159	**CPU**	Central Processing Unit

160	**CR**	Clash Rendition
161	**CRC**	Carbon Reduction Commitment
162	**CRL**	Crossrail Limited
163	**CRS**	Coordinate Reference System
164	**CRV**	Capitalised Replacement Value
165	**CSA**	Coordination and Support Actions
166	**CSCW**	Computer Supported Collaborative Working
167	**CSG**	Constructive Solid Geometry
168	**CSI**	Construction Specifications Institute
169	**CTE**	Código Técnico de Edificación (Spain)
170	**CURT**	Construction Users Roundtable
171	**D**	Deliverable
172	**D2RQ**	Database to RDF Query
173	**DB – D&B**	Design-Build
174	**DB**	Documento Básico (Spain)
175	**DBB**	Design-Bid-Build
176	**DBC**	Design Build Contract
177	**DBFM**	Design-Build-Finance-Maintain
178	**DBFO**	Design, Build, Finance, Operate
179	**DBIA**	Design Build Institute of America
180	**DBMS**	Data Base Management System
181	**DDBB**	Databases
182	**DBB**	Design Bid Build
183	**DCF**	Discounted Cash Flow
184	**DCLG**	Department for Communities and Local Government
185	**DDS**	Data Design System
186	**DFMA**	Design for Manufacturer and Assembly
187	**DfT**	Department for Transport
188	**DIUS**	Department for Innovation, Universities and Skills
189	**DL**	Description Logic
190	**DL**	Deadline
191	**DL**	Deep Learning
192	**DLT**	Distributed Ledger Technology

193	**DGNB**	Deutsche Gesellschaft für Nachhaltiges Bauen
194	**DHW**	Domestic Heat Water
195	**DMP**	Data Management Plan
196	**DMS**	Document Management System
197	**DNA**	Deoxyribonucleic acid
198	**DoA**	Description of Action
199	**DPB**	Discounted Pay-Back
200	**DPP**	Developed Constructor Proposal
201	**DRC**	Depreciated Reinstatement Cost
202	**DSM**	Design Structure Matrix
203	**DSS**	Data Security Standard
204	**DSS**	Decision Support System
205	**DT**	Digital Twin
206	**DTA**	Digital Twin Aggregate
207	**DTE**	Digital Twin Environment
208	**DTI**	Digital Twin Instance
209	**DTI**	Digital Twin Institute
210	**DTP**	Digital Twin Platform
211	**DTP**	Digital Twin Prototype
212	**DTT**	Digital Twin Technologies
213	**DTV**	Design Transfer View
214	**DU**	Dumb, Uncommunicative
215	**DXF**	Drawing eXchange Format
216	**DXF**	DaTA eXchange Format
217	**EAB**	External Advisory Board
219	**EAM**	Enterprise Asset Management
219	**EBS**	European BIM Summit
220	**EC**	European Commission/Committee
221	**ECAS**	European Commission Authentication Service
222	**ECD**	Entorno Común de Datos
223	**ECI**	European Construction Institute
224	**ECI**	Early Contractor Involvement
225	**ECI**	Environmental Cost Indicator

226	**ECM's**	Energy Conservation Measures
227	**EDCE**	Energy Demand Calculation Engine
228	**EDI**	Electronic Data Interchange
229	**EDM**	Electronic Distance Measurement
230	**EDMS**	Electronic Distance Measurement System
231	**Ee**	Elements Table (CPIC Uniclass 2)
232	**EE**	Energy Efficiency
233	**EEAB**	External Expert Advisory Board
234	**EEB**	European Environmental Bureau
235	**EED**	Energy Efficiency Directive
236	**EEO's**	Energy Efficiency Obligations
237	**EER**	Energy Efficiency Ratio
238	**EF**	Environmental Footprint
239	**EIF**	European Interoperability Framework
240	**EIR**	Employer's Information Requirements
241	**ELCD**	European Reference Life Cycle Database
242	**ELSC**	Enterprise Leadership Steering Committee
243	**EMS**	Energy Management System
244	**En**	Entities Table (CPIC Unicalss 2)
245	**EN**	EuroNorm
246	**EOL**	End of Life
247	**EOTA**	European Organisation for Technical Approvals
248	**EP**	European Parliament
249	**EPBD**	Energy Performance of Buildings Directive
250	**EPC**	Energy Performance Contract
251	**EPC**	Energy Performance Certificate
252	**EPPM**	Engineering, Project, and Production Management
253	**EQM**	European Quality Mark
254	**ER**	Exchange Requirements
255	**ERDC**	Engineering Research and Development Center
256	**ERP**	Enterprise Resource Planning
257	**ESCO**	Energy Service Company
258	**ESR**	Evaluation Summary Report

259	**ESEER**	European Seasonal Energy Efficiency Ratio
260	**ETC**	Engineering and Technology Board
261	**ETCP**	European Construction Technology Platform
262	**ETL**	Extract, Transform and Load
263	**ETPIS**	European Technology Platform on Industrial Safety
264	**ETSI**	European Telecommunication Standards Institute
265	**EUI**	Energy Use Intensity
266	**EUPPD**	European Union Public Procurement Directive
267	**EUQ**	Element Unit Quantity
268	**EUR**	Element Unit Rate
269	**EVA**	Earned Value Analysis
270	**EVO**	Efficiency Valuation Organization
271	**EWP**	Early Works Packages
272	**FAIR**	Findable, Accessible, Interoperable, Reusable
273	**FCI**	Facilities Condition Index
274	**FCI**	Function Condition Indexation
275	**FEE**	Fabric Energy Efficiency
276	**FET**	The field-effect transistor
277	**FFE**	Furniture, Fitting and Equipment
278	**FFL**	Finished Floor Level
279	**FFP**	Fitness for Purpose
280	**FIEC**	European Construction Industry Federation
281	**FIM**	Facilities Information Model
282	**FM**	Facility/ies Management
283	**FMA**	Facilities Management Association
284	**FMI**	Facilities Maintenance Indexation
285	**FMP**	Forward Maintenance Plans (or programme)
286	**FOAF**	Friend of a Friend
287	**FRI**	Function Re-investment Indexation
288	**FRS**	Factory Replication
289	**FRS**	Front Running Simulation
290	**FRS**	First Run Studies
291	**FTI**	Fast Track to Innovation

292	**FTP**	File Transfer Protocol
293	**GA**	Grant Agreement
294	**GBCE**	Green Building Council España
295	**GBXML**	Green Building Extensible Modelling Language
296	**GCCB**	Government Construction Client Group
297	**GCS**	Government Construction Strategy
298	**GDL**	Geometric Description Language
299	**GDPR**	General Data Protection Regulation
300	**GEA**	Gross External Area
301	**GHG**	Greenhouse Gas
302	**GC**	General Contractor
303	**GCS**	Government Construction Strategy
304	**GHG**	Green House Gases
305	**GIA**	Gross Internal Area
306	**GIFA**	Gross Internal Floor Area
307	**GIS**	Geographical Information System
308	**GML**	Geography Markup Language
309	**GMP**	Guaranteed Maximum Price
310	**GMSD**	Generative Modular Building System Design
311	**GNSS**	Global Navigation Satellite System
312	**GPS**	Global Positioning System
313	**GRIP**	Governance for Railway Investment Projects
314	**GSA**	Government Services Administration (US)
315	**GSA**	General Services Administration
316	**GSL**	Government Soft Landings
317	**GUID**	Globally Unique Identifier
318	**GWP**	Global Warming Potential
319	**H2020**	Horizon 2020
320	**H&S**	Health and safety
321	**HA**	Highways Agency
322	**HBI**	Human Building Interfaces
323	**HCI**	Human-Computer Interaction
324	**HCOME**	Human-Centered Ontology Engineering Methodology

325	**HCONE**	Human-Centered ONtology Engineering Environment
326	**HIL**	Hardware in the Loop
327	**HMG**	Her Majesty's Government
328	**HOAI**	Honorarordnung für Architekten und Ingenieure
329	**HSE**	Health and Safety Executive
330	**HTM**	Hypertext Markup
331	**HTM**	Human Thermal Model
332	**HTMD**	Human Thermal Model Description
333	**HTML**	Hypertext Markup Language
334	**HVAC**	Heating, Ventilation and Air Conditioning
335	**IA**	Innovation Actions
336	**IaaS**	Infrastructure as a Service
337	**IAC**	Industry Advisory Council
338	**IAI**	International Alliance for Interoperability
339	**IAM**	Institute of Asset Management
340	**IAQ**	Indoor Air Quality
341	**IBACOS**	Integrated Building and Construction Solutions
342	**IBC**	International Building Code
343	**IBC**	Institute for BIM in Canada
344	**IBD**	Intelligent Building Data
345	**iBIM**	Integrated BIM
346	**ICC**	International Code Council
347	**ICD**	Integrated Cycle Design
348	**ICD**	Intelligent Community Design
349	**ICD**	Interface Control Documents
350	**ICE**	Institution of Civil Engineers and Innovative Contractor Engagement
351	**iCIM**	iCIM is a community resource monitoring and management platform that improves sustainability performance (see IESVE)
352	**ICIS**	International Construction Information Society
353	**ICL**	Intelligent Communities Lyfecicle
354	**ICONDA**	International CONstruction Database
355	**ICT**	Information and Communication Technologies
356	**ID**	Identification

357	**IDABC**	Interoperable Delivery of European eGovernment Services to public Administrations, Business and Citizens
358	**IDAE**	Instituto para la Diversificación y Ahorro de la Energía (Spain)
359	**IDD**	Integrated Design & Delivery
360	**IDM**	Information Delivery Manual
361	**IDDS**	Integrated Design & Delivery Solutions
362	**IDP**	Integrated Design Process
363	**IDP**	Intelligent Design Planning
364	**IDS**	Integrated Design Solutions
365	**IE**	Information Exchange
366	**IEEE**	Institute of Electrical and Electronics Engineers
367	**IEQ**	Indoor Environmental Quality
368	**IES**	Integrated Environmental Solutions
369	**IESVE**	IES Virtual Environment (IESVE)
370	**iESD**	Intelligent Energy System Designer
371	**ILCD**	Integrated Life Cycle Design
372	**IFC**	Industry Foundation Classes
373	**IFC**	Information For Construction
374	**IFD**	International Framework for Dictionaries
375	**IFMA**	International Facilities Management Association
376	**IFoA**	Integrated Form of Agreement
377	**IG**	Irish Grid
378	**IGES**	International Graphics Exchange Standard
379	**IGLC**	International Group of Learn Construction
380	**IIOT**	Industrial Internet of Things
381	**ILCD**	International Reference Life Cycle Data System
382	**IM**	Information Modelling
383	**IMP**	Information Management Process
384	**IMU**	Inertial Measurement Unit
385	**INE**	Instituto Nacional de Estadística (Spain)
386	**IOT**	Internet of Things
387	**IP**	Intellectual Property
388	**IPC**	Integrated Project Coordinator
389	**IPCC**	Intergovernmental Panel on Climate Change

390	**IPD**	Integrated Project Delivery
391	**IPI**	Integrated Project Insurance
392	**iPIM**	iPIM is a building portfolio and asset management tool for the visualisation of key performance indicators and data.
393	**IPLV**	Integrated Part Load Value
394	**IPMVP**	International Performance Measurement and Verification Protocol
385	**IPP**	Initial Project Proposals
396	**IPP**	Inspection Point Program
397	**IPR**	Intellectual Property Rights
398	**IR**	Information Requirements
399	**IRMP**	Integrated Risk Management Plan
400	**IRR**	Internal Rate of Return
401	**IS**	International Standard
402	**iSCAN**	Intelligent Control and Analysis
403	**ISE**	The Institution of Structural Engineers
404	**ISES**	Intelligent Services For Energy-Efficient Design and Life Cycle Simulation
405	**ISG**	Implementation Support Group (Building Smart)
406	**ISO**	International Standards Organisation
407	**IT**	Information Technology
408	**ITeC**	Institut de Tecnologia de la Construcció de Catalunya
409	**ITIL**	Information Technology Infrastructure Library
410	**ITSM**	IT Service Management
411	**IUK**	Infrastructure UK
412	**IVN**	Intelligent Virtual Network
413	**IWMS**	Integrated Workplace Management System
414	**JCT**	Joint Contract Tribunal
415	**JIB**	Joint Industry Board
416	**JIT**	Just in Time
417	**JSON**	JavaScript Object Notation
418	**JV**	Joint Venture
419	**KER**	Key Exploitable Results
420	**KET**	Key Enabling Technologies
421	**KMS**	Knowledge Management System
422	**KoM**	Kick-off Meeting

423	**KPIs**	Key Performance Indicator
424	**KRS**	Knowledge Representation Systems
425	**LADAR**	Laser Detection and Ranging
426	**LAM**	Laser Aided Modelling
427	**LAN**	Local Area Network
428	**LAS**	Look-ahead Schedule
429	**LBC**	Lean BIM Construction
430	**LBD**	Linked Building Data
431	**LC**	Lean Construction
432	**LCA**	Life Cycle Assessment
433	**LCC**	Life Cycle Contract
434	**LCC**	Life Cycle Cost
435	**LCI**	Lean Construction Institute
436	**LCI**	Life Cycle Inventory
437	**LCIA**	Life Cycle Impact Assessment
438	**LCIE**	Life Cycle Information Exchange
439	**LCR**	Life Cycle Repairs /Replacement (Renewal)
440	**LCS**	Location Coding System (London Underground)
441	**LCT**	Life Cycle Tower
442	**LD**	Linked Data
443	**LE**	Large Enterprise
444	**LEAR**	Legal Entity Appointed Representative
445	**LEED**	Leadership in Energy and Environmental Design
446	**LIDAR**	Light Detection and ranging
447	**LIPS**	Lean in Public Sector
448	**LOD**	Level of model Detail or Level of Definition
449	**LOD**	Level of Development (in US)
450	**LOD**	Linked Open Data
451	**LOI**	Level of model Information
452	**LOIN**	Level of Information Need
453	**LPD**	Lean Project Delivery
454	**LPDS**	Lean Project Delivery System
455	**LPS**	Last Planner System

456	**LPT**	Lean Production Theory
457	**LRM**	Last Responsible Moment
458	**LRM**	Linear Referencing Method
459	**LRS**	Linear Referencing System
460	**LU**	London Underground
461	**LZC**	Low to Zero Carbon
462	**M2M**	Machine-to-Machine
463	**MC**	Main Contractor
464	**MCIA**	Material Cost Impact Analysis
465	**M&E**	Mechanical and Electrical
466	**M&O**	Maintenance and Operation
467	**MEP**	Mechanical, Electrical, Plumbing
468	**MET**	Metabolic Equivalent of Task
469	**MFA**	Material Flow Analysis
470	**MFA**	Material Footprint Assessment
471	**MIDI**	Master Information Delivery Index
472	**MIDP**	Master Information Delivery Plan
473	**ML**	Machine Learning
474	**MMHW**	Method of Measurement for Highway Works (Highway Agency)
475	**MOPU**	Ministerio de Obras Públicas y Urbanismo (Spain)
476	**MP**	Management Plan
477	**MPA**	Multi-Party Agreement
478	**MPDT**	Model Production and Delivery Table
479	**MQC**	Model Quality Control
480	**MR**	Mixed Reality
481	**MRT**	Mean Radiant Temperature
482	**MSD**	Manpower Sources Diagram
483	**MSG**	Model Support Group (Building Smart)
484	**MSM**	Mirrored Spaces Model
485	**MTOE**	Million Tons of Oil Equivalent
486	**MTTR**	Mean Time to Resolution
487	**MVD**	Model View Definition
488	**N3**	Notation 3

489	**N3Logic**	Notation 3 Logic
490	**NaaS**	Native as a Service
491	**NAO**	National Audit Office
492	**NBE**	Norma Básica de Edificación (Spain)
493	**NBIMS**	National BIM Standard (US)
494	**NBS**	National Building Specification
495	**NBS**	National Bureau of Standards
496	**NC**	Numerical Control
497	**NDA**	Non-Disclosure Agreement
498	**NDEA**	Non-Domestic Energy Assessment
499	**NEC**	New Engineering Contracts
500	**NEC3**	New Engineering Contract (3rd Iteration of the NEC contract)
501	**NEEDS**	New Energy Externalities Development for Sustainability
502	**NF**	National Framework
503	**NIA**	Net Internal Area
504	**NIBS**	National Institute of Building Sciences (US)
505	**NIEM**	National Information Exchange Model
506	**NIF's**	National Interoperability Frameworks
507	**NIST**	National Institute of Standards and Technology (US)
508	**NLP**	Natural Language Processing
509	**NMS**	National Master Specification
510	**NDA**	Non-Disclosure Agreement
511	**NPC**	Net Present Cost
512	**NPV**	Net Present Value
513	**NRM**	New Rules of Measurement
514	**NS**	Net Savings
515	**NSB**	National Standards Body
516	**NST**	Negotiated Select Team
517	**NURBS**	Non-Uniform Rational B-Spline Surfaces
518	**O&M**	Operations and Maintenance
519	**OA**	Open Access
520	**OASIS**	Organisation for the Advancement of Structured Information Standards
521	**OBDA**	Ontology-Based Data Access

522	**OBS**	Organisation Breakdown Structures
523	**OCCS**	OmniClass Construction Classification System
524	**OCE**	Order of Cost Estimates
525	**OCI**	Optimised Contractor Involvement
526	**OCIP**	Owner Controller Insurance Program
527	**ODA**	Olympic Delivery Authority
528	**OEF**	Organisational Environmental Footprint
529	**OGC**	Office of Government Commerce
530	**OGC**	Open Geospatial Consortium
531	**ÖGNI**	Österreichische Gesellschaft für Nachhaltige Immobilienwirtschaft
532	**OHLE**	See OLE
533	**OIR**	Organization Information Requirement
534	**OLE**	Overhead Line Electrification
535	**OMSI**	Operations and Maintenance Support
536	**OOP**	Objective Oriented Production
537	**OPA**	Organizational Process Assets
538	**OPex**	Operating Expenses
539	**OPex**	Operational Expenditures
540	**OPS**	Outline Procurement Strategy
541	**OR**	Operational Rating
542	**ORD**	Open Research Data
543	**OS**	Ordinance Survey
544	**OWA**	Open World Assumption
545	**OWL**	Ontology Web Language
546	**PaaS**	Platform as a Service
547	**PACE**	Property Advisers to the Civil Estate
548	**PAM**	Property Asset Management
549	**PARL**	Percentage Asset Remaining Life
550	**PAS**	Publically Available Specification
551	**PCI**	Pre-Construction Information
552	**PCI**	Payment Card Industry
553	**PC Price**	Prime Cost Price
554	**PC Sum**	Prime Cost Sum

555	**PD**	Predicted Desirable
556	**PDCA**	Plan – Do – Check – Adjust
557	**PDF**	Portable Document Format
558	**PDM**	Project Delivery Manager
559	**PDP**	Project Definition Plan
560	**PDSM**	Problem Driven Scope Management
561	**PDT**	Product Data Templates
562	**PEB**	Positive Energy Block/District
563	**PEB**	Proyectos de Ejecución BIM
564	**PEF**	Product Environmental Footprint
565	**PEP**	Project Execution Plan
566	**PESTLE**	Political, Economic, Social, Technological, Legal, and Environmental analysis
567	**PFI**	Private Finance Initiative
568	**PHP**	Hypertext Pre-processor
569	**PIB**	Planned Inspection of Buildings
570	**PII**	Professional Indemnity Insurance
571	**PIM**	Project Information Model
572	**PIN**	Prior Indicative Notice
573	**PIP**	Project Implementation Plan
574	**PIX**	Project Information Exchange
575	**PIR**	Project Information Requirement
576	**PIT**	Project Implementation Team
577	**PLC**	Product Life Cycle
578	**PLM**	Product Lifecycle Management
579	**PM**	Person Month
580	**PMB**	Protocolo de Modelos BIM
581	**PMO**	Project Management Office
582	**PMO**	Product Modelling Ontology
583	**PMT**	Project Management Team
584	**PMV**	Predicted Mean Vote
585	**PO**	Policy Officer
586	**PO**	Project Officer
587	**POC**	Proof of Concept

588	**POE**	Post Occupancy Evaluation
589	**POS**	Proof of Stake
590	**POW**	Proof of Work
591	**PP**	Phases Table (CPIC Uniclass 2)
592	**PPA**	Public Purchase Agreement
593	**PPC**	Project Partnering Contracts
594	**PPC**	Percent Plan Complete
595	**PPD**	Predicted Percentage of Dissatisfied
596	**PPM**	Planned Preventive Maintenance
597	**PQQ**	Pre-Qualification Questionnaire
598	**Pr**	Products Table (CPIC Unicalss 2)
599	**PSCD**	Public Sector Construction Database
600	**PSRL**	Product Semantics Representation Language
601	**PU**	Predicted Undesirable
602	**P&ID**	Piping and Instrumentation Diagram
603	**P&CM**	Project and Construction Management
604	**PV**	Present Value
605	**PV**	Photovoltaics
606	**QA**	Quality Assurance
607	**Q&A**	Questions and Answers
608	**QL**	Quality Level
609	**QoS**	Quality of Service
610	**QS**	Quantity Surveyor
611	**QTO**	Quantity Take Off
612	**R&D**	Research and Development
613	**RACI**	Responsible, Accountable, Consulted and Informed
614	**RAG**	Red, Amber, Green
615	**RAM**	Random Access Memory
616	**RCA**	Root Cause Analysis
617	**R2RML**	RDB to RDF Mapping Language
618	**RCM**	Reliability Centred Maintenance
619	**RDF**	Resource Description Framework
620	**RFDa**	Resource Description Framework in Attributes

621	**RDFS**	RDF Schema
622	**RDS**	Room Data Sheet
623	**RDS**	Room Data Schedule
624	**RFI**	Request for Information
625	**RFID**	Radio-Frequency IDentification
626	**RFP**	Request fro Proposal
627	**RGB**	Red, Green, Blue
628	**RIA**	Regulatory Impact Assessment
629	**RIA**	Research and Innovation Actions
630	**RIAS**	Royal Incorporation of Architects in Scotland
631	**RIBA**	Royal Institute of British Architects
632	**RICS**	Royal Institute of Chartered Surveyors
633	**RIF**	Rule Interchange Format
634	**RIT**	Room Integrity Testing
635	**RMIT**	Royal Melbourne Institute of Technology
636	**ROI**	Return of Investment
637	**RPI**	Retail Price Index
638	**RSL**	Reference Service Life
639	**RST**	Rhetorical Structure Theory
640	**RTL**	Register Transfer Level
641	**RTC**	Real Time Clock
642	**RTO**	Research Technology Organization
643	**RV**	Reference View
644	**R&D**	Research & Development
645	**R&M**	Renovation & Modernization
646	**SA**	Site Area
647	**SAL**	Security Aspect Letter
648	**SaaS**	Software as a Service
649	**SAP**	Standard Assessment Procedure
650	**SAP**	Systems, Applications, Products in Data Processing
651	**SBC**	Standard Building Tribunal
652	**SBD**	Set-Based Design
653	**SBEM**	Simplified Building Energy Method

654	**SBS**	Small Business Service
655	**SCADA**	Supervisory Control And Data Acquisition
656	**SCCS**	Supply Chain Capability Summary
657	**SCPS**	Smart, Connected Product Systems
658	**SLCA**	Social Life Cycle Assessment
659	**SDD**	System Design Description
660	**SDNF**	Steel Detailing Neutral Format
661	**SDO**	Standards Developing Organization
662	**SDS**	Space Data Sheet
663	**SDS**	Space Data Schedule
664	**SECAP**	Sustainable Energy and Climate Action Plan
665	**SETAC**	Society of Environmental Toxicology and Chemistry
666	**SGNI**	Schweizer Gesellschaft für Nachhaltige Immobilienwirtschaft
667	**SIA**	Security Industry Authority
668	**SIL**	Safety Integrity Level
669	**SIL**	Software in the Loop
670	**SIM**	Structural Information Model
671	**SIR**	Savings to Investment Ratio
672	**SKOS**	Simple Knowledge Organization System
673	**SLA**	Service Level Agreement
674	**SME**	Small and Medium Enterprises
675	**SMP**	Standard Method and Procedure
676	**SMT**	Site Management Team
677	**SOA**	Service Oriented Architectures
678	**SOAP**	Simple Object Access Protocol
679	**Sp**	Spaces Table (CPIC Uniclass 2)
680	**SPARQL**	Simple Protocol and RDF Query Language
681	**SPie**	Specifiers’ Properties information exchange
682	**SPE**	Single Purpose Entity
683	**SPF**	STEP Physical File
684	**SPFF**	STEP Physical File Format (IFC)
685	**SQL**	Structured Query Language
686	**Ss**	Systems Table (CPIC Uniclass 2)

687	**SSL**	Structural Slab Level
688	**SSL**	Secure Sockets Layer
689	**SSN**	Semantic Sensor Network
690	**STEP**	STandard for Exchange of Product Model Data
691	**STL**	Standard Tessellation Language
692	**STOs**	Specific Technical Objectives
693	**SWOP**	Semantic Web-based Open engineering Platform
694	**SWRL**	Semantic Web Rule Language
695	**TA**	Technical Adviser
696	**TAI**	Teaching as Inquiring
697	**TBD**	To Be Defined
698	**TBM**	Tunnel Boring Machine
699	**TBM**	Temporary Benchmark
700	**TCQ**	Temps, Cost, Qualitat
701	**TER**	Target Emission Rate
702	**TIDP**	Task Information Delivery Plan
703	**TILT**	Transfer Implementation Leadership Team
704	**TL**	Tube Lines
705	**TLS**	Terrestrial Laser Scanner
706	**TOC**	Table of Contents
707	**TOID**	Topographic Identifier
708	**TPI**	Tender Price Index
709	**TPS**	Toyota Production System
710	**TRL**	Technological Readiness Level
711	**TVD**	Target Value Delivery
712	**TVD**	Target Value Design
713	**TVP**	Target Value Production
714	**UC**	Use Case
715	**UCD**	User Centred Design
716	**UCL**	University College London
717	**UD**	Unpredicted Desirable
718	**UK**	United Kingdom
719	**Umbel**	Upper Mapping and Binding Exchange Layer

720	**UML**	Unified Model/ling Language
721	**UNDP**	United Nations Development Programme
722	**UNEP**	United Nations Environment Programme
723	**Uniclass**	Unified Classification System
724	**UPRN**	Unique Property Reference Number
725	**URI**	Unique Resource Identifier
726	**URI**	Uniform Resource Identifiers
727	**US**	United States (of America)
728	**USACE**	United States Army Corps of Engineers
729	**USGBC**	United States Green Building Council
730	**UX**	User Experience
731	**UXB**	Unexploded Bomb
732	**UU**	Unpredicted Undesirable
733	**VCMP**	Virtual Construction Management Platform
734	**V2B**	Vehicle to Building
735	**V2G**	Vehicle to Grid
736	**VC**	Virtual Call
737	**VC**	Virtual Construction
738	**VDC**	Virtual Design and Construction
739	**VDR**	Virtual Data Room
740	**VE**	Virtual Environmental
741	**VERDE**	Valoración de Eficiencia de Referencia de Edificios
742	**VFM**	Value for Money
743	**VPN**	Virtual Private Network
744	**VR**	Virtual Reality
745	**VRML**	Virtual Reality Modelling Language
746	**VSM**	Value Stream Mapping
747	**W3C**	World Wide Web Consortium
748	**WAN**	Wide Area Network
749	**WBDG**	Whole Building Design Guide
750	**WBI**	Well Building Institute
751	**WBS**	Work Breakdown Structure
752	**WGBC**	World Green Building Council

753	**WIP**	Work-in-Process
754	**WLC**	Whole Life Costing
755	**WP**	Work Package
756	**WR**	Work Results Table (CPIC Uniclass 2)
757	**WRAP**	Waste & Resources Action Programme
758	**WS**	Work Results for Specifications (CPIC Uniclass 2)
759	**WTO**	World Trade Organization
760	**WWP**	Weekly Work Plan
761	**WWW**	World Wide Web
762	**XML**	eXtensible Markup Language
763	**X-REF**	Cross Reference
764	**XSD**	XML Schema Definition
765	**XSLT**	eXtensible Stylesheet Language Transformations
766	**XSP**	Cross Section Positions
767	**Zz**	CAD Table (CPIC Uniclass 2)

13 Appendix A – IPD Contractual Setups

Designing and constructing under IPD principles, means forgetting about traditional processes considerations. The agreement should be developed and aligned with the integrated project itself.

Adoption of Lean and BIM as standards of practice. Main Intention: To attain high quality delivery of a project eliminating redundancy, errors and waste.

The agreement should reinforce IPD principles:

- **Mutual respect and trust**
- **Mutual benefit and reward**
- **Collaborative innovation and decision making**
- **Early involvement of key participants**
- **Early goal definition**
- **Intensified planning**
- **Open communication**
- **Appropriate technology**
- **Organization and leadership**

Tri-Party vs Multi-Party IPD contracts - Tri-Party Agreement - A contract where the owner, primary designer and primary builder execute a single contract for delivery of a project. Other partners for design and construction may be bound to the same terms as the primary signatories yet they do not sign the base agreement. Multi-Party Agreement (or Poly-Party Agreement) - A contract where the owner, primary designer, primary building and other key parties execute a single contract for the delivery of a project. Each member is a primary signatory with at least 4 signatories and as many as the team chooses to include in the contract.

Negotiation Aligns the Team - Negotiating the IPD agreement is hard, but valuable work. Helps to align the team to the project goals. It gives each participant the opportunity to learn who their potential partners are while the stakes are still low. Includes key workshops to develop the business and contract model. Refine the model with the team, and jointly negotiate the final terms.A conscious and well-done alignment can greatly diminish the actual time spent negotiating the legal contract terms. The contract doesn't lead this process, it follows and documents it.

Contract Steps - Start with three parties contracting together to eliminate the Owner in the middle. A team of Owner, Builder and Designer lead the project with a bias toward consensus decision making. The program should be complete, and a target price set agreeable to all. All three parties agree to openly share information. Collaborate cooperatively for the project, as well as for mutual benefit. As trade contractors and design consultants are added, they should acknowledge this arrangement.

Considerations - Engage the builder during early design so that pricing, constructability and value engineering are integrated from the very beginning. Make cost and schedule design criteria. Set appropriate contingencies, share one between Builder and Designer. Put profit for both, Builder and Designer at risk for failure to perform as a team with corresponding reward shared by both if they perform above the standard of care. Engaging trade contractors early for the purpose of collaborating with their complimentary engineering discipline and driving innovation. Major trade contractors should be selected during schematic design to facilitate an integrated collaborative design process, as well as counting with their skills and knowledge on design decisions.

Contracts and Negotiation - For the development of the renovation solutions for building residential projects, all of the form contracts should be studied and discussed so as to find the appropriate format to be applied to each one of the cases that we will consider.

DESIGNING RULES - Main conditions to design. First of all, design the process, then design the project. Current set-based design that take forward multiple design alternatives to the last responsible moment. Incorporating value as the key design proposition. Contracts supports Lean Design.Build virtually before building physically: Eliminate redundant efforts and conflicts. Optimizing means and methods. Maximizing off site construction. Zero RFI goal.

CONTRACT TEMPLATE DOCUMENTS TO BE CONSIDERED:

AIA A195 (2008) Standard Form of Agreement between Owner and Contractor for Integrated Project Delivery.

AIA A295 (2008) General Conditions of the Contract for Integrated Project Delivery.

AIA B195C (2008) Standard Form of Agreement between Owner and Architect for Integrated Project Delivery.

This family are transitional IPD arrangements. Being a collaborative approach, they are not completely integrated.

ConsensusDOCS 300 (2007) Standard Multi-Party IPD Agreement.

This is the first standard IPD agreement published in the United States. The Owner, Designer and Constructor all sign the same agreement, that incorporates Lean principles and is also known as a relational contract. A core team at both the project management and project development levels is created to make consensus-based project decisions to increase project efficiency and results.

Being a multi-party agreement, it fails while considering the Owner keeps the right to make all decisions. Target cost is set late unbalancing risk/reward. Has traditional approaches to contingency.

AIA C195 (2008) Standard Form Single Purpose Entity Agreement for Integrated Project Delivery.

AIA C195 (2009) Standard Form Multi-Party Agreement for Integrated Project Delivery.

This one is completely integrated, but while creates a project based limited liability company, drives to corporate management and should be used for projects that support additional administrative overhead.

HANSON BRIDGETT (2009) IPD contract

Developed from a custom multi-party agreement based on the IPD Guide principles. Drafted with little philosophical discussion so as to make it easy to see the nature and structure of the parties agreement. The contract has been drafted using clean business English to increase precision and readability, which leads to a deeper understanding of the parties' agreement and once clearly understood, enables intelligent adjustment of the contract structure to meet the project's particular requirements and goals. The document avoids requiring specific management techniques. Besides the model itself, they recommend a process to negotiate properly to solve problems in advance.

AIA CD396 (2016) Tri-Party Agreement for Integrated Project Delivery (IPD)

Considered a Joining Agreement, it is intended for use with the *ConsensusDocs 300 IPD Agreement*. It provides a clear articulation of how to contract for lean integrated project delivery by addressing the construction process, commercial terms, and organizational structure. It is expected to become THE standard IPD agreement going forward to both experienced and relatively new IPD practitioners alike.

AIA CD305 (2018) New ConsensusDocs Lean Addendum

Lean Constructing Tools without an IPD Contract. Opens a new range of possibilities to apply Lean Practices where traditional minds don't admit the irruption of IPD in a direct way. CD305 is not a complete contract by itself, it is a document you add to a project contract to provide for selected Lean project features.

AIA CD541 (2018) New Design-Assist Addendum

Addendum to Agreements Between Owner and Construction Manager and Between Owner and Design Professional for Design-Assist Services. Creates a contractual structure to better coordinate design professionals, construction managers, and subcontractors in developing and constructing design documents. It coordinates with the recently released *ConsensusDocs 305 Lean Construction Addendum* by allowing users to opt into several Lean construction tools and processes. The Lean and design-assist Addendums work well together or independently.

Intention / Relational contract

The agreement goal should be to attain high quality delivery of a project through elimination of redundancy, errors and waste. The goal is realized by aligning owner, builder and designer interests with a mutually agreed definition of project success.

14 Appendix B – Scans per Country on Sector, Regulations, Barriers and Solutions

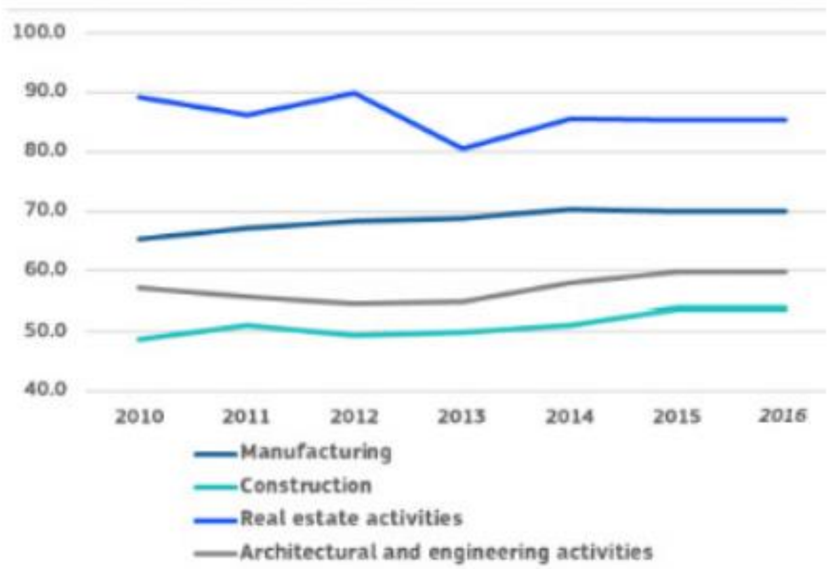
14.1 IDDS Scan - Situation in Belgium

Local Context - Productivity in Belgium and current state

Labour productivity in the broad construction sector in Belgium experienced a slight 4.3% increase over 2010-2014. Namely, productivity in the manufacturing sub-sector experienced a 7.3% increase between 2010 and 2016. Productivity in the construction sub-sector increased by 10.2% and architectural and engineering activities sub-sector by 4.6% over the same period.

Conversely, productivity in real estate activities experienced a slight decline of 4.4%, possibly due to the rapid increase in low-productivity household help services since 2004, as a consequence of the government's attempt to minimise informal economic activity and raise low-skilled employment through the system of subsidised vouchers for household help.

Labour productivity in the construction sector in Belgium over 2010-2016 (EUR k)

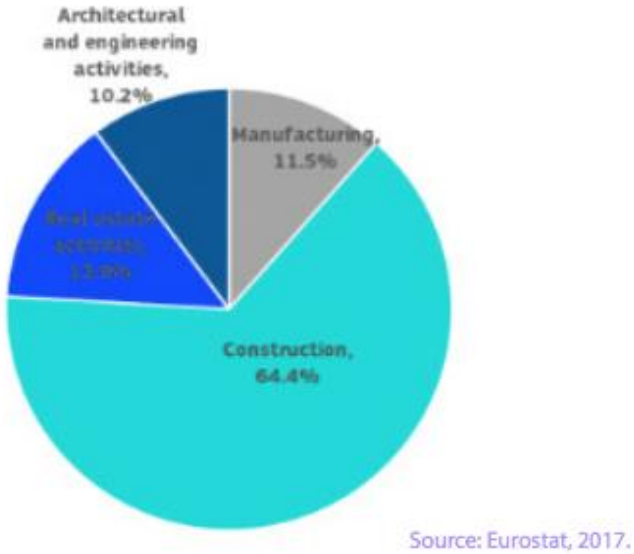


Source: Eurostat, 2017.

Construction is one of the sectors that presents the most bottleneck vacancies, particularly for professions such as engineers, technicians, designers, electricians. Employers often consider the lack of soft skills, in particular motivation and work attitude, as one of the reasons for the bottleneck vacancies. An average of 70% of companies find difficulties in filling up job positions related to construction. Moreover, the lack of skills had detrimental effects on the productivity of 2.2% of construction companies in 2012.

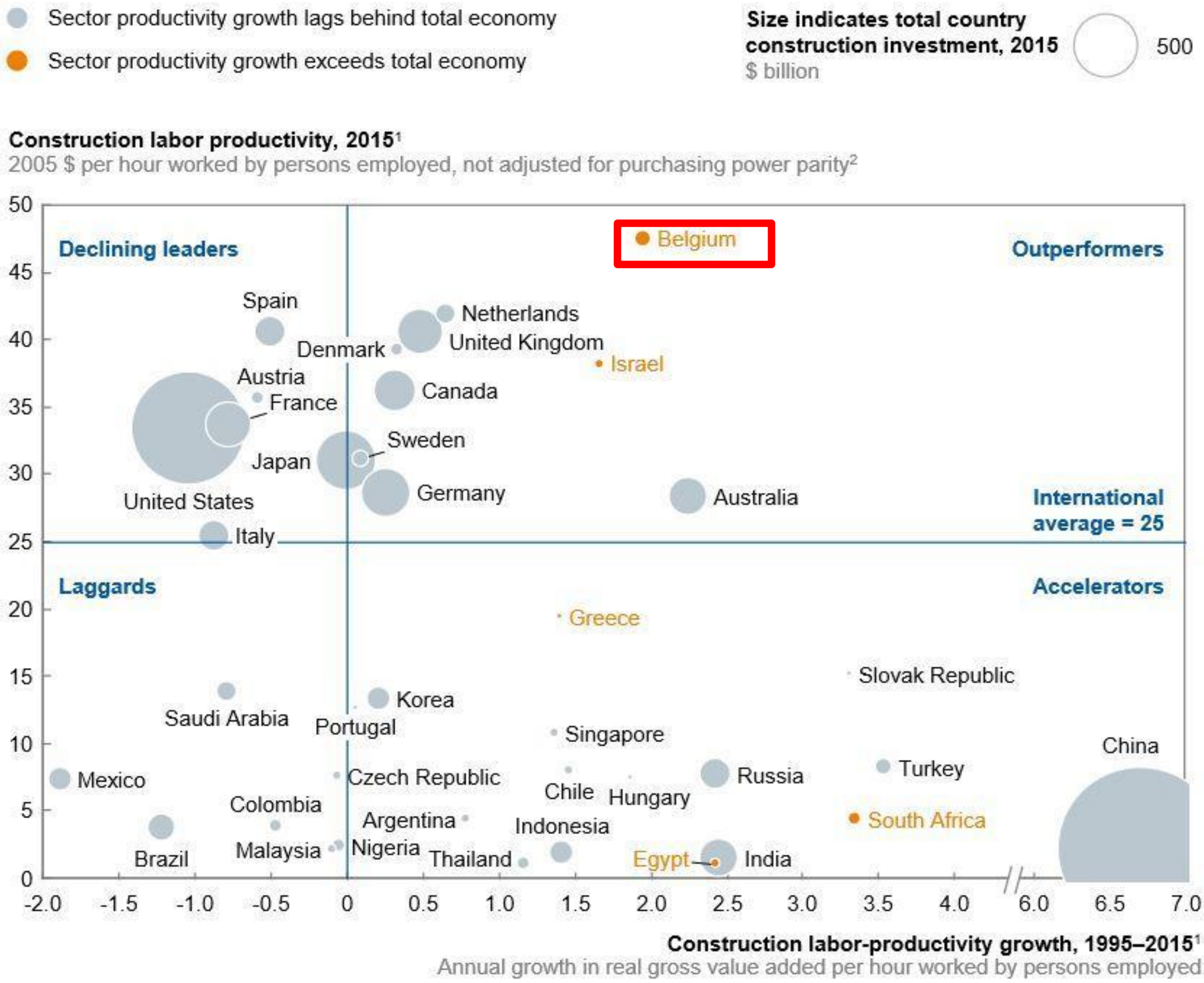
All sub-sectors experienced an increment in the numbers of workers employed with most pronounced the real estate activities sub-sector.

People employed by construction sub-sectors in Belgium in 2016 (%)



Production in construction of buildings dropped by 1.8% between 2010 and 2016, the largest decline among all sub-sectors, while the construction sub-sector decreased only by 0.8% over the same period of time. Conversely, production in civil engineering experienced a 10% growth until 2012 and it has been decreasing ever since, however it overall rose up by 2.7% between 2010 and 2016.

A small number of countries have achieved healthy productivity levels and growth rates



1 Countries with a shorter time series due to data availability: Argentina, Australia, Brazil, Chile, Ethiopia, Japan, Mexico, Nigeria, South Africa (1995–2011); Belgium (1999–2014); China, Colombia (1995–2010); Czech Republic, France, Israel, Malaysia, Russia (1995–2014); Egypt (1995–2012); Indonesia (2000–14); Saudi Arabia (1999–2015); Singapore (2001–14); Thailand (2001–15); and Turkey (2005–15).
2 Published PPPs are either not applicable (i.e., are not for the construction sector specifically or not for a value-added metric) or vary too widely in their conclusions to lend any additional confidence to the analysis.

SOURCE: OECD Stat; EU KLEMS; Asia KLEMS; World KLEMS; CDSI, Saudi Arabia; Ministry of Labor, Saudi Arabia; WIOD; GGDC-10; Oanda; IHS; ITF; GWI; McKinsey Global Institute analysis

Lean Construction. Situation in Belgium

Since clients are increasingly demanding high-quality and reliable products at low cost, and the construction industry faces an increased competitiveness caused by globalisation and deregulation, established firms need to revise their strategy. These firms need to do so by building on their competitive strengths through a deliberate and managed process to improve the capacity and effectiveness of the industry and to support sustained national economic and social objectives (Stewart and Spencer, 2006). Their study suggests that this development, in part, can be achieved by learning how to increase efficiency and productivity through process improvement.

Both BBRI (Belgian Building Research Institute) and the Construction Confederation have LEAN high on the agenda. Both institutes organise frequent courses and workshops. The adoption of LEAN Construction is growing, but typically it's only being adopted within a subset of the project team and there's a lack of an integrated vision throughout the entire project organisation.

Business as usual practices

Next to the adoption of LEAN Construction, public owners typically require the contractor to apply Systems Engineering (SE) to assure quality (mainly in Flanders and similar like in The Netherlands).

Systems engineering is an interdisciplinary field of engineering and engineering management that focuses on how to design and manage complex systems over their life cycles. At its core, systems engineering utilizes systems thinking principles to organize this body of knowledge. The individual outcome of such efforts, an engineered system, can be defined as a combination of components that work in synergy to collectively perform a useful function.

Issues such as requirements engineering, reliability, logistics, coordination of different teams, testing and evaluation, maintainability and many other disciplines necessary for successful system development, design, implementation, and ultimate decommission become more difficult when dealing with large or complex projects. Systems engineering deals with work-processes, optimization methods, and risk management tools in such projects. It overlaps technical and human-centered disciplines such as industrial engineering, mechanical engineering, manufacturing engineering, control engineering, software engineering, electrical engineering, cybernetics, organizational studies, civil engineering and project management. Systems engineering ensures that all likely aspects of a project or system are considered, and integrated into a whole.

Basic principles of SE can be found as well in the PAS 1192 which is in the process of becoming an ISO standard for BIM.

Applicable laws

In Belgium, there are two insurance categories.

Insurance related to constructing activities. Such as civil liability insurance of contractors, professional insurance of architects, experts, engineers.

Insurance related to the protection of certain goods. Such as all risks insurance for the construction site and insurance against decennial liability of contractors and architects following the final acceptance of the works

In addition to the Civil Code and the Breyne law(*) also constitutes important legislation with regard to the execution of construction works in the public sector. As for infrastructure and utilities, these are mainly regulated by the public planning law of the Flemish, Walloon and Brussels Capital Regions(**).

(*)The Breyne law: the Law of 15 June 2006 regarding construction of residential buildings and the sale of houses that have yet to be built or are in the process of being built.

(**)The public planning law:

Flemish Region: the Flemish Public Planning Code of 15 May 2009, Walloon Region: the Public Planning and Patrimonium Code of 27 November 1997

Brussels Capital Region: the Brussels Code regarding Public Planning of 9 April 2004

In addition to the regional regulations, national laws and building ordinances, there are several widespread but non-compulsory standards used in construction contracts. These include the NBN standards, issued by the Belgian Normalisation Institute (NBN), and the Technical Prescriptions (Prescriptions Techniques – PTVs), normative documents drafted by a qualified technical institute, which confer the BENOR quality mark to construction products or processes.

Barriers in the construction sector

Company failure

Between 2010 and 2014, the business demography in the broad construction sector witnessed a decrease in the number of company births and an increase in company deaths across all sub-sectors.

Construction sub-sector: the number of births slightly increased by 3.0%. The number of company deaths increased by 44.2%.

Real Estate sub-sector: The number of births went down the most in the Real estate sub-sector over 2010-2015. The number of company deaths increased by 106.3%, reaching a total of 3,919 companies.

Architectural and engineering sub-sector: The number of births went down the most in the real estate sub-sector over 2010-2015 (-5.1%), followed by a 4.7% decline in the architectural and engineering sub-sector. The number of company deaths increased by 45.6%.

The business failures are expected to decrease further, however, despite previous decreases, insolvencies in the construction sector will still remain high

Trade credit

Belgian firms are hesitant to grant trade credit in business-to-business (B2B) transactions. This may reflect the perceived risks linked to the persisting higher insolvency rates of Belgian companies.

Domestic sales: the total value of domestic B2B sales was conducted on credit terms.

Foreign sales: 31.0% of sales on credit were transacted to foreign B2B.

The domestic and foreign B2B is the same homogenous perception of the risk of payment.

Respondents in Belgium are less prone to sell credit terms to B2B customers. Despite the decreasing value of credit-based sales, the construction sector is one of the industries where transactions based on trade credit are most common.

Late payment

According to the European Payment Report 2017, Belgium payment practices are considered below average compared to other European countries, in terms of payment stability and risks.

Payment practices change depending on the sector.

Financial services and the service sector: present the shortest payment delays.

The construction sector: records the highest number of 'bad payers'. In 2014, 61% of construction companies wrote off debt, as they were not able to collect it. Late payments in the construction industry are frequently linked to insolvencies of the customer.

The Late Payment Directive was transposed through the Act of 22 November 2013. It stipulates that payment terms be set at 30 days, if the contract does not specify otherwise. For B2B transactions, the two parties may agree on payment terms up to 60 days or longer, provided that the agreement is not unfair to the creditor.

Time and cost obtaining building permits and licenses

Belgium ranked 39th in 2018 with respect to "Dealing with construction permits", according to the World Bank Doing Business 2018, slightly better than the previous year (44th in 2017).

The number of procedures required to build a warehouse is 10, which is above the OECD high-income average of 12.5.

The time needed to complete them stands at 212 days, considerably longer than the OECD high-income average of 152.3.

The cost of building a warehouse represents 0.9% of the value of the warehouse, below the OECD high-income average of 1.5%.

Skills shortage

Belgium experiences labour shortage of about 20,000 construction workers every year, which will result in a delay for long-term residential construction.

The number of job vacancies in the construction sub-sector has decreased but increased in the real-estate sub-sector, indicating greater difficulties in finding the appropriate skills on the market.

In addition to current challenges in recruiting qualified personnel, finding skills for the construction industry will become even harder as the economy is rebounding. The biggest scarcity is in recruiting trained technical personnel with a highly technical degree, engineers, project managers, and mathematicians.

Sector and sub-sector specific issues

Material efficiency and waste management:

Waste policy differs in the three Belgian regions,

Flanders: Flanders has been developing C&D waste management practices for 25 years and introduced a holistic approach in their legislation change in 2011.

Brussels Capital Region: Sectorial implementation plans were introduced for C&D waste management. In Brussels, C&D waste management is a priority of Brussels Environment, the environment and energy administration of the Brussels-Capital Region, given that this type of waste constitutes a third of non-household waste in the region. Public authorities and private companies are in close cooperation to manage the waste.

Since 2012 Bruxelles-Propreté established dedicated Recyparks to manage waste in the Brussels region

Wallonia: in Wallonia the legal framework implemented the Waste Framework Directive, but is however subject to frequent changes

Climate and energy:

Emissions of greenhouse gases from construction and real estate activities in Belgium amounted to a total of 2,563,500 and 180,405 tonnes in 2014.

Emissions decreased for both the construction and the real estate sub-sector during the period 2010-2014.

Private sector vs Procurement-based practices

The main parties involved in local development projects are the:

Owner. Controls the development and appoints the development team.

Developer. The owner can choose to appoint a developer who will ensure the performance of the construction programme for a fixed price and thus takes up most of the responsibilities.

Architect(s) and consulting engineers. In charge of the conception of the project and of monitoring the construction phase. Appointed by the owner/developer.

Health and safety coordinator. Monitors and manages health and safety risks during the entire project. Appointed by the owner/developer.

Contractor(s). In charge of the construction of the project.

Subcontractors. A contractor can choose to hire subcontractors with separate contracts.

Parties are largely free to determine the contractual framework of the development, as long as they comply with the principles of the Belgian Civil Code. However, there are two types of contracts which limit the contractual freedom:

Public contracts. Specific procurement rules and procedures apply in the public sector, set out in the Public Procurement Act of 17 June 2016 based on the EU procurement law.

Housing promotion contracts. The “Breyne Act” applies.

Whether one or all of the main parties are international contractors or consultants, the above mandatory rules apply. For international projects, the contracts issued by FIDIC (Fédération Internationale des Ingénieurs Conseils) are usually referred to in Belgium.

What should be changed in the construction industry?

Digitalisation of construction processes to improve productivity and profitability. Since 2011, construction budgets have been cut tremendously. In order to accommodate these budgets, boosting productivity should be a top priority in the coming years.

Education for both students and industry professionals in the relevant software should be stimulated and maintained. This is crucial to sustain innovation and digitalisation.

The industry should work towards a more collaborative approach. Far too often, the different parties are working independently, resulting in inefficiency or errors. We should work towards a first-time-right mentality by collaborating from the start.

The industry should work towards a standard for BIM. Currently the application of BIM is daunting for most professionals. There are simply too many options and ways of working with BIM that most don’t know where to start. A standard would help to alleviate this barrier.

Innovation needs to be rewarded adequately. The incentive for innovation is often lacking since there’s no economic motivation. The government has recently set up a sustainability/ innovation fund for procurement practices which is a step in the right direction.

14.2 IDDS Scan - Situation in Germany

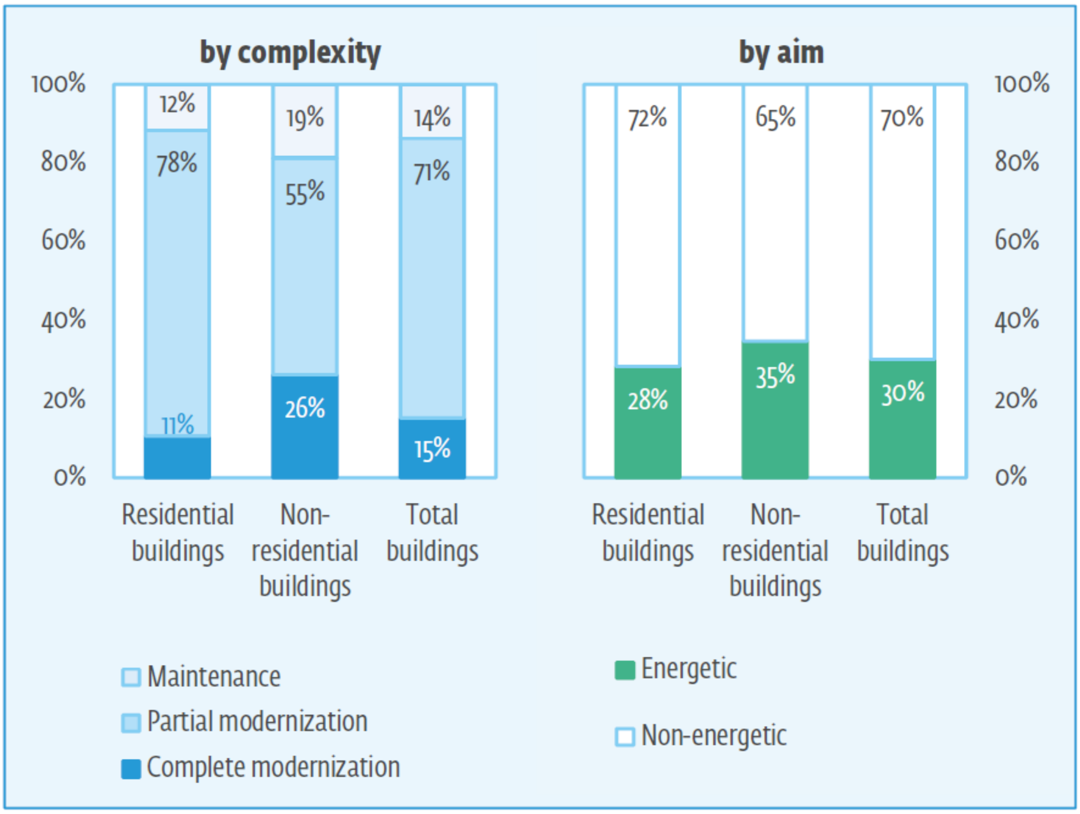
Local Context: Productivity in Germany and current state

In economic terms, Germany is still experiencing a strong upswing, even though the [illegible] some momentum (GDP 2017: +2.2%, GDP 2018: +1.6%, GDP 2019: +1.7%). The current situation is marked by high capacity utilisation, a sharp increase in the number of employees, government fiscal surpluses as well as a remarkably high propensity to invest among companies and the public sector. Nevertheless, economic growth is expected to expand somewhat more slowly in the medium term. Thus, private consumption, which has been largely responsible for the high pace of growth since 2015, will noticeably lose momentum, despite various impulses from the government. In addition, capital investment is likely to be weaker up to 2021. On the one hand, corporate investment is likely to return to normal, and on the other, the upturn in new residential construction is nearing its end. Also government consumption, apart from the swings in 2018 and 2019, which are related to the protracted formation of a government and the subsequent distribution of financial surpluses, will grow at a somewhat weaker pace as has recently been the case. And the positive impulses of foreign trade should continue to play a subordinate role, due to extensive imports.

After two years of strong growth of around 2½% each year, construction activity will reach its peak in 2018 (+ 0.8%). For 2019 only a lateral movement (+0.1%) is assumed, which will then pass over to a decline (2020: -0.6%; 2021: -0.9%). Thus, new residential construction will only expand until 2019; the current expansive cycle has already been in motion since 2010. In non-residential construction as well as in civil engineering, important developments are also coming to an end: companies and public authorities have been investing heavily in new buildings since 2016; in this context, a significant slowdown in construction activity is to be expected in the medium term. In addition, the federal government has continuously increased its spending on transport infrastructure in recent years. According to budget planning, this investment ramp-up has been partially completed in 2018. In addition, however, two negative factors are gaining in importance across all construction sectors: sluggish land-use designation and rising construction prices due to high capacity utilisation. In principle, the projected, only slight decline in construction activity should not be interpreted too negatively: the volume of construction increased significantly between 2005 and 2018, namely a total of one fifth.

In residential construction, the impetus is currently coming from the new construction segment. The numerous stimulus factors include, among others, the very low interest rate level, the pronounced investment crisis, rising real income levels and the surge in demand for residential accommodation in several regions as a result of immigration and internal migration. The extremely high level of refugee inflows has resulted in, among other things, significantly expanded residential construction activities by the municipalities. However, with familiar problems (building land shortage, high construction costs) getting worse, the permission figures for multi-family house projects will drop again in the medium term. After a temporary uptick in demand due to new energy regulations, the market for new 1+2 family buildings also looks unlikely to see any upswing in the near future. Demographic ageing will increasingly impact this sub-segment in the long term. Planning and permission are one aspect of activities in this segment, while the implementation of construction projects constitutes another. The realisation of multi-family building projects in particular is only expected to be sluggish (for example, due to bureaucracy, bottlenecks in the construction industry as a whole or citizens' protest).

Measures on Existing Buildings in Germany
Structure in the year 2017, in percentage



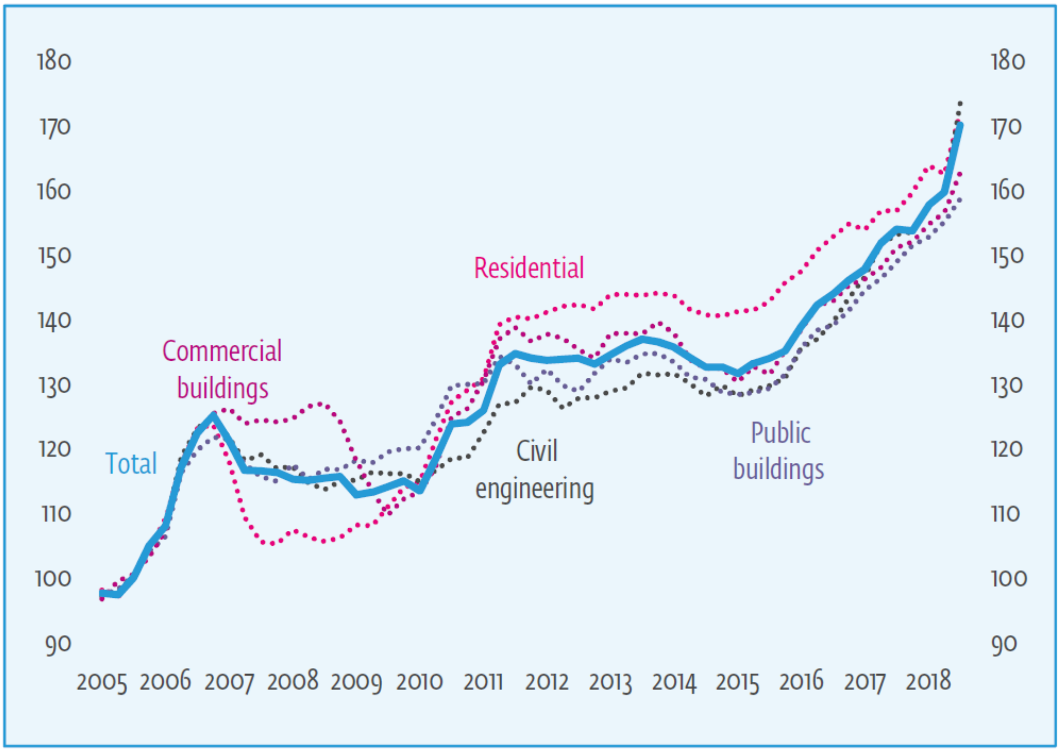
Source: Federal Statistical Office, Heinze GmbH, model calculation by German Institute for Economic Research (DIW).

Measures on Existing Buildings in Germany.

The new federal government has indeed initiated some measures, including a child-linked building allowance, a special depreciation for rental housing and more federal funding for social housing. Overall, however, there are hardly any additional impulses to be expected, above all due to the currently high capacity utilisation and the problems with the mobilisation of building land.

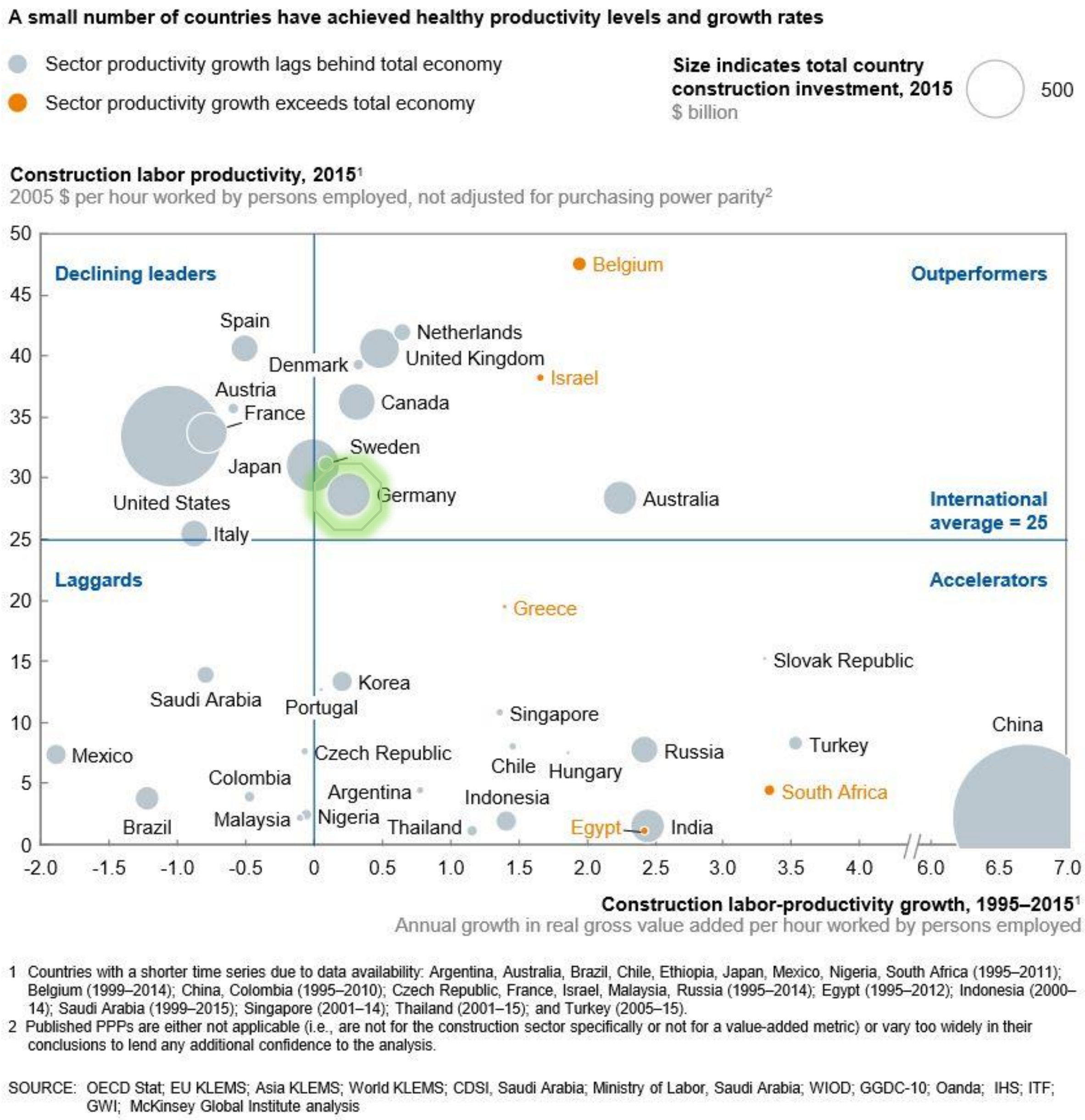
Renovation measures have already been at an extremely high level for a decade. This has led to a significant reduction in the need for refurbishment and to a declining trend in this sub-segment in the medium term. Nevertheless, the unfavourable age structure of the very extensive residential building stock, good economic conditions and the keenness of many owners to invest are indicative of continued buoyant renovation activity. While the demand for property modernisation generating age-appropriate and/or accessible dwellings continues to grow, the demand for energy-saving renovation services is likely to show little growth potential, not least due to the still comparatively low energy prices. In addition, there are a number of constraints (such as often little additional potential for energy savings, unclear usage horizons, buildings with complex ownership structures, complex state funding combined with ambitious targets) pointing to a cooling down in the renovation market. The increasing influence of policy makers on rental prices and the high average age of the labour force in the manual trades should also have a dampening effect on the demand for renovation measures in the medium term.

Current Business Situation of German Main Construction Trades Balances of positive and negative responses, index 2005 = 100; results seasonally adjusted and summarized to quarters



When interpreting the results consider that there are structural and production capacity changes over time.
Source: ifo Business Survey

Current Business Situation of Germany Main Construction Trades



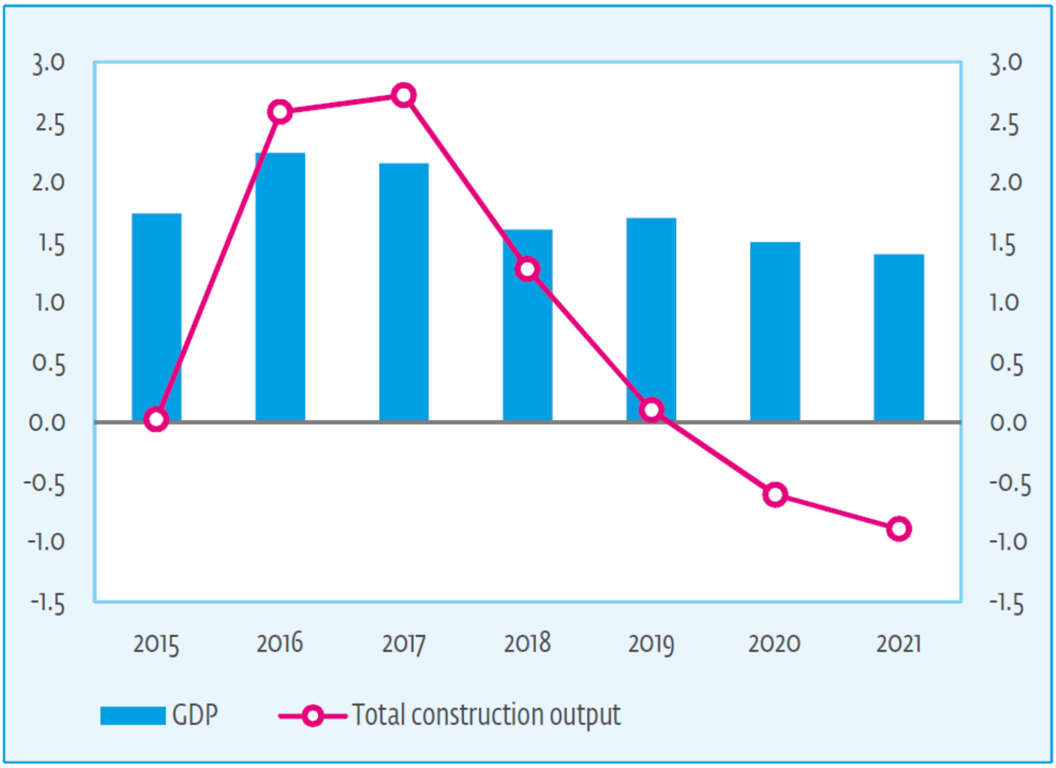
Construction Labour Productivity Growth

Macro-economic Outlook

The upturn in Germany is currently in its fifth year. One of its central pillars is the domestic economy, which is being stimulated by strong growth in employment and low interest rates. At the beginning of this year, capacity utilisation levels were still very high, but they have not increased further for both demand-side and production-side reasons. On the one hand, the number of incoming orders has been in decline since the beginning of the year 2018, partly because the economy in the largest German sales markets slowed down during the first six months of the year. On the other hand, companies are apparently facing growing supply-side bottlenecks, especially in terms of labour and intermediate goods. This is reflected in the production slowdown this year, despite full order books. A special restraint for 2018 refers to problems in the automotive industry related to the introduction of the new

World Harmonised Light Vehicle Test Procedure (WLTP), which has clearly impacted GDP growth due to the branch's economic weight.

GDP and Total Construction Output from 2015 to 2021
year to year change in %



Source: EUROCONSTRUCT (86th Conference)

Fiscal policy will stimulate the economy at the beginning of 2019. Transfers and expenditure programmes will be expanded and the tax burden on employees will be lightened. Sustained favourable monetary conditions will also continue to bolster the economy. Stimuli from foreign trade, however, will be weaker as the world economy gradually slows down. On top of this, the domestic labour force potential is increasingly being exhausted and immigration is slowing down. Overall, the upturn is expected to gradually lose impetus in the coming years.

Gross domestic product is expected to expand vigorously this year (+1.6%) and even somewhat stronger next year (+1.7%). In 2020 and 2021, the economic upswing will lose momentum (+1.5% and +1.4%) since domestic consumption and corporate investments will become continuously weaker. The contribution of foreign trade is expected to remain rather insignificant.

In the labour market, the longer periods of time that job vacancies remain unfilled as well as higher wage pressure suggest that the supply of workers is increasingly unable to satisfy firms' high demand. Accordingly, growth in employment will gradually weaken over the forecasting horizon. On the one hand, it will be increasingly difficult to fill vacant positions with jobseekers. On the other hand, the potential labour force will increase to a lesser degree than to date. Positive trends in participation and immigration will increasingly fail to compensate for the age-related decline in the labour force.

Private consumption will continue to make a significant contribution to economic growth. The disposable income of private households will rise clearly in the two years ahead, boosted by fiscal policy, including reductions of the effective income tax rate and the return to equal contributions by employers and employees in statutory medical insurance. Disposable income will also be stimulated in the year ahead by the sharp increase in social benefits, mainly due to the higher pensions for mothers and another significant increase in old-age pensions. Nevertheless, the public sector can expect significant fiscal surpluses in the midterm.

The risks for the German and international economy have grown since the spring. In particular, the rise of protectionism threatens the economy, as does any further escalation of the trade conflict between the US and China. Special risks for the European economy stem from the possibility of Britain‘s disorderly exit from the EU and the greater risk of a debt crisis in Italy. In light of the decreasing growth (potential) of the German economy over time (cf. long-term development over past decades), growth rates for Germany of around 1½% already indicate an economic boom.

Housing Market. New residential construction

Demand for new residential buildings is subject to long-term cycles: in 1990, German reunification touched off a huge housing boom – supported by massive state subsidies. The years 1997 to 2009 were then marked by a considerably weaker demand for construction, with government promotion of new construction again being significantly reduced in early 2006.

Since mid-2009, a new upswing has been underway, during which new building permits for multi-family buildings have risen continuously. The interim extremely high refugee migration rate (2015/2016) again gave a strong boost to this development.

Following the strong increase in 2016, permission activity was again weaker in 2017, on the one hand because the special loan programme for refugee residences expired and because familiar old market constraints (like land shortages, construction costs and bureaucracy) have regained importance. These market constraints are likely to cause declining permission numbers for flats especially in the coming years.

The numbers in Table 3 for “multi-family dwellings” (permits 2017: 234,895 dwellings), in addition to units in newly built multi-family buildings (2017: 187,362 units), now include flats in newly built non-residential buildings (2017: 5,310 units) as well as in existing residential buildings (2017: 39,462 units) and in existing non-residential buildings (2017: 2,761 units). Permit activity for flats in existing buildings or in new non-residential buildings has indeed picked up considerably in the meantime (presumably due primarily to the rapid increase in demand in the wake of the escalating influx of refugees). However, demand has already decreased significantly, and the implementation ratio is much lower than expected. This sub-sector is likely to shrink further in the coming years.

For 1+2 family buildings, the upswing came to a standstill back in 2011 at around 110,000 approved residential units. The high interim level of permits in 2015/16 can be attributed to a tightening of the statutory energy regulations and the resulting anticipatory effects. It can nevertheless be assumed that the market for newly-built private homes will shrink in the long term. This is primarily due to the ageing population, which will weaken demand and increase the supply of second-hand buildings at the same time.

Permissions for Dwellings in New Residential Buildings

	living area in 1 000 m²			volume in 1 000 m³		
	1+2 family dwellings	Flats	Total	1+2 family dwellings	Flats	Total
Q1/2014	3 600	2 357	5 957	19 560	12 745	32 305
Q2/2014	4 168	2 625	6 793	22 654	14 005	36 659
Q3/2014	3 986	3 005	6 991	21 527	16 140	37 667
Q4/2014	3 545	2 830	6 375	18 947	15 158	34 105
Q1/2015	3 528	2 403	5 931	19 149	12 690	31 839
Q2/2015	4 248	2 702	6 950	23 045	14 564	37 609
Q3/2015	4 572	2 984	7 556	24 603	15 979	40 582
Q4/2015	4 138	3 313	7 451	22 169	17 935	40 104
Q1/2016	4 378	2 980	7 358	23 697	15 981	39 678
Q2/2016	4 444	3 770	8 214	24 084	20 166	44 250
Q3/2016	4 140	3 635	7 775	22 351	19 450	41 801
Q4/2016	3 989	4 043	8 032	21 327	21 326	42 653
Q1/2017	3 781	3 055	6 836	20 443	16 465	36 908
Q2/2017	4 332	3 579	7 911	23 383	19 202	42 585
Q3/2017	4 256	3 399	7 655	22 894	18 394	41 288
Q4/2017	3 852	3 756	7 608	20 718	20 120	40 838
Q1/2018	3 721	3 147	6 868	20 178	17 088	37 266
Q2/2018	4 264	3 667	7 931	23 130	19 746	42 876
Q3/2018						
Q4/2018						

Source: Federal Statistical Office

There are several reasons for the overall positive development since 2009:

- Sharply fallen interest rates and a very good credit supply
- Sharply fallen interest earned from “secure” investments and lack of investment alternatives

- Significantly reduced vacant housing units in numerous regions; ongoing urbanisation/migration to fashionable cities (Schwarmstädte); at the same time increasing housing shortage in several growth regions
- Positive economic development and considerably lower unemployment
- Significantly increased real wages
- Significantly increased immigration; in particular, the refugee shock of 2015/16 led to numerous measures with the aim of further accelerating the expansion of the housing supply. Among other things, the federal and state governments provided additional funds, while municipal housing programmes contained significantly higher targets.
- In the long term, a declining number of average persons per household; i.e., continuously increasing living space per capita.

In contrast, there are a number of factors that will dampen new construction activities in the coming years:

- Sharply increased construction costs also due to considerably stricter energy regulations, numerous building code requirements, (e.g. obligatory parking spaces, noise abatement and fire protection), capacity bottlenecks in the construction industry (especially in the trades and increasingly in the main construction industry) as well as increased demands on quality and furnishings.
- Strongly increased incidental building costs, also due to urban development contracts (e.g., investor’s share of (transport) development costs and additional daycare centres) and a large number of building code requirements (e.g. noise and environmental assessments)
- Often municipal requirements for multi-family building projects: minimum share of social housing or other rent-restricted housing; in some areas private developers are obliged to sell newly-built flats to municipal housing companies at preferential prices; this lowers the profitability of the overall project.
- In many places, considerably higher land prices as well as scarce supply or sluggishness in making building land available; adding another storey/ conversions are often not profitable.
- High additional purchase costs (notary fees, land transfer tax of 3.5–6.5%)
- Government subsidy for home ownership is much lower than in earlier periods; in the case of rental intentions, the tax depreciation rate is now at an unrealistically low 2% per year, while rising land prices are also significantly reducing the assessment base
- Planning and execution using building information modelling (BIM) is still underdeveloped, the same applies for modular and serial construction; however, a framework agreement has now been signed between the government and the housing industry on a total of nine serial and modular housing concepts, with the aim of making parts of the tender, awarding, planning and approval more efficient or less expensive and of reducing construction time with the increased use of prefabrication.

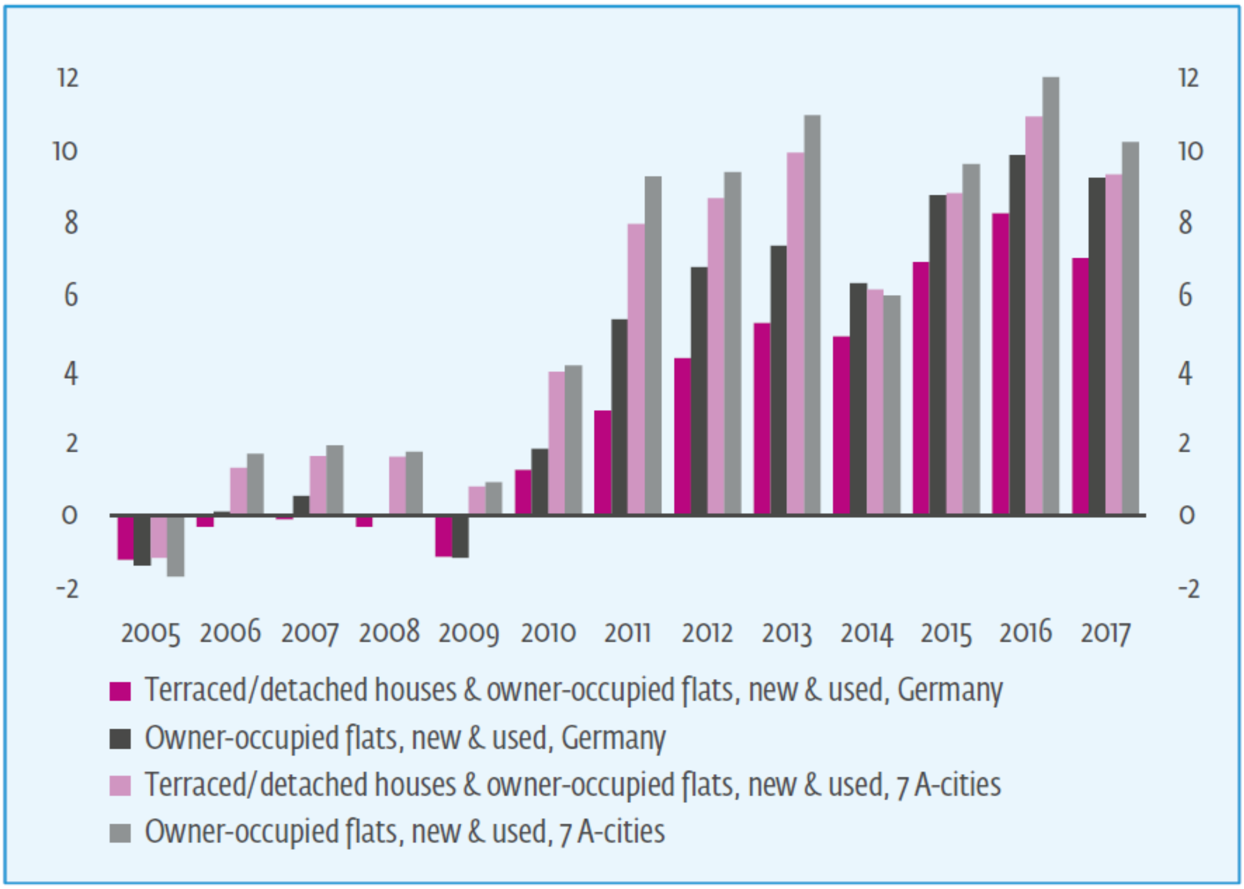
- Significantly increased supply of existing 1+2 family houses, partly due to strong internal migration (of young people to growth regions) and an increase in the number of inheritance cases; puts pressure on need for new construction.

There is currently a great need for new flats, which can be traced back to housing bottlenecks in many metropolitan areas. However, the planning, approval and implementation of housing projects is becoming more and more difficult, as the designation of new building land is slow and licensing authorities and the construction industry are already working at their limits. The increasing capacity bottlenecks are reflected in the sharp rise in construction prices, which make the desired residential construction projects more expensive. The increasing number of building regulations, municipal regulations and minimum quotas for subsidised flats as well as local protests continue to delay building activity.

Completions in	2015	2016	2017	2018	2019	2020	2021
New residential buildings (see Table 1)	217	236	245	260	275	280	290
Existing and non-residential buildings	31	42	40	40	35	35	30
Total	248	278	285	300	310	315	320

Housing Completions - 1000 dwellings Source: Federal Statistical Office, ifo Institute

The new federal government has now decided on a number of measures to defuse the situation. One example is the introduction of a home ownership-linked child subsidy (Baukindergeld, grant of €1,200 per child per year for 10 years; for households with annual incomes up to €75,000, a raising of this limit by an additional €15,000 for each child; initial applications will be accepted up to the end of 2020). This also promotes the acquisition of an existing piece of real estate. Especially in strained markets, this additional demand impetus is likely to drive prices higher. Given the bottlenecks in terms of land and construction capacity, it is unlikely that any additional housing units will be created in these regions. This criticism also applies to the already decided special depreciation for rented flats (newly constructed or acquired; in the first four years 20% additional deductible, valid for objects with acquisition / construction costs under 3,000 euros/m² but only 2,000 euros/m² relevant for tax; initial applications up to the end of 2021 are possible) as well as the further increase in federal subsidies for social housing in the federal states (from 2.5 to 5 billion euros in the period 2018 to 2021). In addition, the current housing offensive policy includes a variety of other measures (for example, more effective implementation with regard to the sales of federal land to municipalities at reduced prices that has been in effect for some time) but should not lead to any significant impetus for new construction activity. In the important harmonisation of the 16 federal state building regulations, we only have the existing intention to make changes. At the same time, the government is increasingly intervening in the market-driven rental pricing (extending the observation period for comparative rents from 4 to 6 years; validity of rental indices from 2 up to 3 years; the rental price brake, which has been in place for several years, will be readjusted with improved information requirements) and is making decisions that are negatively affecting owners, such as a reduction of the modernisation allocation (new regulation valid for five years; valid in tight markets, only 8% instead of 11% of the actual modernisation costs can be passed on to the renters and additionally limited to a maximum of 3 euros/m² within six years). As a result, the construction of a new rental property should be inhibited rather than stimulated in the long term.



Residential Property Prices in Germany. Change per year in %. Source: Bundesbank calculations based on data provided by bulwiengesa AG.

Measures on existing buildings

Investments in the renovation of old buildings rose sharply in the years 2006 to 2008 and in 2017 were still worth nearly a quarter more than in 2005 on a price-adjusted basis. In spite of strongly expanding new construction activity, some two-thirds of residential construction activity is currently in existing buildings. There are numerous reasons for the increase at the time and for the currently still huge amount of work on the existing building stock:

- Long-term decline in new construction up to 2009 accelerated the ageing of the housing stock and increased the need for measures on existing buildings

- Positive economic development gave many owners increased investment opportunities
- Energy prices, which have risen sharply since the mid-2000s, triggered major investments in heating systems, building shell and windows
- Formerly, a generous promotion for the feed-in of solar power; consequently, in many places' installation of photovoltaic units on roof tops; self-generation is now much more attractive; and there is now also separate support for tenant power plants (but up to now because of present legal arrangements less attractive)
- On-going ageing of society: generation 50+ is the most important demand group for modernisation measures (especially bathrooms); government support for age-related conversion measures
- Significant decline in interest rates has drastically reduced financing costs; lack of investment alternatives increases attractiveness of modernisation
- Significantly increased government support for energy-related renovation measures; increasing importance of subsidies/repayment subsidies, but linked to high energy targets; now also special support for replacement of heating and ventilation systems
- An acute housing shortage in many regions, combined with soaring land prices and the sluggish pace of new-build have significantly increased the attractiveness of projects on existing houses; large portfolio managers in particular use this option, but this is also due to the fact that this kind of apartment project has become very complex (due to regulations, for example) and demand high effort and competences
- Increased number of sales of existing 1+2 family buildings has led to more renovations; the inheritance factor is becoming increasingly important.

Currently a figure of about 124 billion euros (in 2017 prices) is spent annually on construction measures for existing buildings (incl. additional construction costs; without taxes). After a settling-down of the market from 2012 to 2015, work on existing buildings increased noticeably again in 2016 and 2017, according to DIW calculations, especially energy-efficiency measures were able to regain ground. The stronger focus of the fitting-out trade on renovation projects in 2017 was, to a large extent, at the cost of the new construction sector, confirming the high level of capacity utilisation of firms in the fitting trades. Renovation requirements of the roughly 43½ million dwellings in residential and non-residential buildings (ifo estimate based on census results and forward projections) will indeed remain high in the long term. A further decline is to be expected, however, which will also be accompanied by a shift in focus: e.g., less outer wall insulation but more age-appropriate reconstruction measures. The following factors are having a constraining impact:

- To date energy-saving renovations were primarily made to residential buildings with a high energy-cost economising potential; incentives for energy-saving renovations in the other housing units tend to be much smaller

- To date renovations have been carried out mainly by owners with sufficient capital or income; the other owners will tend to need much greater financial assistance (by public authorities); the federal government, after several attempts and proclamations, has still not managed to introduce a special depreciation for energy-efficiency renovation measures

- To date, primarily objects that have only one owner or just a few co-owners have been fully modernised; in larger condominium associations (WEGs), however, the decision for such projects is far more difficult to achieve; the Association of Property Managers recently reported a significant decline in the growth of energy projects of WEGs
- Elderly senior citizens often shy away from larger investments (uncertainty regarding their remaining life expectancy), especially if their offspring show little interest in using their real-estate at a later date
- Larger renovation measures are often not undertaken until the property changes hands; but inheritance cases will clearly increase in the long term, especially for 1+2 family buildings
- In (rural) areas with a high housing surplus there is little incentive for owners to renovate as the low level of rents means that only small rent increases can be implemented; renovation measures therefore tend to be on a smaller scale
- The energy status of a large share of dwellings provided by housing companies is already satisfactory to good
- The topic of building renovation is too complex for many homeowners (what measures? / what financing?)
- Problems with statutory energy regulations: often clear differences between calculated energy saving and subsequent actual consumption; too little consideration is given to the characteristics of individual buildings; there is too little support for area-wide solutions (whole district!); strict energy standards apply for major renovations resulting in investment restraint or a preference for smaller-scale measures
- Tax law reduces the incentives to refurbish a property comprehensively after acquisition, since the costs can then no longer be written off completely and immediately (this applies only if expenses in the first three years amount to a maximum of 15% of the purchase price) but over a period of 50 years
- Measures such as the rental price ceiling for new leases (since June 2015, rental price in tight housing markets can only be up to 10% above the local reference rent; exceptions: first leases, comprehensive modernisation), but also the previously tightened ceilings for existing tenancy agreements (increases of a maximum of 15% in three years in tight markets) send clear, regulatory signals to the potential owners of rental properties; on the other hand the rental price cap has not had the intended effect because of the widespread massive housing shortage. In addition, the new federal government recently approved a longer reference rental period (currently new contracts or changes over the last four years, in future over six years), as well as, a longer validity period for rental indices and thereby has exerted a stronger, political influence on local comparative reference rents

- The new federal government has implemented a reduction of the modernisation costs to tenants from 11% to 8% of the costs that can be passed on (not more than 3 euros rental increase per m² for 6 years); new regulation limited to five years
- The economic viability and technical problems of façade insulation is a recurring topic of public debate; this segment has now lost importance and is likely to experience difficulties in the future
- Upturn of new construction and/or increased replacement of old buildings reduces modernisa- tion requirements
- Lower heating-energy prices weaken incentives for energy savings; although oil prices have picked up noticeably in the recent past, they are still considerably below the levels of 2008 or 2011–14
- Considerable (future) demand for barrier-free buildings / flats, but numerous obstacles especially in cases of the retrofitting of elevators (e.g., lack of space, fire safety regulations, monument protection)
- Increasing lack of skilled labour in the finishing trade; decline in apprentice numbers now stopped, but no hope for significant recovery; although in the medium term the weakening in the boom for new construction will theoretically release capacities for renovation projects, at the same time the industry’s high average age of the labour force threatens to reduce capacities in the future.

Lean Construction. Situation in Germany

There is little, if any, information available about the range and dissemination of lean concepts among construction companies in Germany. Building on the methodologies and conceptual frameworks used in earlier work in the UK (Common et al., 2000) and the Netherlands (Johansen et al., 2002) qualitative and quantitative analysis of different questionnaire's campaign to large German construction companies indicates that there is little awareness of lean in the German construction industry and that hardly any company uses lean concepts on a company wide basis despite evidence that procedures and techniques that are used on German construction sites are generally consistent with lean construction practice. There appears to be cultural resistance to a manufacturing derived, production-system-view of construction.

It appears that conversion thinking still governs the German industry and that the integration of lean related project processes has not taken place. This is mainly reflected in conventional procurement methods and the frequent utilization of planning and control techniques that are responsible for large amounts of waste in construction. The results also give the impression that there is limited understanding of the complexity of the industry network and its potential for improvement. Management concepts that have been proven efficient in the construction industries of other countries are still little used. In particular, the efficiency of mapping techniques and supply chain management has been disregarded.

Looking at German construction sites, it seems, there is general agreement with the lean philosophy. Principles of transparency are implemented and measures are taken to guarantee build-in-quality. Also, the production process occurs in a continuous flow while materials are customarily pre-fabricated and delivered at the appropriate time. The responses also indicate a good attitude towards change.
Overall, the results imply good conditions regarding installation, modest conditions in terms of collaboration and behavior, and inadequate conditions on the subjects of procurement, management, planning/control, design and supply.

Apparently, the German construction industry has a lot to catch up on in the way it manages its activities. The greatest deficiency appears to be the narrow perspective contractors might have regarding value generation in general and effective management of the network of service and product providers in particular. However, as far as the implementation of lean construction on the production level is concerned the German construction industry seems to provide a good foundation. Usually the workforces are highly skilled due to the level of education set out by the Handicrafts Code, which facilitates the compilation of multi-skilled work crews.

Business as usual practices

Information from the Federation of the German Construction Industry (Hauptverband der Deutschen Bauindustrie) indicates that the share of actual construction work carried out by the larger companies is declining. The majority of the larger German building firms have developed into general contractors and building service companies. The common procurement method in Germany has changed to general contracting (Hochstadt, 2002). The larger companies take on the position of a project management organisation while the construction work itself is principally sub-contracted to smaller companies.

Applicable laws

Construction Laws

The responsibility for public construction law in Germany is divided between federal and state governments. Zoning law (*Bauplanungsrecht*) is federal law. It determines the purpose for which a property may be used and whether a building project fits into its surroundings. The federal states are responsible for building regulations law (*Bauordnungsrecht*), which determines how buildings may be designed and constructed in order to meet planning law requirements. Each state issues its own building regulation. However, most of the states have adopted a specimen building regulation issued by the state ministries which also makes provision for certain standardization within this field.

Building Permits

A building permit (*Baugenehmigung*) is required for the construction, alteration, demolition, or change in use of a building. The building permit is granted if the project complies with the planning and building regulation law as well as with all other applicable laws (such as environmental laws).
An application for a building permit must be submitted to the local building authority or the building supervisory authority (*Bauamt*). The application must include a detailed plan of the project, accompanied by necessary supporting documentation such as site plan, construction drawings, building specifications, and, where applicable, documentation regarding heating, noise prevention, and fire protection plans. The documentation required for the application must also be presented to adjacent property owners.

Legal framework

Two bodies of laws regulate the material legal relationships between the parties to a construction contract:

- The German Civil Code (BGB), statutory provisions applicable to contracts for work and services are found in Sections 631 to 650v German Civil Code.
- Contracting rules for the procurement of public works (VOB/B), in contrast to the provisions of the Civil Code, the regulations contained in this legal framework do not have the character of law but are general terms and conditions.

Whilst the provisions of the Civil Code apply automatically, the application of the VOB/B must be expressly agreed as an integral part of the contract between the parties. However, a simple Civil Code contract is rarely used for complex building projects. Since 1 January 2018, the Civil Code has defined a construction contract, consumer construction contract, architect and engineer contract and the construction developer contract and partly provides special provisions for each of those contracts. For the first time, building contract law was codified as a separate area of law, taking into account the complexity of the construction process and its specific requirements.

Environmental assessment and sustainability

In particular, the following legal frameworks deal with environmental assessment and sustainability with regard to various aspects of construction projects, mainly as a consequence of stipulations made by the European Community:

- **Building and construction materials.** In compliance with the EU Construction Products Directive aimed at encouraging the sustainable use of natural resources, the Construction Product Law (*Bauproduktengesetz 2013*) regulates the use of construction products and the application of the CE conformity mark in relation to the free movement of construction products within the European Community. In addition, other legal frameworks setting out requirements for the actual use of construction products, such as the building codes of the Federal States (*Bauordnung*), remain applicable.

- **Energy performance of buildings.** The Energy Saving Ordinance (*Energieeinsparungsverordnung – ENEV*), which is based on the Energy Saving Law (*Energieeinsparungsgesetz*) sets out a framework to calculate the energy performance of buildings and the setting of minimum energy performance requirements. Separate requirements are set for new and existing buildings. In addition a new scheme of energy certificates has been introduced. In addition, the Renewable Energy Heating Law (*Erneuerbare-Energien-Wärmegesetz*), which applies to buildings erected after 1 January 2009 as well as to buildings held by public authorities and fundamentally refurbished after 1 May 2011, ensures that by 2020 at the latest 14 percent of the heating and hot water energy in Germany will be provided by renewable energy sources. In order to achieve this, the law contains obligations to use renewable energy sources and provisions relating to financial promotion and the expansion of heat networks by local authorities. It entitles the Federal States to implement laws which provide also that existing buildings must use renewable energy sources.

- **Other standards.** The German Society for Sustainable Construction (*Deutsche Gesellschaft für nachhaltiges Bauen e.V.*) has, together with the Federal Ministry of Transport, Building and Urban Affairs, developed a certification system for buildings with regard to energy efficiency, hazardous substances and environmental requirements etc (*Deutsches Gütesiegel Nachhaltiges Bauen*). This certification system is not (as) yet binding, but may, however, give a competitive advantage. Besides the DGNB certificate, other certificate can be found on the German market such as BREEAM or LEED.

Barriers in the construction sector

Firstly, German industry is highly regulated. Construction work is primarily regulated by the German Building Contract Code (Vertragsordnung für Bauleistungen, or VOB). It is common practice in the German construction industry to base awarding procedures and contractual relations on the VOB (Bosch and Philips, 2003). A unique feature of the German construction industry is the monopoly of the master craftsperson, which "ties the management of building firms within the handicraft trades to proof of qualification and thus constitutes an important barrier to an increase in the number of low-qualified self-employed people, existing, for example, in the Untied Kingdom" (Bosch and Philips, 2003). The Handicrafts Code (Handwerksordnung) specifies who is allowed to set up such a business. The accelerated structural change in the industry, the poor economic progression and the intensified internationalisation of the market are expected to slow down the innovative capability of the construction industry (Hochstadt, 2002). In order to meet the challenges in the German construction industry, reforms have been implemented concerning primarily the vocational training and the Handicrafts Code (Bosch and Philips, 2003).

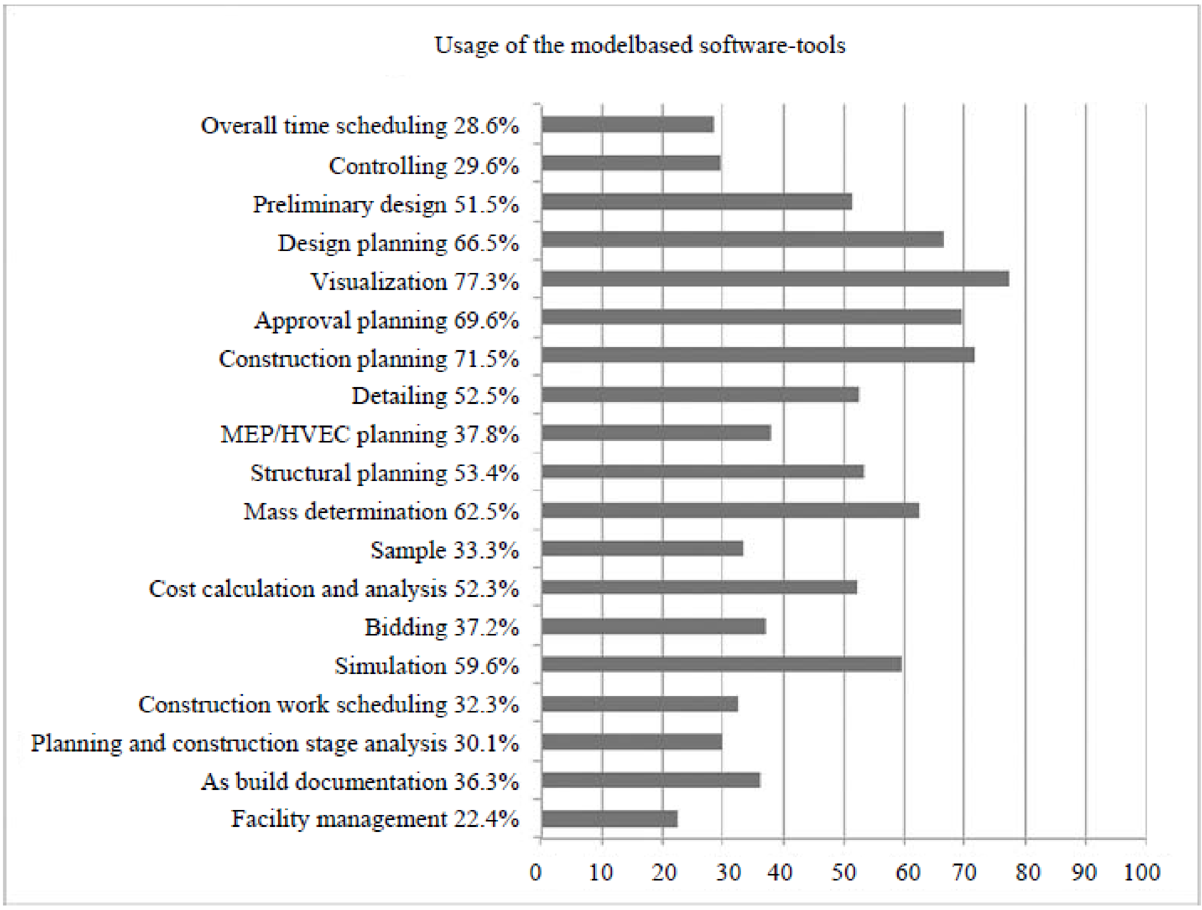
On the other hand, implementation of the BIM method in Germany is still at its very early stages. In comparison with the US and the Nordic countries, the German AEC (architecture, engineering and construction market) sector has yet to exhaust the potentials of the method and technology. Although software vendors already offer BIM (building information modeling) solutions adapted to German processes, with the exception of a few general contractors and public-authority pilot projects, few practitioners use these applications to calculate project-related resources, costs, revenue and overall profitability.

It would seem that the fine, granular organisational structure of the German AEC market is one of the barriers to the integrated adoption of the BIM method. Besides strong functional segmentation of the processes into separate companies, the size of the companies involved too is critical for generating global added-value: Over 92% of construction companies employ less than 20 individuals (German Federal Statistical Office, 2010) and the average size of architects and engineers offices is between three and five employees (Hommerich and Ebers, 2006). In this context, special attention needs to be paid to the poor economic situation of architects and other planners in Germany: Only around 50% of architects and engineers calculate project-related resources, costs, revenue and overall profitability, and the annual profit of around 30% of design offices is €15,000 or less (Hommerich and Ebers, 2006).

With respect to working methods, most adhere to antiquated principles, and the benefits of the software are not exhausted in the slightest, with even modern model-based CAD (computer-aided design) systems used purely as "digital 2D drawing boards". Thus, possible added-value through high-density and high-quality information in the planning and subsequent lifecycle phases is not exploited. The elaboration of a specific action plan to ameliorate this situation seems difficult because reliable analyses concerning the application of BIM in Germany have yet to be carried out.

BIM is only one method among others and is applied as an exclusive strategy only in exceptional cases. So on average, two to three different methods are applied simultaneously in projects or companies. To date, 2D planning is the most popular method used. Planners in particular are using the software for pure 2D planning (60% of overall usage), as are construction companies (70%).

Also of interest is the extent to which BIM is used in the different AEC processes, this is shown in Fig. 1. BIM is the favorite method, especially in the early design phases. It is used for over 77% of visualizations and 66% of design planning work. When it comes to detailing (52%), sampling (33%), preparation for tender (37%), and construction-work scheduling its popularity decreases. Astonishingly, use of the model-based method in the area of facilities management is low (22.4%).



A similar picture can be drawn in relation to data exchange: The dominant exchange formats, regardless of the target group, are still paper, PDF and Auto Desks CAD-format DWG. Use of model-based formats (including by BIM users) remains very rare. This can be seen as an indicator of the lack of model-based working cooperation partners and also insufficient technical interfaces.

With respect to project size, use of BIM rises, especially in projects over €2 million. A similar correlation exists concerning the size of the enterprise: In companies with up to 10 employees, the number of non-BIM-users is higher than average. The highest number of BIM users is found in medium-sized enterprises with between 3 and 300 employees. Companies with over 300 employees generally are not using BIM at the moment but are willing to do so in the near future.

Technological Barriers to the Implementation of BIM - Evaluation of the hypotheses concerning technological aspects reveals remarkable differences: BIM-users and non-BIM-user differ when it comes to the questions regarding hardware requirements and complexity of model-based software. Whereas BIM-users described the hardware requirements as unproblematic, they seem to be a barrier for encountered non-BIM users. Similar differences are encountered in the statements. Concerning the complexity of BIM software: Non-BIM users agreed that “the complexity of BIM software is too high”, whereas experienced BIM users did not consider this a problem.

Interestingly there is similarity in the degree of agreement when it comes to the statement that model-based BIM software has functional limitations. Interoperability in particular seems to be a major problem. While BIM users assessed the effort required to import data into the model-based software as fairly problematic, for non-BIM-users it seems to be a considerable barrier.

About data exchange standards, the existing exchange formats for digital building models are not consistently available. The IFC (industry foundation classes) format in particular and its implementation in software interfaces still do not fulfill the requirements of the target groups.

Economic Barriers - One high barrier for non-BIM users seems to be the availability of capital for investment. For those already using BIM software the financial aspect does not seem to be a barrier or problem. Non-BIM users agreed that they did not have enough financial resources for BIM-related investments.

Also, the phase-oriented awarding of contracts was seen to be a general barrier. Those involved are unable to enhance their added-value as would be possible with overarching integrated work, nor is the model-based method applied continuously.

Educational Barriers - The skills and abilities of entrants into BIM-relevant areas—with the exception of those in possession of the CAD qualification—are rated collectively as below average and insufficient. The application of the integrated and collaborative working methods linked with the BIM methodology and the associated increased costs of coordination and synchronization enable new processes and responsibilities and roles to emerge that are insufficiently covered in “traditional project management”. Team-based approaches have yet to be practically formulated and are hardly feasible in the existing organizational and cooperative structures. The BIM introduction and usage processes have so far been implemented very individually by the different actors according to the respective corporate environment.

Normative Barriers

Standardization is an important auxiliary means for simplified and secure contracting.

By referring to normative descriptions, contracts can be concluded efficiently and securely between clients and planners/contractors.

When applying the BIM method, project partners exchange models rather than blueprints or drawings. This allows for an integrated process without media interruption. Especially in the case of model changes it is beneficial to extract data directly out of the model. This demands a consistent model but also clearly specified exchange parameters and quality criteria.

With respect to the cooperative aspect, however, the survey made it clear that there are currently a large number of prejudices and reservations when it comes to sharing and collaborative use of BIM models between companies.

Private sector vs Procurement-based practices

The main parties involved in a project are the:

- **Principal.** For example, project developers or investors.
- **General contractor.** The principal can use a general contractor, in most cases under turnkey-ready contracts that is, where the works are constructed and delivered ready to use.
- **Specialist contractors.** The principal sometimes divides the scope of the works into subsections or specialist trades (*Einzelgewerke*), contracting directly with the respective contractors.
- **Planners (architects, engineers and so on).** These are contracted by the principal or the general contractor, depending on the project's structure. If the works are executed by more than one contractor, the principal usually provides the design and supervision of the project. A general contractor is usually contracted on the basis of a basic planning (*Entwurfsplanung*) and a building permit obtained by the principal. In this event, the general contractor executes the detailed planning (*Ausführungsplanung*) on that basis. However, differing design and build structures with additional responsibilities for the general contractor are also used.

Public procurement

Special statutory procurement arrangements only apply to local contracting public authorities. The Contracting Rules for Award of Public Works Contracts, Part A (*Vergabe-und Vertragsordnung für Bauleistungen, Teil A*) (VOB/A) and the Act against Restraints on Competition (*Gesetz gegen Wettbewerbsbeschränkungen*) contain rules on the procurement of contracts in accordance with EU competition law standards. Local and international parties should be treated equally, although few international construction companies have been able to establish themselves in the German market.

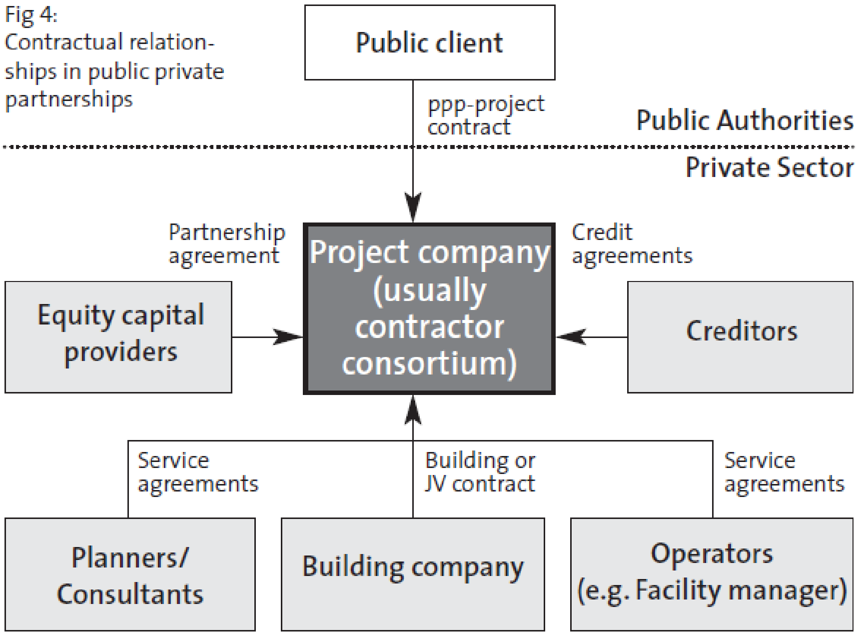


Fig 4:
Contractual relationships in public private partnerships

Private contracts

Private parties are free to choose their contractual agreements and procurement route. For local construction projects, the parties to a contract usually refer to VOB/B, which contains specific general terms and conditions for the execution of the construction works.

The parties can also agree on alternative procurement models such as construction management contracts or guaranteed maximum price (GMP) contracts.

International contracts

If some or all parties are international, international procurement arrangements like engineering, procurement and construction (EPC), engineering, procurement and construction management (EPCM) and design-and-build contracts are frequently used.

Transaction structures

Local projects. Depending on the size of a transaction and the expertise required, parties often engage in projects using a joint venture structure.

This can be formed as a:

- **German limited partnership.** This is the most common form. The joint venture company is organised in the form of a German limited partnership with a German limited liability company (*Gesellschaft mit beschränkter Haftung*) (GmbH) as general partner. This structure is known as GmbH & Co. KG. The GmbH & Co. KG combines the advantages of a corporation regarding shareholder liability (that is, the limited partners who have made capital contributions have no liability) with the tax transparency of a partnership. The GmbH & Co. KG is not subject to income tax itself. Instead, profits and losses are directly allocated to the partners. The GmbH & Co. KG itself is only subject to trade tax, value added tax (VAT), real estate tax and real estate transfer tax (if any).

- **German limited liability company.** This is a straightforward form of corporation with flexibility for shareholders to structure the corporate governance.

In a joint venture, the articles of association and partnership agreements are usually accompanied by shareholder agreements providing for the:

- Financing of the joint venture company.
- Insolvency of one of the joint venture partners.
- Handling of deadlock situations and conflicts in general.
- Restrictions on the transfer of shares.
- Non-compete rules.

Exit rules (including distribution of proceeds from an exit).

Typical transactional structures usually comprise a set of newly founded GmbHs and GmbH & Co. KGs (or the recently acquired shelf companies). These structures are largely tax driven, particularly to avoid real estate transfer tax where legally possible.

International projects

Contractors or investors from abroad sometimes use corporate vehicles in a German limited partnership structure, but with a foreign entity as general partner. For example, a:

- Private limited liability corporate entity (*société à responsabilité limitée*) (SARL) & Co. KG (Luxembourg).
- Private limited liability company (*besloten vennootschap met beperkte aansprakelijkheid*) (BV) & Co. KG (The Netherlands).

These structures can be used for corporate tax and trade tax reasons. However, the permissibility of a partnership structure with its administrative seat abroad is doubtful. This is because German corporate law provides in principle that a partnership is not recognised as a partnership (and can be dissolved) if it does not have its seat of administration in Germany. This structure is therefore becoming less popular.

Sustainable development

The zoning plan and building permit usually cover sustainable development considerations.

The Buildings Energy Saving Act (*Energieeinsparungsgesetz*) and the Buildings Energy Saving Ordinance (*Energieeinsparverordnung*) both:

- Require a reduction in energy use.
- Provide technical standards to be complied with (for example, in relation to heat insulation and facility technology).

An energy pass must be obtained if a building is newly developed or substantially amended or sold.

There are requirements concerning carbon emissions for certain industrial projects (*Greenhouse Gas Emissions Trading Act* (TEHG)). These projects must provide emission certificates to the competent authority. The owner of the project is responsible for compliance with these requirements.

What should be changed in the construction industry?

Prioritize innovation - The use of digital tools can truly open up the construction process and allow for faster and data-driven decisions. In the German building industry, the biggest advantage of digital solutions (eg. construction software) could be the collection and scientific management of big data. For instance, predictive analytics can help with the faster analysis of the impact that a new building could have on an area. The ability to identify potential risks and patterns depending on the building location could eventually lead to the generation of a construction road-map for certain types of areas or projects. It goes without saying that this could save German construction a good amount of time and resources in similar future projects.

Modular construction - Modular buildings is one of the hottest trends in construction for 2018. Germany could be no exception to that. By investing in the industrialized building, the sector could save valuable time and skip some extremely costly and time-consuming steps during the construction process. In the long run, such strategy could have a considerable impact on the housing prices. The less money spent during the building phase, the more affordable housing prices.

Building in a virtual world - Artificial intelligence (AI), software systems and autonomous construction equipment replace most manual work throughout the engineering and construction value chain.

Factories run the world - Construction activities move largely to factories and the industry uses lean principles and advanced manufacturing processes to pre-fabricate modules that are later assembled on-site.

A green reboot - The construction industry uses sustainable technologies and new materials to meet tough environmental regulations.

Attract new talent and build up required skills - As any future scenario requires talent with substantially different skills than today's workforce possesses, and adequate upskilling processes are largely not in place.

Integrate and collaborate across the construction industry's value chain - As the construction industry is characterized by a disintegrated and highly fragmented value chain, which hampers the seamless data flows and integrated systems that are essential in any future scenario.

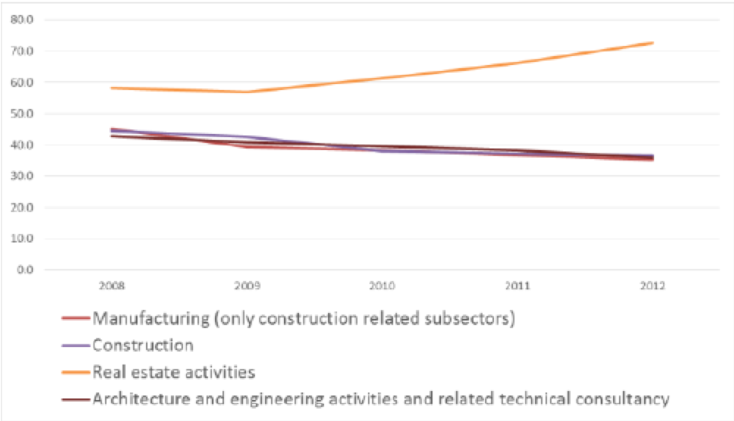
Adopt advanced technologies at scale - As the construction industry has been slow to adopt new technologies and still heavily relies on manual labour and mechanical technologies, resulting in poor productivity.Further key actions are: to maximize the use of data and digital models throughout processes; to review existing product portfolios and embrace new business opportunities; and to enable change-management and adaptiveness.

14.3 IDDS Scan - Situation in Spain

Local Context - Productivity in Spain and current state

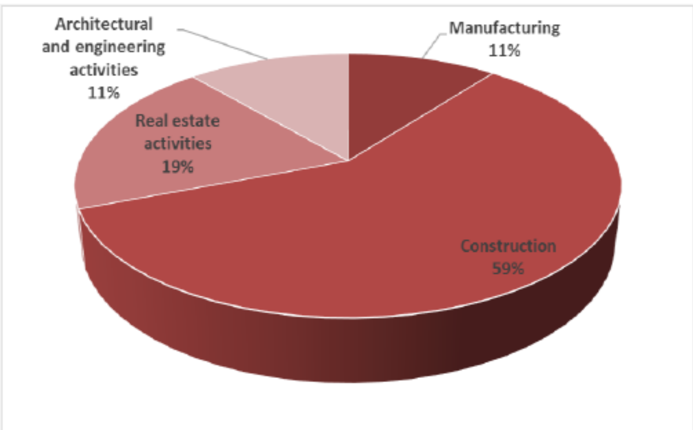
Productivity in Spain has been declining for most of the construction sub-sectors since 2008. Narrow construction, manufacturing and architectural services have shown similar productivity trends, dropping by 16-22% in 2008-2012. Real estate activities have shown the opposite trend, increasing productivity by 25% since 2008.

Labour productivity in the construction sector in Spain over 2008-2012 (EUR k)



Source: Eurostat, 2015.

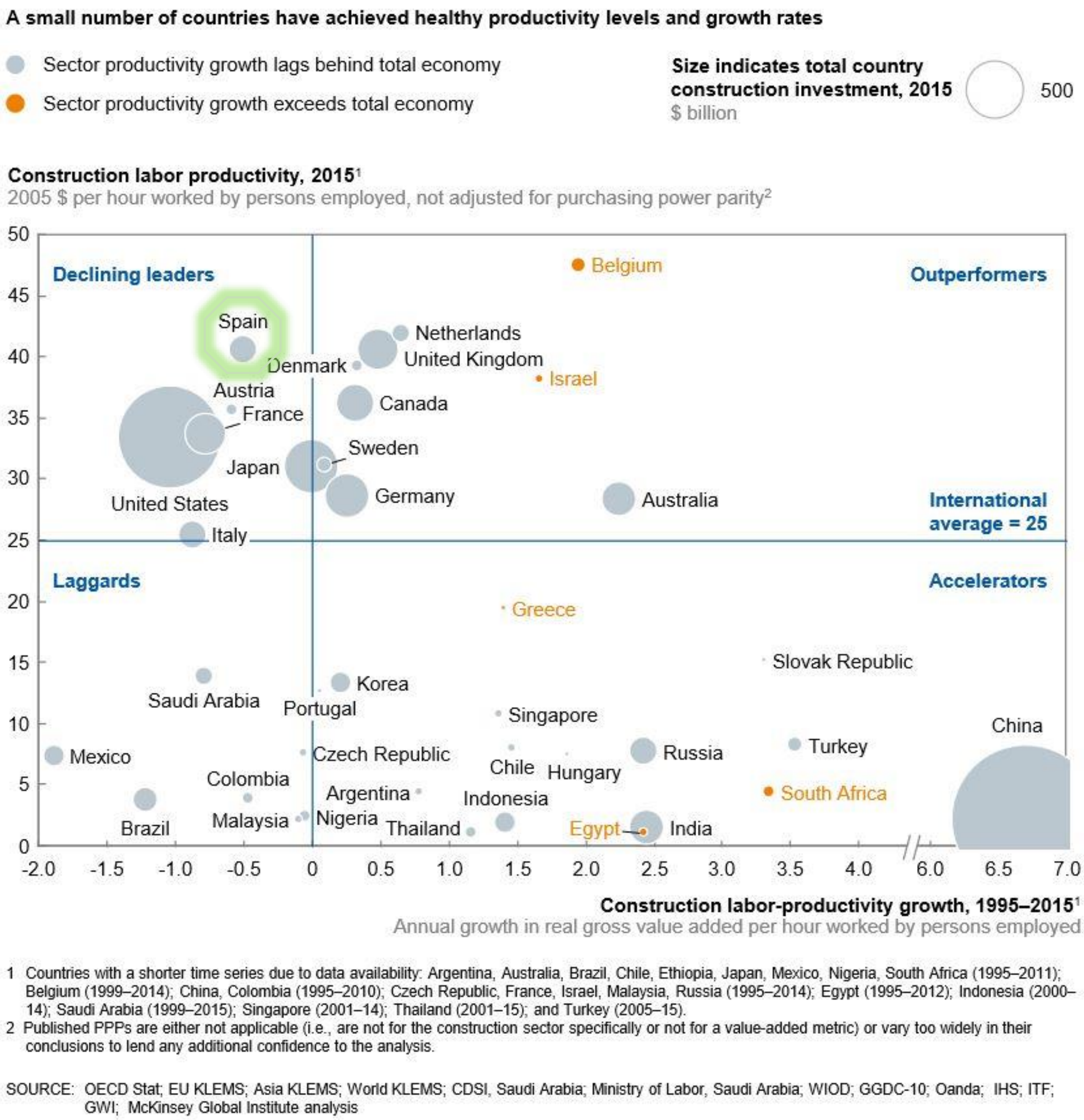
In 2012, there were 567,347 enterprises operating in the broad construction sector in Spain, with the narrow construction sector (NACE F) accounting for 56.6% of them. This represents a 19% decrease in the broad construction sector since 2008 (699,848 companies). Most of the decline was reported in the construction (-24%) and manufacturing subsectors (-21%). The construction sub-sector contributed 59% to the total added value1 of the sector in 2012, in line with its share in the number of companies. On the other hand, the manufacturing sub-sector adds twice as much value as it would be expected from its share in the number of companies, suggesting a higher efficiency and lower cost base.



Source: Eurostat, 2015.

Value added in the construction sector in Spain in 2012 (%)

Production in the construction of buildings dropped by 46.3% from 2008 until 2012, subsequently picking up by 23% until 2014, but is still 34% below the pre-crisis level. Similarly, production in civil engineering decreased by 48% between 2008 and 2013, after which it started to recover slightly, but was still 46% below the 2008 level in 2014.



Source: European Construction Sector. Observatory. Country profile Spain. Ref. Ares (2016)1948526 – 25/04/2016

Considering construction labour productivity in different countries, productivity levels and growth rates in the construction sector in Spain can be vastly improved. It seems, however, that at least before the Real Estate crisis the operating construction system itself did not call for any change in the use of building systems and working methodologies.

WHY?

The main reason why there has not been a need for a change so far was its economic impact considering that the incidence of constructions costs of a building was abnormally low compared to the ground costs and financial costs, taxes, marketing, etc. Thus, any investment intended to enhance the construction process and its management did not imply a solid improvement on the final cost of the Real Estate product.

The cost of labour also influences the implementation of more advanced construction systems. Years before the real estate crisis, the labour force in the construction sector in Spain was extensive and low-skilled, with cheap hiring costs that made unprofitable the implementation of more productive construction systems that require less skilled and better-paid labour.

In the last few years, it has changed the distribution of the percentage of the final price, and the construction cost is reaching up to 60% of the final product. The construction sector and its labour market are approaching the average of surrounding countries, by implementing more modern systems with a more skilled workforce.

Therefore, it is urgent to increase the productivity in the sector as it significantly improves the final product, because the advantageous scenario of the construction sector of few years ago surely will not be reproduced.

There are other aspects that need to be improved as much as productivity, aiming at looking for alternatives and new procedures:

- The delays in the execution times
- Changes introduced in the project dues to a bad approach in the initial early stages
- Cost overruns
- Lack of planning
- Reworks
- Ineffective logistics
- Unnecessary consumption of raw materials
- CO2 emissions
- Maintenance costs
- Lack of quality in a sector with a traditionally under-trained labour and under-industrialized systems

Source: Building and Management, Integrated Project Delivery, An alternative to the usual form of construction work in Spain. *Miguel Ángel Álvarez, Alfonso Bucero, Carlos J. Pampliega.* Vol. 1, Issue 3. September - December 2017.

Lean Construction. Situation in Spain

Even Lean Construction concept was generated between 1992 and 1993, in Spain there was no dissemination or real interest until 2010, especially thanks to the creation of the ***Spanish Group for Lean Construction*** and later the organization of the ***International conference LIPS 2015 in Barcelona*** and various initiatives of the ***Labour Foundation of Construction of Pamplona.*** In 2015, the first edition of a Lean Construction certification was made by the Lean Institute in the Polytechnic University of Catalonia.

Business as usual practices
in Spain the usual practice in project and construction processes continues to be the traditional one, that is:

Owner → Architect → Main Contractor → Subcontractors + Trade Contractors

However, following the European Directives, and their mandatory transposition, the contracting systems of the public administration are becoming more and more similar to those of the rest of Europe. New tendering and bidding procedures are replacing the old systems that only took into account the cost.

Spanish construction has a single form of development: **Design, Bid, Build**, this is the assumed paradigm, as if there was no other alternative, reinforced by the current Legislation in the matter.The results of this situation are as described in the table below.

Objectives under classic procedures	Quality	Cost	Time
Owner	Max	Min	Min
Designers (Architects, Engineers)	High	Just	Just
Contractors	Acceptable	High	No matter

Applicable laws
The construction process in Spain is governed by the following legislative provisions:

- **LOE (Law 38/1999), from EU Directive 85/384/CEE**, it has been the first legal precept of the Spanish modern regulation in this sector. Concerns basically:
    - Identify the agents of the building process (Owner, Designers, Contractor's, Construction Manager, etc., and their roles).
    - Regulate the Construction Process.
    - Define the scope and the juridical concepts involved on the process.
    - Civil liability of the different stakeholders.
    - Temporary terms of guarantees and insurance coverages (10 years max.).

- **LCSP (Law 30/2007), from EU Directive 2014/18/CE**, updated subsequently, concerning specifically:
    - Regulates forms of public sector procurement.
    - Includes for the first time in Spain the **PPP (Public Private Partnership) Contracting Mode**, born in the UK in the 90's, with some common aspects with the IPD.

- **CTE (Technical Code of Building – Royal Decree 314/2006), from EU Directives 89/106/CEE and 2002/91/CE**, updated later on, issued as a legislative deployment of the abovementioned LOE, and concerning technical requirements, as follows:
    - Scope of the different documents (Basic Project, Detailed/Executive Project, etc.).

  - Minimum contents required for each type of documents (Drawings, Project Quantities, Unit Prices, Detailed Budget, etc.).
  - Technical requirements and calculation criteria for all the facilities of the building (Structure, HVAC, Energy, Lighting, Electrical, Plumbing, Safety and Security –fire, intrusion-, etc.).

- **Soil Law (Royal Legislative Decree 2/2008)**, updated at a later time.

- **Law 22/2001 from the Government of the Generalitat de Catalunya**, regulating Surface Rights. This legal provision was an effective tool to be able to formalize PPP contracts before the appearance of the LCSP.

  Contracts beyond the handover of the building, contracts with a validity of 20-30 years were possible thanks to this Catalan Law, and the equivalent regulation in the rest of the Spanish territory.

Source: COMSA Team Contribution.

Barriers in the construction sector

Anyway, the legislation allowing PPP Contracts, don't reach the necessary requirements to enable the IPD engagements between the parties in the process, and nor does it allow for the sharing of responsibilities among stakeholders throughout the entire life cycle of the building. So, therefore, they do not fully facilitate the implementation of new management methodologies such as IPD.

- Artificially, the relationship with other agents that are not reflected in the LOE is based on the jurisprudence reinterpreting this law. The inclusion of new agents involved in the construction project will force the administration, insurers and legal departments of companies to establish norms and protocols adapted to the law.
- In Spain, the management of public contracts is based on an obsolete legislation that encourages the previous situation of confrontation between the parties.
- Another key element of the sector, which we can extend to the rest of the national economy, is the lack of a collaborative business culture. Many hours of education and training in the various tools related to Lean Construction will be necessary, starting with IPD. But knowledge of these methods will be useless if there is no culture that favours collaboration.

That has necessarily to do with the legal part reflected in the contracts, the process of rewards, remuneration, civil liability, and trust building among all agents.

- The Project Manager, a job not efficiently used in Spain, should be converted into a change agent in organizations that fosters a collaboration culture. The "Project Manager" role is key as the main responsible for the IPD project.

- The concern of the exploitation of the useful life of the building has been introduced timidly in the construction sector. In spite of this, in the project and construction process, the system is still basically the traditional one, with timid protection measures to limit as far as possible deviations in terms of time and cost.

In certain implicit features of the Latin character and the country's own technological development in this field, we can find reasons that hinder and impede progress towards solutions in line with the IDDS philosophy:

- The appropriate tools to work with IDDS are not disseminated in Spain.
- The implementation of BIM tools in Spain can be placed at 2% in the field of architectural design, and negligible in the Mechanical, Electrical and Plumbing field.
- Administrations are starting timidly to require projects in BIM format, foreseeing that in 2020 this protocol has been normalized within the public administration. However, this forecast is unreal.
- The administration itself lacks sufficient knowledge to issue technical prescriptions appropriate to the demands of the projects it brings to tender.

Another barrier in the Spanish market is that the maintenance contracts themselves, in both the public and private sectors, only exceptionally reach 5 years. The normal is between 1 and two years, and at most, 2 + 2 = 4 years. This is a difficult barrier to overcome. to expand horizons to 20-30-year contracts as imposed by the philosophy of an IDDS agreement.

Source: COMSA Team Contribution.

Private sector vs procurement-based practices

From the very first moment in which the new LCSP came into force in 2008, **collaborative contracting** is already being mentioned, which under Spanish terminology is called CCPP (Public-Private Partnership Contract), similar to the English PPP (Public-Private -Partnership). Concretely. Art. 11 is the one that initiates the reference to this format, it is extended and completed with Art. 118, 164 and 296, among others.

- In the private sector, this type of contracting has much more difficulty in its penetration, due to the risk involved in the survival of the contracting company over such a long period of time.
- In Energy Efficiency contracts (CRE in Spanish, EPC in English), which have the same philosophy as CCPP contracts although with distinctive details, the deadlines with which they are working are much lower. Instead of 20-30 years, work with terms of 5 to 10-15 years at most. Even so, in the private sector, terms beyond the 5 years are difficult to achieve.

Another barrier in the Spanish market is that the maintenance contracts themselves, in both the public and private sectors, only exceptionally reach 5 years. The normal is between 1 and two years, and at most, 2 + 2 = 4 years. This is an insurmountable barrier to expand horizons to 20 - 30 years contracts as imposed by the philosophy of a CCPP, that is, of an IDDS.

International Contracts Considerations

It is possible to make different types of contracts, such as Integrated Project Delivery, Construction Management or Design and Build, Turn-key Projects (another Anglo-Saxon influence which did not work in Spain for the same reasons of culture and sociological profile of the sector), Lump-sum Contracts, Cost plus Fee Contracts, etc., whose main difference with Spanish public contracts is the margin left for collaboration between the parties and those who assume the responsibility and risks of the project.

To that effect, Spanish companies are accustomed to carrying out projects with these forms of public-private collaboration contracts when they compete for international contracts:

- The Directive 2014/24 of the European Union on Government Procurement
- FIDIC international contracts

- World Bank contracts

They include aspects related to proposals for changes, modifications to the project, risk sharing, which facilitate the management of projects and expedite the treatment with the contracting administration.

Source: Building and Management, Integrated Project Delivery, An alternative to the usual form of construction work in Spain. *Miguel Ángel Álvarez, Alfonso Bucero, Carlos J. Pampliega.* Vol. 1, Issue 3. September - December 2017.

What should be changed in the construction industry?

A different way must be put in place, seeking that all the stakeholder's agents have coinciding interests and share the same objectives.

- **IPD** completely focuses in this direction, and what it proposes is that from the very beginning of the design the main actors, mentioned above, work collaboratively in a single team, and that all the information of the project and of the work will be always available to all members of the same. Open books are the formula.

- **Building Information Modelling or BIM.** The development of this tool is contributing as no other to the implementation of IPD in every country.

IPD is the frame, the way to engage partners **BIM is an essential and the main tool**

The ***BIM Commission of the Spanish Ministry of Development*** has announced that from 2020 its use will be mandatory in Spain. The ***Government of the Generalitat de Catalunya*** has recently published a **White Paper** on this subject, a fully documented book on this subject.

Therefore, all the parties involved in the construction, but basically the designers (Architects, Structural and MEP Engineers, etc.) must catch up on this methodology which strengthens like never the collaborative work.

But first of all:

- In a first approach, it is more important to introduce this culture of behaviour in all the parties involved in the construction process than developing the corresponding techniques for the improvement of the whole process.

- The main work of organizations in the future will be to determine on what to base our trust and collaboration. Spain needs a serious change of mindset.

Three mayor interventions are needed to move past long-standing innovation challenges and seize the innovation opportunity According the MGI Construction Productivity Survey, and despite the proven advantages of innovation:

- Respondents ranked underinvestment in innovation only seventh out of ten root causes of low productivity.
- Digital tools to improve processes outstripped innovation in both adoption rates, and perceived impact.
- A study of profits across several industries put in evidence that innovative firms had 15 to 20% higher margins than the not innovative ones.

Innovation in the construction industry continues to be constrained by deep-seated barriers, including a lack of emphasis on R&D, a high degree of fragmentation, and widespread risk aversion. Considering this, three areas should be prioritized:

Embedding innovation throughout the organization and across the value chain Construction organizations have not fully developed the fundamental capabilities they need to innovate. The MGI Construction Productivity Survey found that a lack of internal processes to quantify and communicate the business case for innovation was most often cited by respondents as the primary reason a given technology has not been implemented. Contractors should ensure that they have a dedicated function for seeking and piloting new construction technology, a chief technology officer or chief innovation officer. One other notable aspect of embedding innovation into the organization is buying knowhow through acquisition.

Strengthening the link between technology suppliers and owners. The link between suppliers and owners is important for innovation but is often weak. In the MGI Construction Productivity Survey, the factor cited second most often was a lack of adoption of agreed standards by suppliers and their customers, an indication that the two need to work more closely.

The biggest barrier to digital technology is a lack of internal processes; for the adoption of new materials and methods, it is a lack of standards

Most important barriers to adoption by technology type
Frequency of ranking in top three most important barriers (n = 141)

● Primary barrier (most often ranked)
○ Secondary barrier (second most often ranked)

		No internal process to quantify or communicate business case and benefits	No clear industry standard yet, subs and customers need to adopt	Management not interested, no budget at project level	Frontline workers insufficiently trained or unwilling to use	Lower-cost options available
Digital	Real-time collaboration	●	○			
	Collaborative mobility solutions	●	○			
	Digitized project workflows	●		○		
	Real-time workforce production tools	○	●			
	Sensor and NFC technology	●		○		
	Pattern-/trend-based advanced analytics	●	○			
	Surveying and inspection tools	●		○		
Materials	Modular construction	○	●			
	Durable and lightweight materials		●	○	○	
Automation	Advanced automation		●			○

SOURCE: MGI Construction Productivity Survey; McKinsey Global Institute analysis

To improve this situation, owners can significantly revamp their procurement requirements to require the use of proven technologies, especially on large projects, for example by mandating the use of 5D BIM on publicly procured projects. Nordic countries were particular pioneers in this regard with several state-owned bodies requiring BIM use from 2007. Other countries such as the United Kingdom announced the mandate deadline in 2011, several years before implementation in 2016 to allow time for the transition.

- **Owners** should also adopt a reliability and life cycle-cost attitude, and work with contractors to understand the benefits of new materials and a greater array of sensors throughout the life of an asset. By taking a longer-term return on investment perspective, owners can begin to use fact-based and financially sound rationales to understand the full implications of innovations in the sector.

- **Suppliers** have an equally important role in strengthening their relationships with owners. They are often the players who are executing the most innovation, but this often goes unnoticed by the sector.

Together, owners and suppliers can work jointly on industry standards for new materials and methods, clearing the way for contractors to seamlessly take up the baton during the project.

Improving risk sharing of new approaches. Industry associations and regulators can facilitate an innovation transformation by working with owners, contractors, and suppliers:

- To define new standards for emerging innovations
- To assist in providing financial resources for pilots
- To showcase success stories

Grants and subsidies would be an effective way to support innovation. To further reduce risk aversion, owners should co-invest in technology pilots with contractors and share costs and rewards proportionally. Ideally, this could start with smaller scale projects to build confidence and experience before being deployed on larger projects. Contracting structures should also be used to ensure that the risk and reward from innovation are correctly allocated across the actors.

Source: REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY. McKinsey Global Institute. February 2017.

14.4 IDDS Scan - Situation in the Netherlands

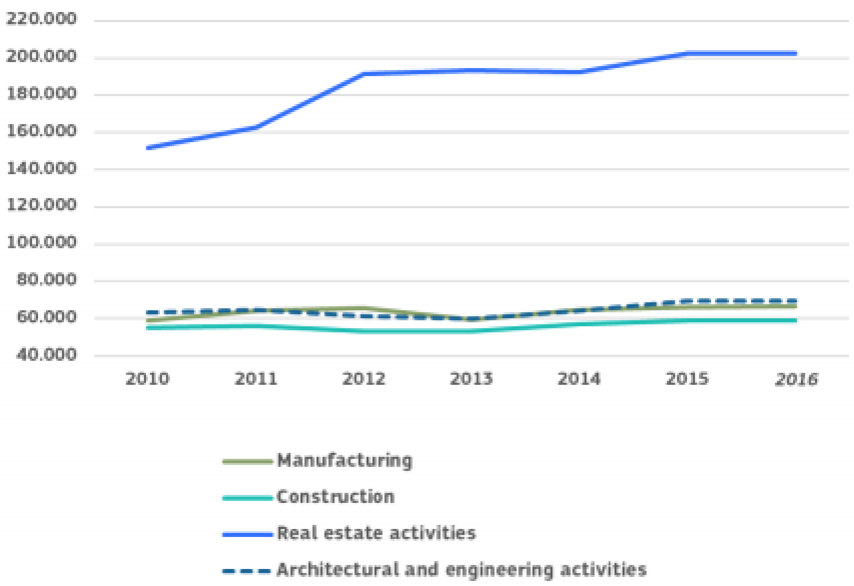
Local Context - Productivity in The Netherlands and current state

Labour productivity in the broad construction sector has shown an increasing trend of 10.1% between 2010 and 2014.

All construction sub-sectors experienced an increase of labour productivity over the period of 2010-2016.

- Real estate: activities recorded the largest increase of 33.4% in productivity, the highest among the sub-sectors.
- Manufacturing: grew by 12.4% increase over the same period.
- Architectural and engineering: Productivity increased by 9.9%
- Narrow construction: rose by 6.5%

Labour productivity in the construction sector in the Netherlands over 2010-2016 (EUR k)



Source: Eurostat, 2017.

The total turnover of the broad construction industry in 2016 increased 5.8% compared to 2010.

The construction sub-sector accounted for 61.5% of the total turnover, followed by real estate activities (18.5%), architectural and engineering activities (10.5%) and manufacturing (9.5%).

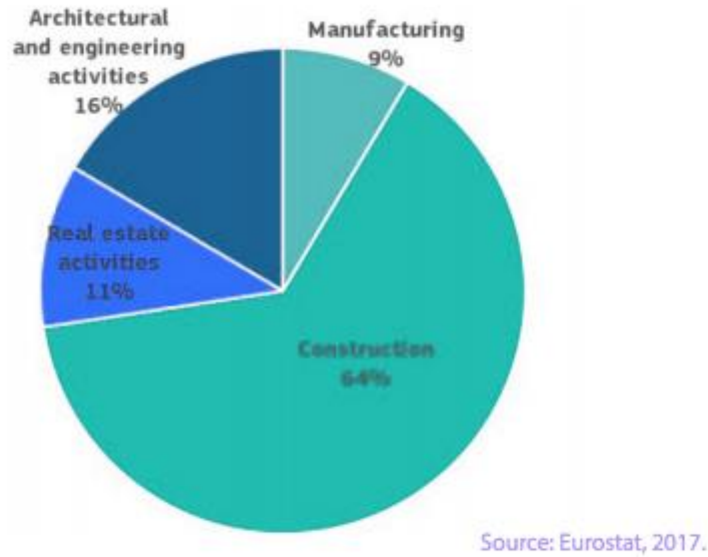
The gross operating surplus of the broad construction sector amounted to EUR 22.1 billion in 2014, 2.9% below the 2010 level.

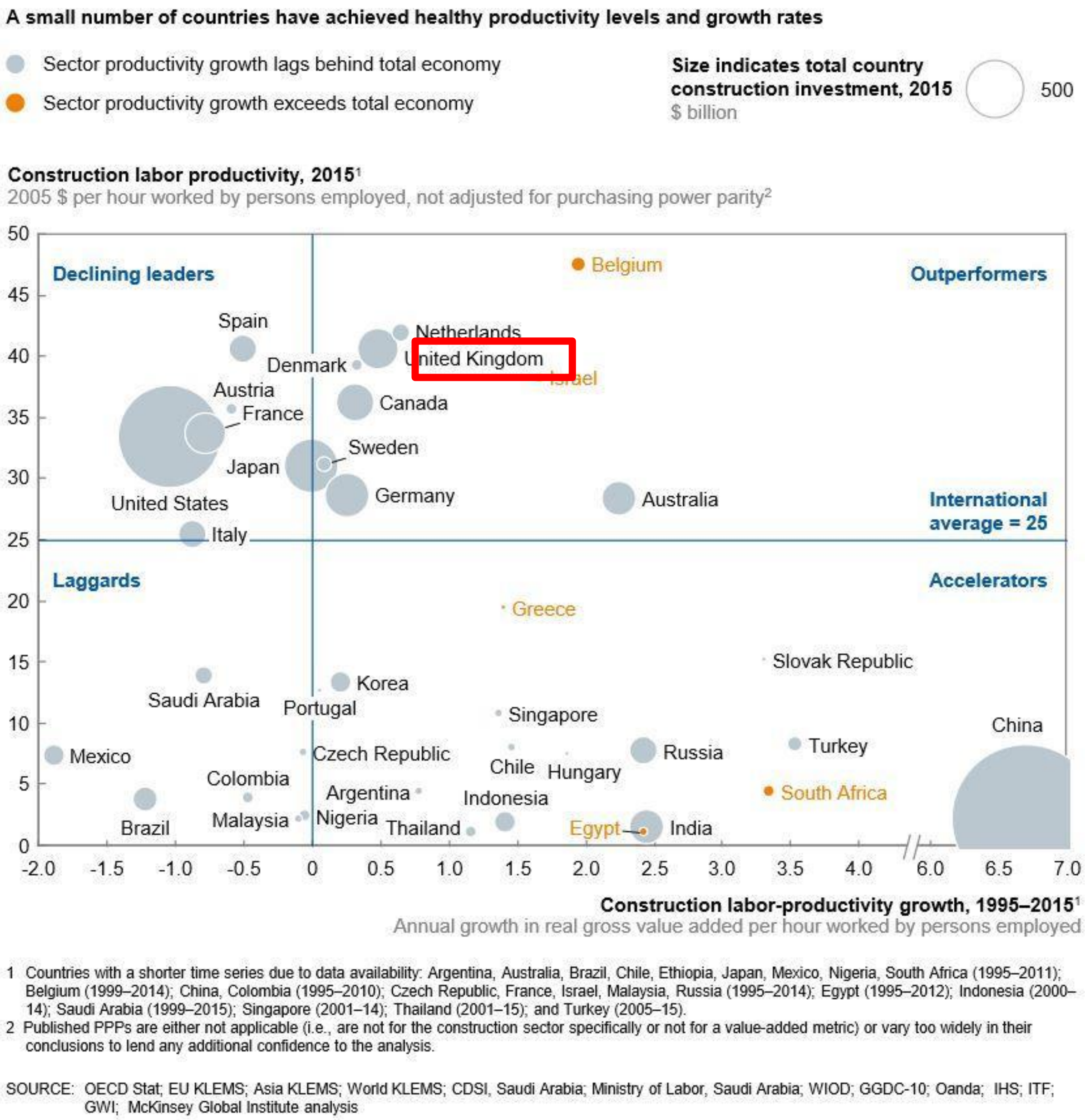
The gross operating surplus of the broad construction sector, which gives an indication of the sector's profitability, was 17.0% in 2014, 1.2 percentage points higher than 2010 (15.8%), and lower than the EU-28 average of 17.9% in 2014.

However, construction costs have been rising, with the construction cost index experiencing a 9.0% increase over 2010-2016, due to increasing material prices (+8.0%) and particularly labour costs (+11.0%), thus threatening the profitability of the sector (Figure 7).

Lower revenues linked with the increased number of enterprises and increasing costs suggest strengthening of competition in the construction sector, especially among self-employed and SMEs.

People employed by construction sub-sector in the Netherlands 2016 (%)





Lean Construction. Situation in the Netherlands

Since clients are increasingly demanding high-quality and reliable products at low cost, and the construction industry faces an increased competitiveness caused by globalisation and deregulation, established firms need to revise their strategy. These firms need to do so by building on their competitive strengths through a deliberate and managed process to improve the capacity and effectiveness of the industry and to support sustained national economic and social objectives (Stewart and Spencer, 2006). Their study suggests that this development, in part, can be achieved by learning how to increase efficiency and productivity through process improvement.

Different universities have agreed together with several SME-construction companies to develop a "toolbox" to enhance the productivity within the Dutch Construction Market. The adoption of LEAN Construction is growing, but typically it's only being adopted within a subset of the project team and there's a lack of an integrated vision throughout the entire project organisation.

Business as usual practices

Next to the adoption of LEAN Construction, public owners typically require the contractor to apply Systems Engineering (SE) to assure quality.

Systems engineering is an interdisciplinary field of engineering and engineering management that focuses on how to design and manage complex systems over their life cycles. At its core, systems engineering utilizes systems thinking principles to organize this body of knowledge. The individual outcome of such efforts, an engineered system, can be defined as a combination of components that work in synergy to collectively perform a useful function.

Issues such as requirements engineering, reliability, logistics, coordination of different teams, testing and evaluation, maintainability and many other disciplines necessary for successful system development, design, implementation, and ultimate decommission become more difficult when dealing with large or complex projects. Systems engineering deals with work-processes, optimization methods, and risk management tools in such projects. It overlaps technical and human-centered disciplines such as industrial engineering, mechanical engineering, manufacturing engineering, control engineering, software engineering, electrical engineering, cybernetics, organizational studies, civil engineering and project management. Systems engineering ensures that all likely aspects of a project or system are considered, and integrated into a whole.

Basic principles of SE can be found as well in the PAS 1192 which is in the process of becoming an ISO standard for BIM.

Applicable laws

The Ministry of Housing, Spatial Planning and the Environment is in charge of establishing the rules for construction.

"Construction agreement" of the Civil Code defines the general contractual liabilities among parties in the construction sector, including the duties of the partners, the liabilities for materials and equipment, the reparation of construction defects or the dissolution of the construction agreement, among others.

Further to the provision of the Civil Code, the general conditions, and in particular the uniform general conditions with regard to building contracts (UAV), are also widely used. The UAV contracts establish a period of liability of 5 years following the completion of the works, and a statutory warranty period of ten years is generally defined for building defects.

Legal provisions of the contracts

In the Netherlands, as well as in the Scandinavian countries, the legal provisions of the contracts generally act as standard clause acts, constituting the main reference for formation of contractual relations in the construction sector.

Therefore, liabilities are often defined in the contractual agreements. However, the large variety of contract models may hinder the understanding of these liabilities. In order to tackle this issue, the Dutch Institute for Construction Law (Instituut voor Bouwrecht) has issued a practical guide that compiles and summarises the main features of construction contracts.

In the Netherlands, there is no mandatory obligation to acquire an insurance for construction parties as such. However, it is often agreed in the contract that the contractor must insure the works to be conducted. Contractors' All Risks (CAR) is the most common insurance in the construction sector, covering all damages that may arise during the construction process.

Building regulations

The three main pieces covering all aspects of building regulations are

New Housing Act: The New Housing Act (Nieuwe Woningwet), which entered into force after revision in July 2015, defines the core tasks and activities of housing associations, as well as the procedures relative to construction and the provision of construction permits. In addition, the Housing Act also ensures a clear separation of Services of General Economic Interest (SGEI) activities and non-SGEI activities.

The Building Decree: The Building Decree (Bouwbesluit) records requirements and establishes minimum criteria for health, safety, usability, energy efficiency and the environment for the construction of buildings in the Netherlands. In addition, the Building Decree sets the regulatory framework regarding the refurbishment, construction, demolishment and occupancy of any building in the Netherlands.

The Spatial Planning Act: The Spatial Planning Act (Wet op de Ruimtelijke Ordening) defines what may be built, where the construction can take place as well as the size and structure of the construction project depending on rules and regulations established in the area concerned. The implementation of the Spatial planning policy is mainly drawn at municipal level due to their knowledge of the local environment, and their interest are presented on spatial visions, which are policy papers summarising the priorities for infrastructure and Spatial Planning. In addition, due to highly regulated use of land for residential and business purposes, the Zoning plan contains regulations on a detailed scale for every plot of land in a municipality.

These regulations indicate and determine the use of the plot (i.e., agricultural, industrial, residential, etc.) as well as the dimensions (building height, volume, number of stories) of the buildings permitted and the exact location of a new building on a plot of land. The Zoning plan is the decisive mechanism for allowing or denying a general environmental permit (omgevingsvergunning) by the municipality of each region.

Barriers in the construction sector

Company failure

The business demography in the broad construction sector has been fluctuating showing similar trends across most sub–sectors.

Company births in the narrow construction sub-sector slightly increased by 1.1%. Conversely, the number of company deaths dropped by 17.3%. Similarly, the real estate activities sub-sector experienced a 0.4% drop in company births and 16.5% in deaths. Company births in architectural and engineering activities declined by 3.6% whereas company deaths increased by 18.7%. Nevertheless, the net amount of enterprises has been on the rise.

The number of companies in the Netherlands being declared bankrupt continues to decrease, showing an improvement in the national economy. According to Statistics Netherlands, the number of bankruptcies is recorded at its lowest level since 2001.

Trade credit

In 2017, 35% of domestic and foreign B2B sales were made on credit. This shows that the Netherlands is fairly open to granting trade credit to B2B customers.

Domestic customers: 39% of the sales were transacted to domestic B2B customers

Foreign customers: only 31% of the sales to foreign B2B on credit

Total amount of B2B sales on credit is below the regional average of 38.8% and almost in line with that of Spain, stood at 37.8%. Like many other Western European countries, respondents in the Netherlands were more unwilling to offer credit terms to foreign B2B customers, highlighting a greater degree of trust when trading with domestic B2B customers.

Late payment

The Netherlands reported a generally good public administration-to-business payment (PA2B) behaviour.

The average time taken by customers to pay improved between 2016 and 2017. European Payment Risk Index shows that the situation improved.

The main causes of late payments were:

inter alia

debtors

financial difficulties

administrative inefficiency

intentional late payment behaviour

Specifically, the construction sector generates a high proportion of overdue invoices, mainly due to liquidity constraints, and outstanding invoices are often used as an equity management strategy. 41% of construction companies experience issues of late payments by their clients. Since mid-2017, agreements on a longer term of payment exceeding 60 days have been prohibited as a new law has been implemented, which aims to improve the conduct of major contractors.

Time and cost obtaining building permits and licenses

The Netherlands ranked 76th in 2018 with respect to “Dealing with construction permits”, according to the World Bank Doing Business, better than the previous year (87th in 2017).

Procedures are required to build a warehouse, higher than the OECD high-income average (12.5), taking 161 days, above the OECD high-income average (154.6).

The cost of building a warehouse represents 3.7% of the value of the warehouse, above the OECD high-income average of 1.6%.

Skills shortage

The number of job vacancies in the construction sub-sector experienced a 9.4% drop since 2010, reaching a bottom low in 2013. The number of job vacancies in real estate activities increased by 5.6% over the same period, following a bottom low in 2013. The situation has been improving since 2013. The number of job vacancies in construction has doubled over 2016-2017. In parallel, adult participation in education and training in the construction sub-sector slightly declined by 2.2% from 17.7% in 2010 to 17.5% in 2015.

On the contrary, in real estate activities, this rate has increased by 3.4%, from 26.3% to 27.2% over the same period. The number of tertiary students in engineering, manufacturing and construction, specifically in architecture and building, increased by 21.4% between 2010 and 2012.

The Dutch construction sector risks a shortage of skilled workers and an inappropriate vocational education training (VET). According to the Building and Infrastructure Contractor Federation (AFNL) and the Dutch Business Association of Finishing Companies (Nederlandse Ondernemersvereniging voor Afbouwbedrijven – NOA), VET is too general and theoretical, as opposed to being more practical and hands-on, lacking the connection to specific jobs.

This fact is reinforcing the issue of skill shortages, which is particularly evident for professions such as bricklayers, carpenters, installation controllers, roofers and plasterers as a consequence of the crisis. A lack of qualified employees in the construction sector is threatening factor to slow down economic growth, especially due to the rapid growth of the sector.

The number of students enrolled in VET for these professions has declined. This drop is also partially due to the lower salaries paid by SMEs to apprentices, and to the fact that SMEs are more reluctant to hire permanent workers, due to the high social costs involved. Furthermore, the construction sector is confronted with the ageing of its current workforce.

Sector and sub-sector specific issues

Material efficiency and waste management:

In 2012, the Netherlands reported a total amount of 81.4 million tonnes of construction and demolition (C&D) waste, a 4.2% increase compared to 2010 and 38.2% above the 2008 level.

According to Waste Processor Renewi (major European player in waste management and recycling), there is a significant increase in the amount of C&D waste on the Dutch market, driven by the recovery of the housing market in 2017.

The main piece of legislation encompassing all national environmental legislation is the Environmental Management Act (Wet Milieubeheer – Wm), which sets out an integrated approach to environmental management in the Netherlands and defines the roles of the national, regional, and municipal government.

Specifically, waste is addressed under Chapter 10 of the Wm. Moreover, waste policy is described under the second National Waste Plan (LAP-2), which includes waste management plans for each sector as well as targets. For C&D waste, the target is to maintain the 95% recovery rate until 2021.

Recently a new platform called "Madaster Foundation" was initiated by architect Thomas Rau in 2017 which improves the construction waste management.

This foundation develops a 'material passport' for the purpose of registering how much it is possible to reuse construction material based on the value, quality and the life span of a building or pieces of a construction object. In this way, the platform provides opportunities to save costs, increase reuse percentages and ultimately eliminate waste. The development of material passports in the construction and real estate sectors will result in smarter building designs.

Climate and energy:

Emissions of greenhouse gases from activities related to construction and real estate in the Netherlands amounted to a total of 3,344,295 and 339,311 tonnes in 2015.

Emissions in the construction sub-sector have decreased by 9.0% and the real estate sub-sector experienced a 33.2% drop during the period 2010-2015, demonstrating that emissions have been decreasing compared to 1990 levels.

Private sector vs Procurement-based practices

Local projects

Private sector contracts are usually bespoke, a custom fit for the needs and requirements of the project and participants. They are derived from standards in place for both private and public works designed to assist the involved parties. Traditional contracts usually refer to UAV 2012, a general terms of agreement consisting of procurement and delivery conditions. Integrated contracts, such as design and build, refer to a customised version: UAV-GC 2005.

The same standards are applied for public projects. In addition, there is a procurement law based on the European guidelines in place: Aanbestedingswet 2012.

International Contracts Considerations

There is no real difference between local and international market practice and the usual contract forms include design and build, EPC (engineering, procurement and construction), EPCM (engineering, procurement and construction management) and guaranteed maximum price contracts. For international projects, the contracts issued by FIDIC (Fédération Internationale des Ingénieurs Conseils) are usually referred to in The Netherlands.

What should be changed in the construction industry?

One of the main issues in construction is its low productivity rate. There have been many individual efforts trying to improve but there's a lack of vision and coherence. To tackle this issue, the whole supply chain needs to be taken into account. An integrated management approach will be key to adopt a LEAN construction process.

To support this approach, the digitalisation of construction needs to be embraced and implemented pro-actively. New technologies are constantly being developed and introduced in different industries, with success. The construction industry is known to be hesitant in adopting these technologies and still relies heavily on manual labour and old machinery. With the adoption and standardisation of BIM

(Building Information Modelling) and SE (Systems Engineering) techniques, construction processes will improve substantially.

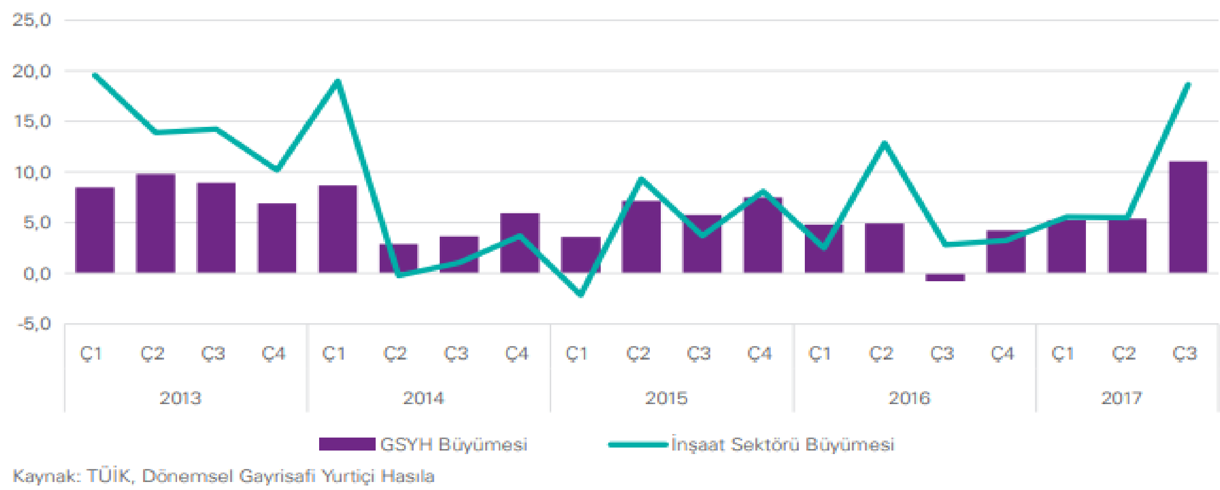
Regardless of digitalisation, a practical education is still key for the construction sector. The Vocational Education and Training (VET) is too theoretical as opposed to a more hands-on approach. There should be a healthy combination of theory and practice with a focus on future-proof skills.

14.5 IDDS Scan - Situation in Turkey

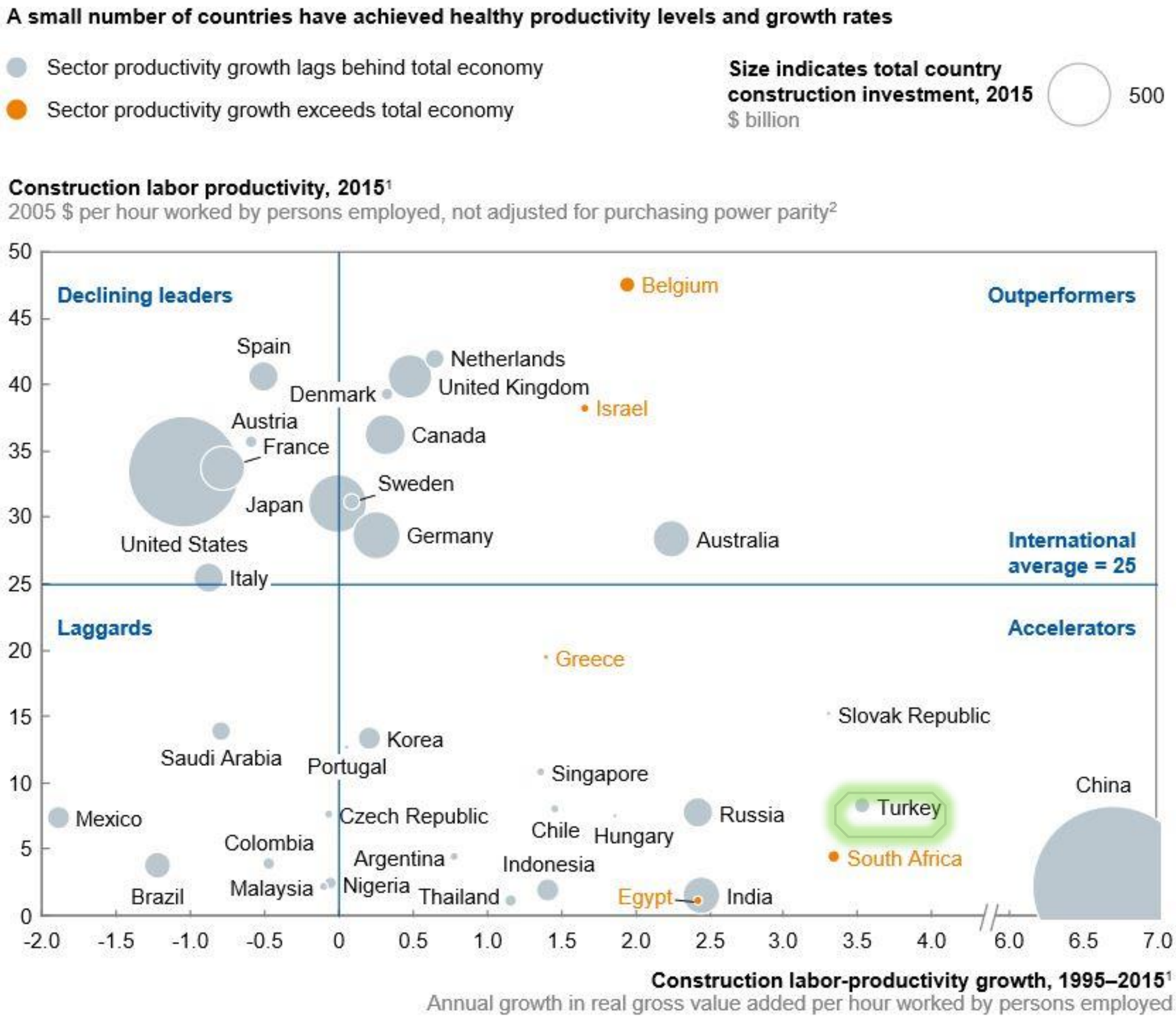
Local Context - Productivity in Turkey and current state

GDP and Construction Sector Growth (2013-2017)

As of 2017, construction sector share in global economy happened as 15%. By 2025, sector share in developed countries is predicted as 10%, and in developing countries as 17%. Construction has been the leading sector (9% of GDP) in Turkey in the last decade. The urban transformation law based on a large proportion of buildings in urban areas that are non-resilient to seismic activities enabled the sector to significantly grow up. As the number of old and resilient buildings is almost negligible, new construction is the dominant activity in the sector.



The table below shows results taken from respondent employees in a variety of Turkish construction companies as homogeneously distributed, and reflects the values of opinions on lean construction fulfilment of the construction sector.BIM use, however, is still at beginning phase and only used in large scale PPP projects such as Istanbul Airport etc., where international companies are part of consortiums.



1 Countries with a shorter time series due to data availability: Argentina, Australia, Brazil, Chile, Ethiopia, Japan, Mexico, Nigeria, South Africa (1995–2011); Belgium (1999–2014); China, Colombia (1995–2010); Czech Republic, France, Israel, Malaysia, Russia (1995–2014); Egypt (1995–2012); Indonesia (2000–14); Saudi Arabia (1999–2015); Singapore (2001–14); Thailand (2001–15); and Turkey (2005–15).
2 Published PPPs are either not applicable (i.e., are not for the construction sector specifically or not for a value-added metric) or vary too widely in their conclusions to lend any additional confidence to the analysis.

SOURCE: OECD Stat; EU KLEMS; Asia KLEMS; World KLEMS; CDSI, Saudi Arabia; Ministry of Labor, Saudi Arabia; WIOD; GGDC-10; Oanda; IHS; ITF; GWI; McKinsey Global Institute analysis

Lean Construction. Situation in Turkey

IPD practices are only used in few projects that are green building certified. IPD is not really implemented in usual practices and seems it will take years for the industry to fully indigenise this delivery method. An advantage of the residential sector is that design-build method is commonly used for residential construction, which brings opportunity for contractor, designer, engineer and other technical staff to work in close contact. However, owner, end user and other parties are usually out of the scope.

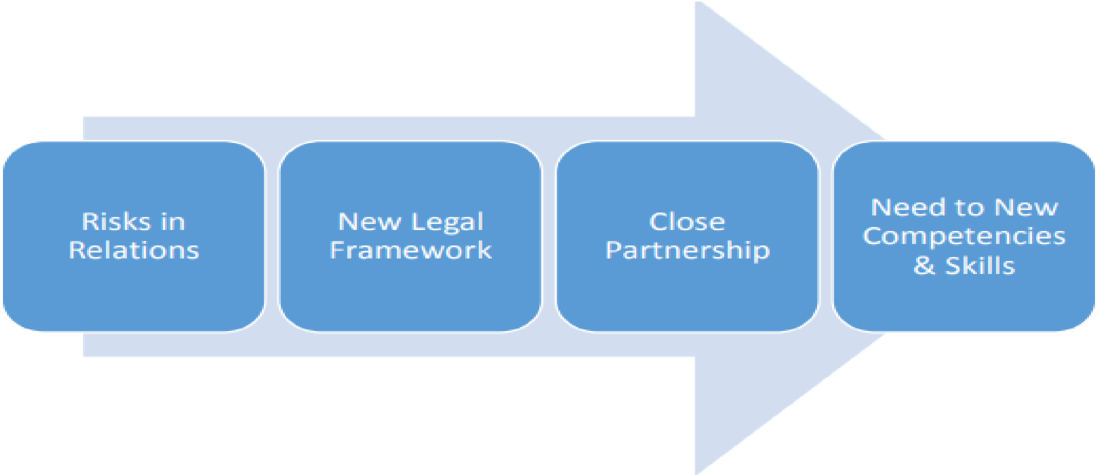


Figure 4. Reasons to slow adaptation of AEC industry with IPD

Table 7. Percent Fulfillment of Classified Groups

	Percent fulfillment				
Classified group (U.S. dollars)	Culture/ people	Continuous improvement/ built-in quality	Customer focus	Elimination of waste	Standardization
Small companies ($1–$10 million)	67.62	68.00	61.43	67.78	67.50
Medium–small companies ($10–$100 million)	64.89	67.20	61.33	69.93	68.33
Medium–large companies ($100–$1,000 million)	82.78	79.67	78.75	82.41	85.42
Large companies (>$1,000 million)	75.56	89.33	86.67	90.37	83.33

Sources: Exploring the BIM and lean synergies in the Istanbul Grand Airport construction project, Mehmet Sakin et al, 2018
Lean Construction Conformance among Construction Contractors in Turkey, Yasemin Nielsen et al, July 2013
ATTITUDE OF TURKISH AND MIDDLE EASTERN ARCHITECTURE ENGINEERING CONSTRUCTION (AEC) INDUSTRY TOWARD INTEGRATED PROJECT DELIVERY (IPD) SYSTEM, Ali Sharefi Abadi, 2015

Business as usual practices

Design Bid Build and Design Build are the most common project delivery methods in Turkey. In PPP projects and any large-scale public projects, DBB is mainly used; whereas in residential construction sector, especially under the urban transformation law, DB is the main method.

IDDS concept is slowly emerging via BIM use and IPD method implementation, but as the Turkish residential construction industry is a dynamic sector, it seems that it will gain acceleration with more lean construction applications, if necessary steps are taken in the economy and regulations.

Some findings on IDDS in Turkey are as below;

- People who are experienced in IPD/IDDS prefer to participate in IPD projects more than those who are not experienced
- In Turkey and Middle Eastern countries, experienced people claim that their work model is not adjustable for IPD. Therefore, fundamental changes should be applied.
- The most suitable delivery method for IPD seems to be DB
- Turkey and Middle East sector players believe that BIM is the main prerequisite of IPD
- Individuals believe that in the upcoming 5 to 10 years IPD/IDDS will gain almost 5% to 10% of the construction market share in Turkey and the Middle East.

Source: ATTITUDE OF TURKISH AND MIDDLE EASTERN ARCHITECTURE ENGINEERING CONSTRUCTION (AEC) INDUSTRY TOWARD INTEGRATED PROJECT DELIVERY (IPD) SYSTEM, Ali Sharefi Abadi, 2015

Applicable laws

Sustainability, Environment and Energy Efficiency Laws

Turkey does not have any applicable laws considering BIM, IDDS and IPD yet. Choosing a sustainable path for the construction of an asset is up to the design team or building owner. On the other hand, Turkey has introduced some regulations concerning energy efficiency, building materials and environmental protection over time.

First regulation considering the energy efficiency, TS 825 was issued in 1970. However, this regulation did not reach its goal since it was not mandatory to follow. Since from then, TS 825 was revised and updated and finally got accepted in 2013. TS 825 sets the minimum standards for isolation material thickness for buildings for each climate zone in Turkey. Also it introduces a upper limit for heat energy used for heating per meter square.

(Classification of the climate causes problems with compability with high-energy efficiency directive for buildings since the cooling days are not included.)

Environment Protection Law (Law 2872/1983) was the first law in Turkey introducing terms such as sustainability and ecology. It is considered as the pioneer of regulations such as renewable energy directives, recycling and anti pollution.

Energy efficiency law (Law 5627/2007) legislated in order to promote the efficient use of energy sources and reduce the energy waste thus energy consumption. Legislation covers broad aspects from energy production to energy transmission to educational reforms that includes raising the awareness. Also, the law obligates having an energy performance certificate for buildings and heating/cooling systems. For the new constructed assets, the lower limit of the energy grade is determined as C. Moreover, buildings with central heating system are obligated to have central and local temperature control systems. In the scope of the regulation, incentives are given to the businesses that reduce their energy use.

Following the Law 5627/2007 and the EU Directive 2002/91/EC, Building Energy Performance Directive was legislated in 2008. As the name suggests, main aim of the directive is to promote the efficient use of energy and resources in the built environment. With this legislation "energy identity certificate" that contains information about the minimum energy demand and energy consumption classification, insulation specifications and technical aspects of the heating/cooling systems used, is introduced. For the built environments, it is obliged to have energy identity certificate and expiration time is set to 10 years. If an alteration regarding the building's energy consumption, the certificate is obliged to be renewed within a year. Moreover, passive energy solutions such as natural ventilation and optimised design for sunlight are promoted with this legislation. However, implying these solutions are not mandatory.

Considering integrated project delivery, existence of the standards and applicable laws are mentioned in General Directorate of Renewable Energy "Integrated Building Design Approach" 2016 and necessity of regulating applicable standards and laws are addressed as future work.

BARRIERS in the TURKISH Construction Industry

Financial Issues

Fluctuating currency exchange rates creates difficulties in planning imported construction materials and equipment. Some fundamental materials, such as reinforcement steel, are also dependent on currency rates.

Another financing issue is the interest rates, which have been very low for several years and allowed the construction sector to flourish. Increasing interest rates creates barriers for a rapidly grown sector.

The payment of instalments and long term contracts may be interrupted by the current financial situation of the stakeholder in debt. This creates a chain of financial issues in the sector. Another issue with long term contracts is currency: stakeholders are reluctant to make long term contracts on fixed prices due to possible devaluation. However, such contracts are needed to manage the cash flow of large projects.

Domestic construction material production is facing decreases in some materials. Fluctuating demand and financial environments causes manufacturers to reduce production volume. However, export rates are increasing.

Regulatory issues

The Public Procurement Law is subject to small and continuing changes. Also, zoning and building permit prerequisites may change. These incur unexpected costs and delays in the construction timespan when the site falls under the category of buildings responsible for the new regulations as well.

Contractors are unsatisfied with regulatory gaps allowing unjust competition. Large projects may be tendered in smaller parts, allowing more contractors to bid with less prerequisites. This results in very low bids and makes competition difficult for qualified contractors. Also, such low bids may end in unfinished projects or other issues in the process.

Demand issues

The contruction sector has an impact on 30% of the national economy. As a sector that has grown rapidly in recent years, it has reached a point where housing supply exceeds demand at some points. The June 2019 report of Association of Turkish Construction Material Producers (IMSAD) states that housing sales in the first 5 months of 2019 has regressed 19.2% against the first 5 months of 2018.

Skilled labor issues

While Turkey has a large base of experts at various levels of the construction value chain, some positions stand as barriers. The education system provides fewer paths for intermediate level technical experts, such as qualified craftsmen. Universities mostly train engineers and higher level experts and laborers are generally uneducated. Also, being open to innovation is a barrier for most levels. Even for engineers and architects, concepts such as IDDS are beyond business as usual.

Private sector vs. Procurement-based practices

Public buildings in Turkey are procured in compliance with law no. 4734 which defines three types of tenders: open, restricted or negotiated. Restricted tenders accept bids from a pre-selection of candidates and negotiated tenders open a negotiation between candidates, however, choosing these over open tenders need to be justified based on project requirements. Open tenders allow bids from any interested party that qualifies for the project based on gross areas of previously completed projects. The winner is chosen as the lowest bid that satisfies the technical baseline requirement.

Private projects are free to follow their preferred procurement method and contract type. Some projects choose to follow routes similar to public projects, while some have their own networks and selection methods.

Compliance with regulation is controlled in a similar way for public and private projects. Building inspection agents and site security experts are hired for each construction and are responsible for the compliance of processes, implementation quality and regulatory requirements.

Local projects

For local projects, open tenders in public buildings deter the practice from innovation by favoring the lowest bid. Adding prerequisites that are not common in the market is not preferred as it may mean the few bidders capable of it have an unjust competitive advantage and other stakeholders are excluded. However, to force the market to develop higher level skills, this may be required. Also, this created design stage concerns regarding the applicability of innovative solutions that would be included in the design.

The private sector is driven by profitability. However, as noted in the barriers defined in this report, lower demand makes the sector highly competitive. This competition is often in terms of cost, but allows few stakeholders to seek marketing advantage through innovation. While innovation in processes, such as IDDS, has less marketing opportunity, this competitive situation allows some private investors to invest in green design related components. IDDS can find a niche in the private sector, which is more adaptable but also more brittle than the public sector, through proven advantages in terms of time and cost. This needs to be lead by example.

Currently, the public sector with its more sound financial models and responsibility to lead by example funds some pilot projects to improve business practices. However, once an application is proven, the private sector is quicker to exploit it while the majority of public projects remain very conventional.

International Contracts Considerations

International contracts are subject to the corresponding international standards and prerequisites such as the FIDIC standard. Turkish construction companies are involved in diverse geographical areas, and also with international funds available in Turkey. The stakeholders of the Turkish contruction sector are known to work with different frameworks and standards when required, however, they may not meet a standard they can work with when it is enforced when it is not required due to cost considerations.

A barrier in international projects is that due to regulation, banks require higher amounts of capital to provide letters of bank guarantee.

What should be changed in the construction industry?

- Education for academic people and relevant trainings for industry members on BIM/IDDS/IPD to have efficient use of technology and processes are necessary, BIM management should be developed in terms of skills, processes and technologies.
- Collaboration culture needs time, but should be developed within the industry. Culture of mistrust should be replaced with the collaboration.
- Innovation should be prioritized and disseminated.

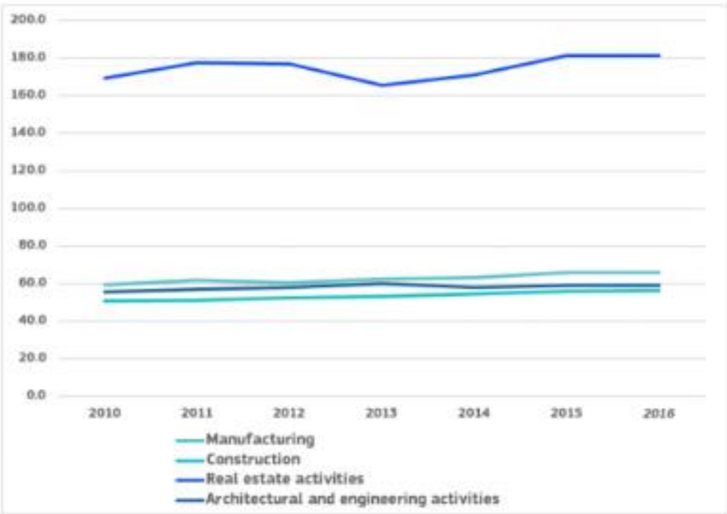
- Stakeholders need to go through a change in paradigm, adopting digitalized solutions and understanding green building concerns. This has roots in the education of sector professionals, and also the demands of large project tenders.
- State of the art technologies should be disseminated and models for their exploitation should be developed for them to be adopted at scale.
- Regulations should be adapted to the changing trends and methods of the construction industry, while collaborating with the construction industry to create regulations that stakeholders can adopt.
- New standards for the new paradigm should be formed.
- New financial models should be developed to create opportunities to invest in innovation.
- Comprehensive insurance systems from government and financial institutions and risk sharing methods are necessary.

14.6 IDDS Scan - Situation in Austria

Local Context - Productivity in Austria and current state

Productivity in building construction in Austria fell by 3.6% between 2008 and 2010. Despite a subsequent period of growth, productivity in 2014 was still 1.6% below the level reached in 2008. Civil engineering productivity experienced a similar trend. Following a decline of 15.2% between 2008 and 2010, productivity was still 2.9% below the pre-crisis level in 2014. Despite the challenging economic environment however, the number of enterprises in the broad construction sector increased by 17.6% between 2008 and 2013.

The workforce in the broad construction sector rose by 8.9% between 2010 and 2016. This was accompanied by a 1.2% increment in production in construction of buildings and a 10.8% growth in production in civil engineering over 2010-2016. The total turnover of the broad construction sector amounted to EUR 80.4 billion in 2016, a 13.2% increase compared to 2010 and the highest ever since, while the gross operating surplus of the broad construction sector amounted to EUR 13.8 billion in 2014, 9.8% below the 2010 level.



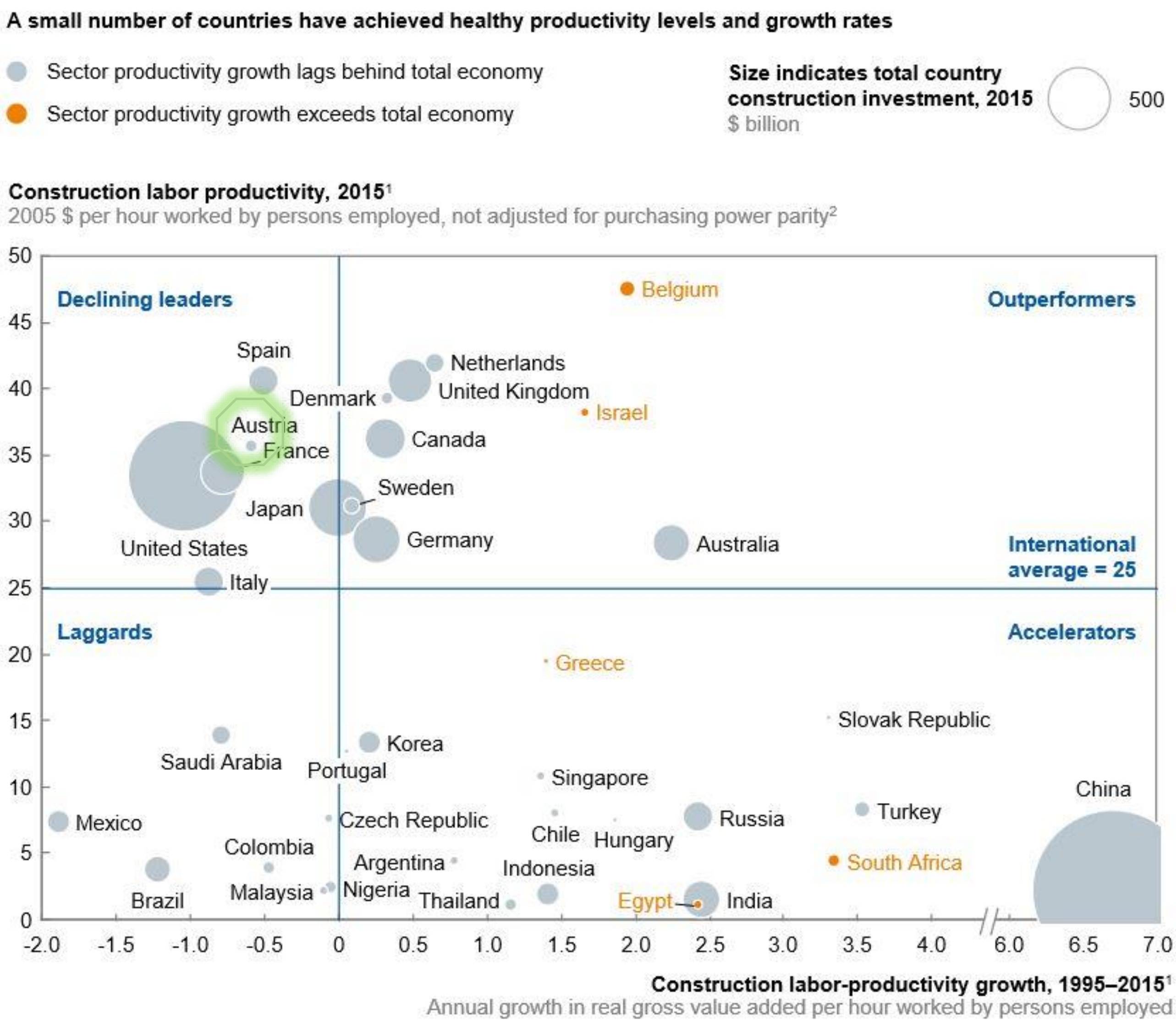
Source: Eurostat 2018

Labour productivity in the construction sector in Austria over 2010-2016 (EUR k)

The gross operating surplus of the broad construction sector amounted to EUR 14.2 billion in 2013, 2.8% below the 2008 level. In contrast, the total turnover of the broad construction sector amounted to 7.7% increase compared to 2008, and employment rose by 5.3% between 2008 and 2013.

The housing market is showing the clearest signs of recovery. The growth of disposable income and improving consumer confidence are boosting the purchasing power of households and the demand for housing. The residential house price index in Austria has experienced solid growth of 30.2% between 2010 and 2015 and the number of residential property transactions in the country reached 112,124 units in 2015, up 16.6% on the previous year.

The outlook for the industry remains modest with an average annual growth rate of 1.17% over the period of 2016-2020, mainly driven by investments in inland infrastructure.



1 Countries with a shorter time series due to data availability: Argentina, Australia, Brazil, Chile, Ethiopia, Japan, Mexico, Nigeria, South Africa (1995–2011); Belgium (1999–2014); China, Colombia (1995–2010); Czech Republic, France, Israel, Malaysia, Russia (1995–2014); Egypt (1995–2012); Indonesia (2000–14); Saudi Arabia (1999–2015); Singapore (2001–14); Thailand (2001–15); and Turkey (2005–15).
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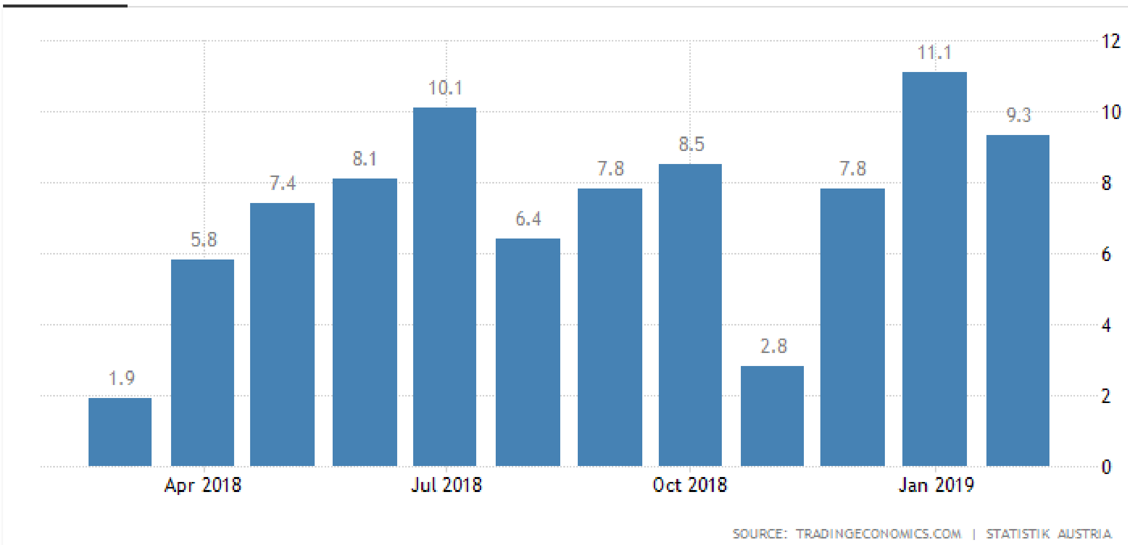
SOURCE: OECD Stat; EU KLEMS; Asia KLEMS; World KLEMS; CDSI, Saudi Arabia; Ministry of Labor, Saudi Arabia; WIOD; GGDC-10; Oanda; IHS; ITF; GWI; McKinsey Global Institute analysis

Construction output in Austria increased 9.30 percent in February of 2019 over the same month in the previous year. Construction Output in Austria averaged 3.25 percent from 1997 until 2019, reaching an all-time high of 25.40 percent in January of 1997 and a record low of -13.10 percent in February of 1999.



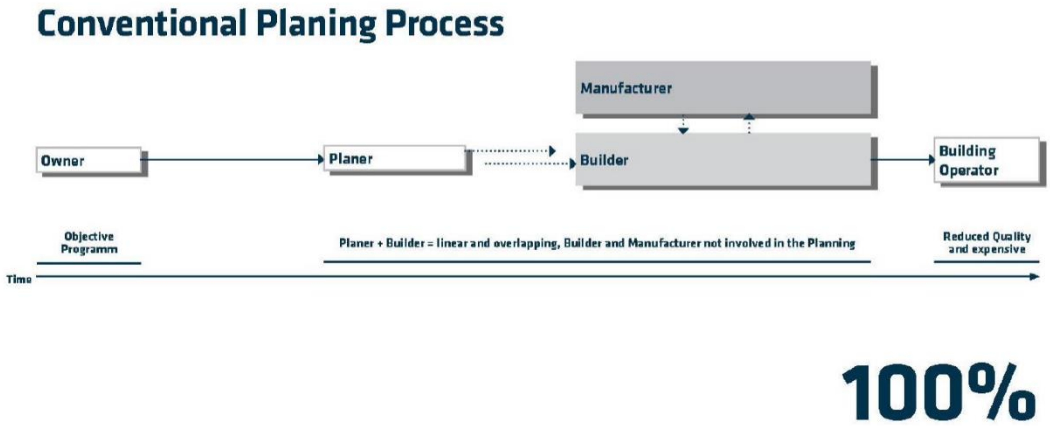
Source: Insight into Construction in Austria by the European Construction Sector Observatory by Simon Hardiman

Lean Construction. Situation in Austria

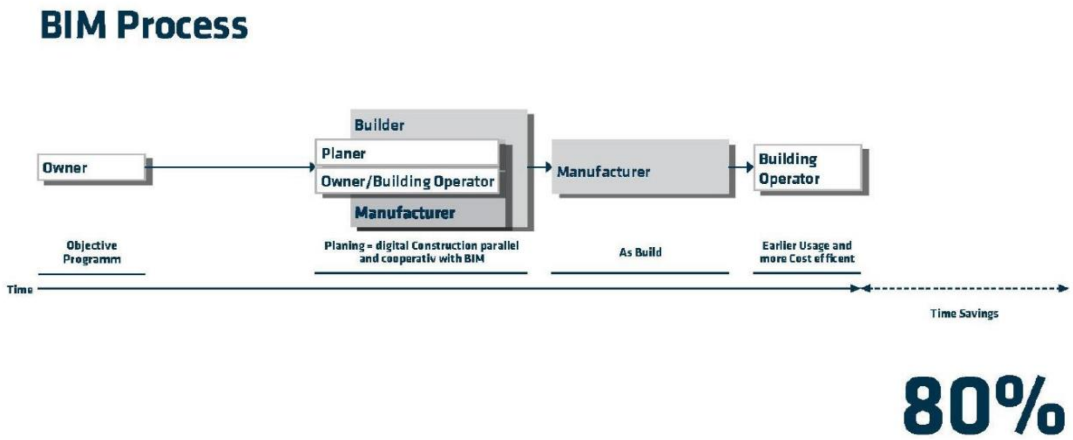
The Lean Construction is not a big thing in Austria yet, but there is some movement in this topic. In 2018 and 2019 were some conferences regarding to Lean Construction in Austria and there is a working group including developers, contractors and clients which is working on launching the Austrian Lean Construction Institute. The aim of the working group is to develop recommendations on how the topic of Lean Management can be implemented in Austria. This could work for example under the roof of the German Lean Construction Institute. In Austria, a regional group could be founded, which then cooperates on equal terms with the German organization.
Source: Arbeitskreis Lean Management

Business as usual practices

In contrast to developments in other European countries, the economic separation of planning and execution has established itself in German-speaking countries due to contracting guidelines. This guarantees independence from economic interests in planning. In prefabricated timber construction, this method reaches its limits. The first contact between the planner and the executing company takes place after this planning process. This means there must be made a redesign, which means a lot of extra work.



This problem can be solved using the BIM Process. All stakeholders are involved in the planning process so that changes can be made to the model, costly and time-consuming modifications at the construction site can be avoided.



Applicable laws

In Austria there are nine different building regulations in the federal states, because the building industry is subject to state legislation. In 2008 most of the technical regulations were harmonized. The basis for this are the OIB Directive Guidelines 1 to 6 prepared by the Austrian Institute for Construction Technology.

OIB Directive Guideline 1	MECHANICAL STRENGTH AND STABILITY	
	OIB Guideline 1	Determination of the load capacity and serviceability of existing structures
OIB Directive Guideline 2	FIRE PROTECTION	
	OIB Guideline 2	Deviations in fire protection and fire protection concepts
	OIB Guideline 2.1	Fire protection in industrial buildings
	OIB Guideline 2.2	Fire protection for garages, covered parking spaces and parking decks
	OIB Guideline 2.3	Fire protection for buildings with an escape level of more than 22m

OIB Directive Guideline 3	HYGIENE, HEALTH AND ENVIRONMENTAL PROTECTION	
OIB Directive Guideline 4	SECURITY OF USE AND ACCESSIBILITY	
OIB Directive Guideline 5	SOUNDPROOFING	
OIB Directive Guideline 6	ENERGY SAVING AND HEAT PROTECTION	
	OIB Guideline 6	Calculation of the cost-optimal requirement level
		Energy-technical behaviour of buildings
		National plan

Source: *Bauordnungen und Raumordnungsgesetze der Bundesländer,* Wirtschaftskammer Österreich

Barriers in the construction sector

The construction industry in Austria has a low return of sale in comparison to other industrial sectors. KMU Forschung Austria cites a return on sales of about 3% for small and medium-sized companies and 2% for large companies. One third of the construction companies operate at a loss. According to data from the Kreditschutzverband (KSV1870), the insolvency ratio of 2.3 % is the highest in all sectors and is only exceeded in the absolute number of insolvencies in retail.

In contrast to the manufacturing industry, the construction company often does not have full control over the entire process consisting of planning and manufacturing but is dependent on interactions across operating and contractual boundaries. Additional companies between the client and the ultimately executing subcontractor make construction processes highly complex, complicate logistics and are a source of costs due to the additional administrative effort and risk.

The uncertainty of costs and deadlines can be identified as a further business management problem. A study of 258 construction projects has shown that 9 out of 10 infrastructure projects exceed costs and that no improvement has been observed over the past 70 years. On average, the costs are exceeded by 28%.

The construction industry contributes 40.1 million euros or 0.59% of total expenditure to research and development, compared with 3.8% in the manufacturing industry. Apart from the low level of research and development activity, the construction industry is said to be reluctant to use new technology. This is supported by a survey conducted by KPMG, according to which only 8% of managers in the construction industry are technological pioneers.

Another challenge is how to respond to global megatrends. Society will be subject to enormous changes in the coming decades. By 2050, Austria's population is expected to grow by 14%, while the working age population is expected to decline from 67.2% to 58.7%. These facts will be reflected in a shortage of skilled workers. Already today, the procurement of professionally qualified workers poses a major problem. Another critical factor is the increasing complexity of construction processes, which will demand a broader qualification profile from skilled workers in the future.

Source: Die Digitalisierung als eine Maßnahme zur Lösung der Probleme in der Bauwirtschaft, Univ.Prof. Dipl.-Ing. Dr.techn. Gerald Goger, Univ.Ass. Dipl.-Ing. Leopold Winkler

Private sector vs Procurement-based practices

The global financial crisis has taken time to affect the Austrian construction market. In the last two years, the construction industry was able to absorb the shock by finishing ongoing projects in home and office construction. 2011, however, was expected to be the greatest challenge the construction industry has ever faced.

The federal government, as well as local governments and communities, have down-sized budgets, with far-reaching consequences, particularly for the road construction industry. As a result, a large number of road construction projects will not be realised in time.

Energy-saving investments and housing sanitation are encouraged by tax benefits and public loans. Under Directive 2010/31/EU on the energy performance of buildings (EPBD), energy passes (providing information about the energy consumption of a house) are obligatory for newly constructed houses. Economic proposals to increase sustainable, energy-efficient construction and renovation activities are also being widely discussed.

Innovation activity in the construction sector has significantly increased due to the public pressure to fulfil new requirements based on cost-effectiveness considerations. Construction companies demand taxation privileges for innovation-related expenses.

Local projects. The following significant construction projects are being developed or are in the process of planning:

- The former airfield Aspern near Vienna is being turned into a modern part of Vienna named Seestadt Aspern with a centrally located lake and connection to a local subway.
- Infrastructure projects concerning Austrian railways are being developed around the new Vienna main station, including shopping areas and office buildings.
- The Brennerbasistunnel, a collaborative project with Italy to construct the second longest railway tunnel in the world.
- The Semmeringbasistunnel, an important tunnel construction project in connection with the construction of a high-performance railway track section leading from Vienna to Spielfeld/Straß in Styria.
- Skyscraper DC Tower Vienna designed by French star architect Dominique Perrault.

International Contracts Considerations. Contractors participating in tender proceedings may be required to provide financial statements, technical qualifications and prove reliability. The contracting authority states such criteria in the tender documents. The contractors usually only provide a financial statement, a confirmation by the tax office that there are no outstanding social security payments, excerpts of the criminal register of the managing directors, details on technical equipment and number and qualifications of staff. International standard forms, such as FIDIC, are generally known but are mostly used only in transactions with international aspects.

The Austrian standard form for construction agreements is the Austrian Standard B 2110, which contains standard contractual provisions for construction services. The standard is widely used, for construction agreements with a smaller contract volume. The applicability of the standard is subject to the agreement between the contracting parties, however it is mandatory under the Federal Procurement Act, where any deviations need to be justified.

There is no legal requirement to use a specific language in the contract. According to the Austrian Standard B 2110 the contractual language is German, but this is not mandatory. The parties can agree to any language they prefer. There is no restriction regarding choice of law or venue for dispute resolution in Austrian law and the parties are also free to agree on arbitration proceedings (safe mandatory consumer protection rules).

In general, owners choose one of three alternatives in Austria, as follows:

- to contract with one contractor covering all services for the construction project;
- to contract with one general contractor and a few additional contracts with specific contractors (eg, architect and project manager); or
- to contract with contractors for specific purposes.

Foreign investors may prefer the first option as they may lack personnel in Austria. While this option is easier to handle as there is only one contractor to deal with, it usually entails a higher remuneration for the one-stop-shop (or all-in-contract). The owner still must engage an effective project management in order to check the single steps taken by the general contractor. If defects or damages occur, there is only one addressee, which makes the situation easier for the owner.

The second option is the most common solution in Austria: the owner engages a general contractor and, at the same time, also engages other contractors such as architects and project managers. This option is a compromise allowing the owner to have one partner for most obligations (ie, the general contractor) while reducing costs with the others.

The third option should only be chosen if the owner has a strong project management team in place, who are able to direct specific contractors at site. Without such management, coordination between the teams may be difficult and problems may arise. The owner may be able to save money when engaging the specific contractors with single contracts. The disadvantage is that there will be the question on who caused defects or damages in case such arise.

Sources: Construction and projects: Austria; by Feller Wratzfeld & Partner Rechtsanwälte GmbH.

Getting the deal through – Austria / construction. August 2018

What should be changed in the construction industry?

Digitisation. The construction industry is currently one of the least digitised sectors in Europe. For the Austrian construction industry to become more efficient over the life cycle of a construction project and not lose competitiveness in international comparison, digitisation in the planning, construction and operation phases must be an opportunity and driven forward. The increasing digitalisation of the construction industry will therefore pose numerous challenges to the sector and to the positioning of Austrian businesses on the market - nationally and internationally.

Challenges of digitisation	Planning	Construction	Operation
Liability issues for planning errors	- -		
Complete completion of the planning before tendering	- -		
New compensation models	- -	-	-
Uniform data storage structures	- -	- -	
Acceptance of the employees	- -	- -	- -
Opportunities of digitisation	**Planning**	**Construction**	**Operation**
Integrated building analysis	+ +	+ +	+ +
Digital building proposal	+ +	+ +	
Integral, collaborative planning	+ +	+ +	+ +

Development of new business opportunities (BIM managers)	+	+	
Use of AR and VR technology (e.g. for visualizations)	+ +	+ +	+ +
More efficient construction site logistics		+ +	

Source: Potenziale der Digitalisierung im Bauwesen. Univ.Prof. Dipl.-Ing. Dr.techn. Gerald Goger Univ.Ass. Dipl.-Ing. Melanie Piskernik Proj.Ass. Dipl.-Ing. Harald Urban

The next steps for digitisation should be:

- the development of a step-by-step plan for the mandatory introduction of Open BIM in public construction projects
- the subsidisation of scientifically supported construction site pilot projects

What also should be changed in the construction company is to have more design-build contracting, to allow for (and benefit from) early contractor involvement in the project and integrated design teams.

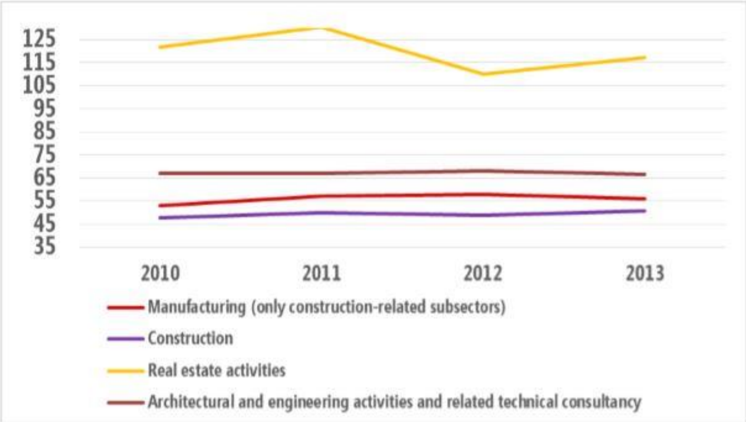
New technology's. The car industry is showing the way. Vehicles are planned on the computer, produced on the assembly line and delivered to the users ready to go. This systemization is efficient, saves time and money. This is precisely what the future should bring to the construction industry. Prefabrication in the construction industry works very well in combination with BIM and guarantees better time management und quality. The potential for prefabrication of wood as a building material is particularly high.

Regulations. Legal regulations and standards are important. They form the framework for the construction and maintenance of existing buildings. But if one no longer fits to the other, the regulations must be subjected to a review. A lot of specialists are working on this topic to improve the regulations for the future to reduce liability risks and cost burdens.

14.7 IDDS Scan – Situation in France

Local Context - Productivity in France and current state

Productivity in manufacturing, narrow construction and architectural and engineering activities sub-sectors remained stable in 2010-2013. Real estate productivity, being twice higher than other sub-sectors, was less stable during this period. It dropped by 9.7% in 2012 and recovered by 6.5% the year after. Such trend can be explained by changes in the value added and employment in this sub-sector over the last years.

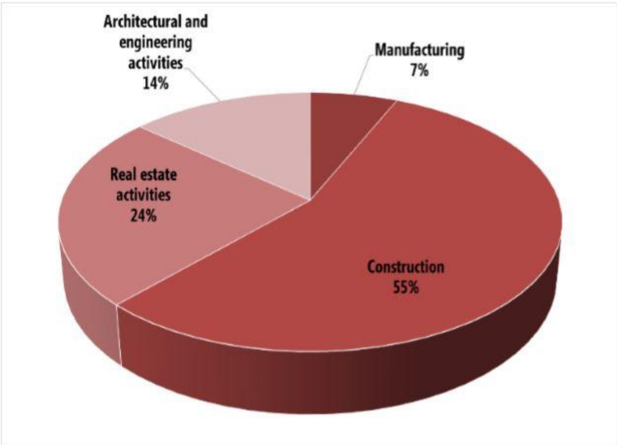


Source: Eurostat, 2015.

Labour productivity in the construction sector in France over 2010-2013 (EUR k)

In 2013, there were 853,440 companies operating in the broad construction1 sector in France, a 2% increase from the previous year. In the narrow construction sector, this increase was more pronounced, amounting to 4.6% (i.e. an additional 23,624 companies). The same year, narrow construction contributed to 55% of the value added2 of the sector. At the same time, the gross value added of the broad construction sector contributed to 18.8% of the GDP in 2013, with the real estate sub-sector accounting for the largest share (11.5%).

Value added in the construction sector in France in 2012 (%)

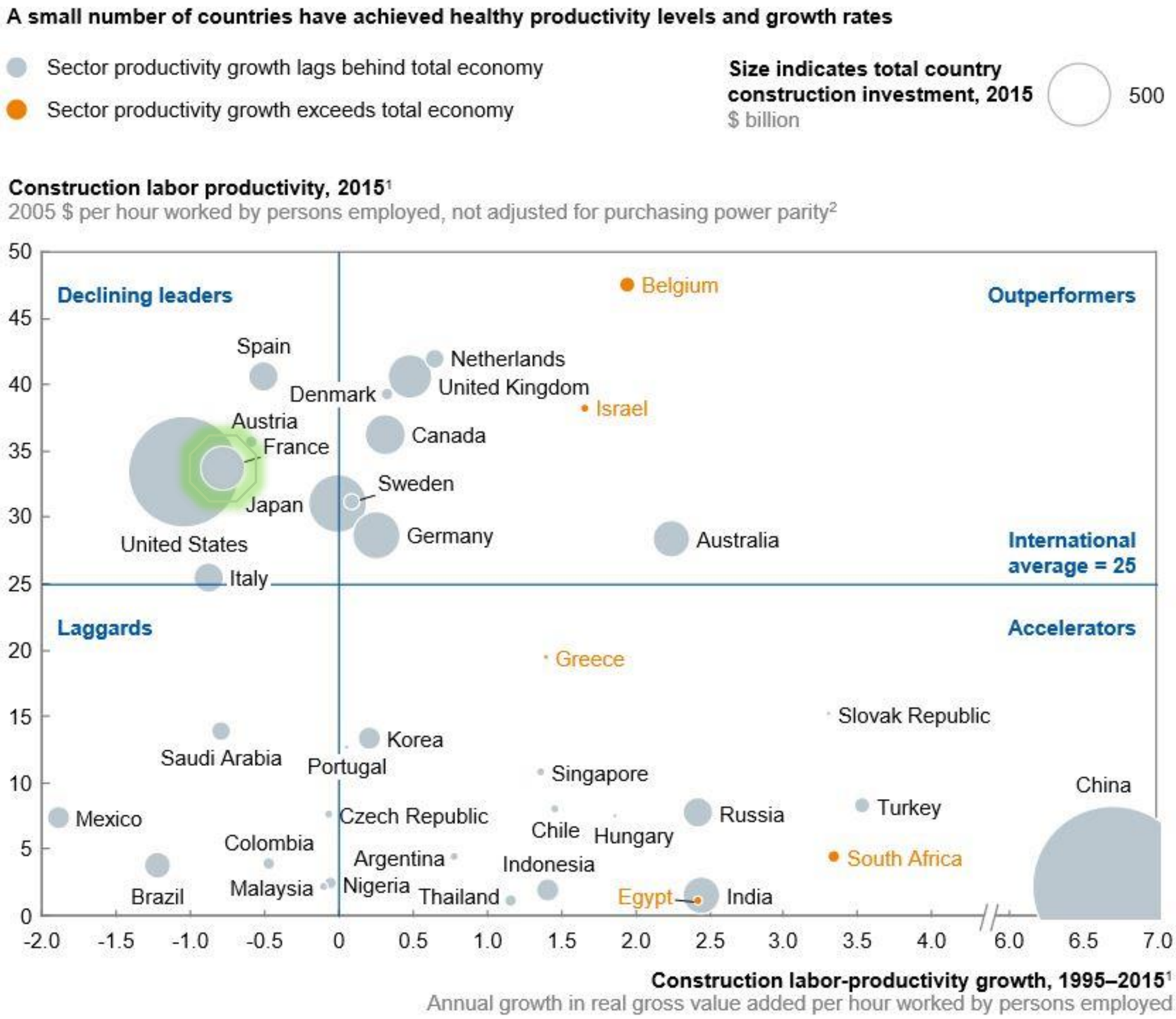


Source: Eurostat, 2015.

Fig X.

Production in civil engineering showed the highest sensitivity to economic changes and has been severely hit by the crisis, dropping by 48% between 2008 and 2012. It subsequently picked up, increasing by 15% until 2014, but is still 40% below the 2008 level. On the other hand, despite an initial 11% decline between 2008 and 2009, production in construction of buildings displayed a slowly recovering trend until 2013, but then turned negative again. According to Eurostat, France was among the Member States in which the largest decreases in production in construction of buildings was recorded (-4% in 2015).

Source: European Construction Sector. Observatory. Country profile France. Ref. Ares (2016)6937094 – 13/12/2016



1 Countries with a shorter time series due to data availability: Argentina, Australia, Brazil, Chile, Ethiopia, Japan, Mexico, Nigeria, South Africa (1995–2011); Belgium (1999–2014); China, Colombia (1995–2010); Czech Republic, France, Israel, Malaysia, Russia (1995–2014); Egypt (1995–2012); Indonesia (2000–14); Saudi Arabia (1999–2015); Singapore (2001–14); Thailand (2001–15); and Turkey (2005–15).

2 Published PPPs are either not applicable (i.e., are not for the construction sector specifically or not for a value-added metric) or vary too widely in their conclusions to lend any additional confidence to the analysis.

SOURCE: OECD Stat; EU KLEMS; Asia KLEMS; World KLEMS; CDSI, Saudi Arabia; Ministry of Labor, Saudi Arabia; WIOD; GGDC-10; Oanda; IHS; ITF; GWI; McKinsey Global Institute analysis

The building sector (new building construction) in France is saturated. A study conducted by (Insee 2015) among real estate home developers in France reveals that the number of new building constructions is decreasing year after year.

Real estate developers experience a clear decrease of home building launch. Rental homes demand knows an aggressive decrease. Even this, World War II buildings in France needs to be renovated since their life cycle is reached (building lifetime is 50 years on average for Post World War II buildings).

WHY?
Renovation is a highly interesting niche market in France. The French government is investing in renovation projects and new technologies for renovation as well. A trend shift in building renovation is noticed by “Fédération Francaise de Bâtiment”:

- A 53% increase in building renovation in 2013 against 51% in 2012.
- In contrast, new building construction decreased from 43% in 2012 to 41% in 2013.

According to (Direccte 2014), an increase of 60% is expected in the renovation market in France by 2020 and a 75% increase by 2030 based on 2010 index.

As a consequence of this new trend, other industry markets are flourishing.

About Energy Affaires. A key feature of the building sector is its excessive energy consumption. In 2007, residential and commercial buildings consumed 67.6 mtoe (adjusted consumption climate effects), or 44% of final energy consumed in France. This consumption is up 42% since 1970 (Ministère de l’écologie du développement durable et de l'énergie 2007).

To remedy this problem, France has set a reduction target of 2% per year in final energy intensity by 2015, and 2.5% per year to 2030 as part of the POPE law (Energy Policy Framework. Legifrance 2005). However, the average annual decrease in energy intensity since 2005 stands at 1.3% (ADEME 2012). The reduction of energy consumption implicitly involves the construction sector as it is largely the largest consumer of energy in France.

About Thermal Isulation. Thermal insulation is needed for almost all renovation projects. The insulation market generates an annual turnover of nearly € 1.3 billion in France, with an increase of 174 million from 1 January 2014 (Planetoscope 2014). The insulation market represents nearly 1% of the turnover of the French construction companies.

While the construction industry is considered as one of the prominent markets in France, it still lacks efficiency in terms of quality and technology integration.

Lean Construction. Situation in France. In France, construction stakeholders (client and construction companies) start to assess the limitations of current project delivery systems and the need to go for a more collaborative project delivery systems from project genesis.

IPD practice, however, isn’t yet introduced and applied in France. In the next decade, rearranged in the favour of more cooperative systems.

Lean construction, Building Information Modelling (BIM), bid data are identified as the main trend enablers. Regarding French market status, it is dominated by a more divided project delivery system and a more integrated and collaborative system is starting to raise the concern of construction stakeholders.

Finally, a shift from new building construction to renovation is introduced slowly in the French market due to the need to reassess Post World War II buildings. The real stake now is to switch toward a more collaborative system and early integration of project stakeholders earlier in the project lifecycle to make a substantial gain in in project performance (quality, cost and time). For this to happen, the major change should be instilled by the government (policies) and the client (prioritize integrated project delivery approaches).

Source: The Journal of MacroTrends in Technology and Innovation. Development strategies for the French construction sector. Zakaria DAKHLI and Zoubeir LAFHAJ. Ecole Centrale de Lille, Lille, France.

Business as usual practices

In the French construction industry, several project delivery systems exist:

Design-Bid-Build (D/B/B):

It is the most common delivery system in France, more than **70%** of building projects. (Rabot Dutilleul 2015).

- Characterized by a sequential process.
- The architect team starts by designing the project.
- Bidding phase: Tender is launched in order to select a contractor (builder) considering price, technical feasibility, sustainability, etc. Main criteria of selection is the price.
- The selected contractor can begin the construction with a complete design and clear schedule.
- Separate phases realized by a different set of actors.
- Loss of information and rework is common.

Construction Management at risk:

- The client secures the services of a Construction Manager to work with the design team and the trade contractors.
- The risk is now taken by the construction manager who is responsible of the project success according to the design fixed with respect to the schedule and the budget.

This way of building has been introduced in France in 1992 by the Federation of the European Construction Industry (FIEC).

Public Private Partnership:

This type of procurement system concerns offers provided by the public sector designated to the private sector:

- The contractor oversees the construction, maintenance and management of the public work.
- The contractor can receive direct payment from the public partner, or he can use the public installation (example: highway) for a certain period of time as a payment method.

Public Private Partnership (PPP), born in Anglo-Saxon countries have taken reality in France since the order of 17 June 2004. This type of delivery system is considered by major AEC French companies as possibly having an impact on the future markets. This formula allows private financing of public works and services, associating a private third party to a public project, and beyond the usual duration of public service delegation.

Source: The Journal of MacroTrends in Technology and Innovation. Development strategies for the French construction sector. Zakaria DAKHLI and Zoubeir LAFHAJ. Ecole Centrale de Lille, Lille, France.

Applicable laws

To stimulate the construction sector, France has introduced the following legislation:

- **Decree No. 2018-617 of 17 July 2018 amending the Code of Administrative Justice and the Urban Planning Code**. This decree introduced several modifications including the reduction of the period during which a building permit or a planning permission can be challenged to six months after completion of the construction instead of a full year, therefore limiting the risk of challenge after construction.

- **Law No. 2018-1021 of 23 November 2018 on the evolution of housing, planning and digital technology** (*Loi n°2018-1021 du 23 novembre 2018 portant évolution du logement, de l'aménagement et du numérique*) (ELAN). The purpose of this Act of Parliament is to simplify urban planning rules to facilitate housing construction procedures. It contains measures intended to secure building permits.

Since 2016, legal provisions have allowed builders to derogate from certain construction standards (such as fire safety) relating to the construction of public facilities and social housing. **Law No. 2018-727 of 10 August 2018** goes a step further by enabling public and private employers to derogate from established construction standards if they can demonstrate that the results achieved are identical or superior to those which would be achieved under the applicable construction standards. Two ordinances are expected to elaborate on this right to derogate from applicable construction standards.

Source: ID 8-502-1461 © 2019 THOMSON REUTERS

Barriers in the construction sector

The use of BIM started during the last decade. Many countries embraced BIM early and others were obliged to follow the trend to stay competitive.

- **North America**
  - Is advanced in BIM implementation compared to Europe.
  - Jumped from 28% in 2007 to 49% in 2009.
- **France**
  - Holds the highest rate of BIM adoption in with 38% in 2010.
  - A real interest raises among construction actors to rethink the way construction is conducted.

However, the level of BIM maturity is still to be developed compared to other European countries (UK and Scandinavian countries).

Company failure. According to the **French Central Bank**, 15,943 company failures concerned enterprises of the construction sector in the period from September 2014 until September 2015. This accounted for 25.3% of the bankruptcies in the overall French economy.

The **French Building Federation (Fédération Française du Bâtiment)** explains the fragility of the companies by the price decrease in the construction industry since 2008 and the recurring issues of late payment leading to company failure. Despite the difficulties faced by construction companies, the amount of company births exceeded the number of failures since 2008. Thus in 2012, the number of new companies in the narrow construction sector exceeded the number of bankruptcies by 80.3%, showing high SME (Small and Medium-sized Enterprises) activity in the sector.

Trade credit. Trade credit is a widespread financing practice across the French construction sector, involving various actors from contractors to construction products manufacturers. It has developed into a "cascade" system among the various tiers of subcontractors, whereby lower tier constructors receive credit from outside the industry, which they pass on to the next level of contractors, and ultimately to the client. Thus, problems for low-tier contractors in accessing credit would have repercussions throughout the entire supply chain.

Late payment. Late payment is one of the main causes of SMEs failure. The average duration of payment is 35 days from the invoice date in France, slightly above the average for Western Europe (34 days). In this context, in February 2014 the French government adopted the **Consumption Law (Loi Consommation)** in order to regulate payments on the private market. It reduces the payment delay from 60 to 45 days after the invoicing date. The invoice verification and acceptance times are included in the time granted for payment. However, the French Construction Federation argues that reducing the regulatory limitation of the payment will damage construction SMEs because their clients (private individual) are not subject to the same payment rules.

Time and cost of obtaining work permits and licenses
The World Bank ranked France 40th (out of 189 countries) in 2015 in terms of "dealing with constructions permits". Nine procedures and 183 days were required to complete administrative formalities, for a cost representing 4.7% of the considered building value in 2015. In comparison, Denmark ranked 5th, with 64 days needed to build the same, and Germany 13th with 96 days.

- The most expensive procedures are hiring an external inspection company and obtaining the building permit.
- The longest procedures are obtaining a building permit (90 days) and the urbanism certificate (60 days).
- Connection to the power network takes 71 days and should be initiated in parallel with the start of construction.

Skills shortage . Job vacancies in construction and real estate followed similar trends in 2008-2012. The vacancy rate in increased in both sub-sectors between 2008 and 2010, reacting to the sudden changes in the demand and exceeding the pre-crisis value. Afterwards, however, it has been steadily decreasing until 2012.

Source: European Construction Sector. Observatory. Country profile France. Ref. Ares (2016)6937094 – 13/12/2016

Private sector vs Procurement-based practices
Local projects. In France, civil construction contracts are usually bespoke contracts. However, some of those contracts are derived from standard forms that have been issued for both private and public works, such as:

- Voluntary ***Association Française de Normalisation*** **(AFNOR)** standards, which are widely used for both public and private procurements and identified by the abbreviation NF (*normes françaises*). The two main AFNOR norms used for private construction works are:
    - NF P.03-001 for private works
    - NF P.03-002 for civil engineering works

- The **General Administrative Conditions of Contract (*cahier des clauses administratives générales*) (CCAG)** and the **Special Administrative Conditions of Contract (*cahier des clauses administratives particulières*) (CCAP)** for public procurements contract, which are used in public contracts and contain contractual provisions to be referred to by the parties.

International Contracts Considerations. Parties to international projects usually refer to standard forms of contracts provided by the **International Federation of Consulting Engineers (*Fédération Internationale des Ingénieurs-Conseils*) (FIDIC)**. In practice, the most commonly used FIDIC contracts are:
- The **Red Book** - construction works.
- The **Yellow Book** - design-build.
- The **Silver Book** - engineering, procurement and construction / turnkey contracts.

A revision of the FIDIC templates was released in 2017.

The main differences:
- Red Book - design obligations are borne by the employer

- Yellow Book - design obligations intended to be borne by the contractor

- Silver Book - also provides for design and build obligations for the contractor; however, as it is a turnkey contract, the contractor accepts most of the risks arising from the contract (including unforeseen geological conditions) in exchange for a higher fixed price than in the Yellow Book.

A recent trend has been the developing use of **collaborative contracts** (for example, joint contracts tribunal and new engineering contracts) for international projects, as opposed to contracts relying on the apportionment of risks between the parties (for example, FIDIC).

Source: Construction and projects in France: Overview of the construction and projects sector. THOMSOM REUTERS PRACTICAL LAW®

Rewire the contractual framework
According to McKinsey Global Institute in Reinventing Construction: A Route to Higher Productivity. (February 2017), there is a need to move away from the hostile contracting environment that characterizes many construction projects to a system focused on collaboration and problem solving. To achieve this:

- Tendering processes should be based on **best value and past performance** rather than cost alone, and public processes streamlined.

- Establishing a **“single source of truth”** on projects for monitoring progress early, potentially supported by **collaborative technology**, helps to minimize misalignments and enable joint **corrective action**.

- Where players continue to use traditional contracts, **incentives** should be **introduced** to significantly **improve performance and alignment** not at a trade level, but at the project-outcome level.

- Appropriate alternative contracting models such as **Integrated Project Delivery (IPD)** help to build long-term collaborative relationships.

- **Relational contracts** will need to become more prevalent than transactional contracts. Sufficient investments in up-front planning incorporating all parties’ input have been shown to raises productivity substantially.

What should be changed in the construction industry?

With the advent of BIM, a rethinking of Construction Company’s organization is required.

- For Human Resources a new job is created: “BIM manager”, to manage workflow and coordination under the BIM platform.

- For Planning Department, a shift in responsibility occurs since the focus would be more directed towards gathering models and synthetizing stakeholder’s models.

BIM definitely affects every corner of the construction business. The real stake is to anticipate those changes and to prepare for the next step most effectively.

Future trends and vision of the French construction sector

Project delivery shift towards more collaborative system:

- Project delivery system describes the relationship between project stakeholders and the client.
- Clients select PDSs to define the roles of project participants.
- Share authority and responsibility.
- Allocate profit and risk.
- Organize and incentive participants to fulfil the clients' project objectives.

(According to Qiang et al. 2015).

Three mayor interventions are needed to move past long-standing innovation challenges and seize the innovation opportunity

According the MGI Construction Productivity Survey, and despite the proven advantages of innovation:

- Respondents ranked underinvestment in innovation only seventh out of ten root causes of low productivity.
- Digital tools to improve processes outstripped innovation in both adoption rates, and perceived impact.

- A study of profits across several industries put in evidence that innovative firms had 15 to 20% higher margins than the not innovative ones.

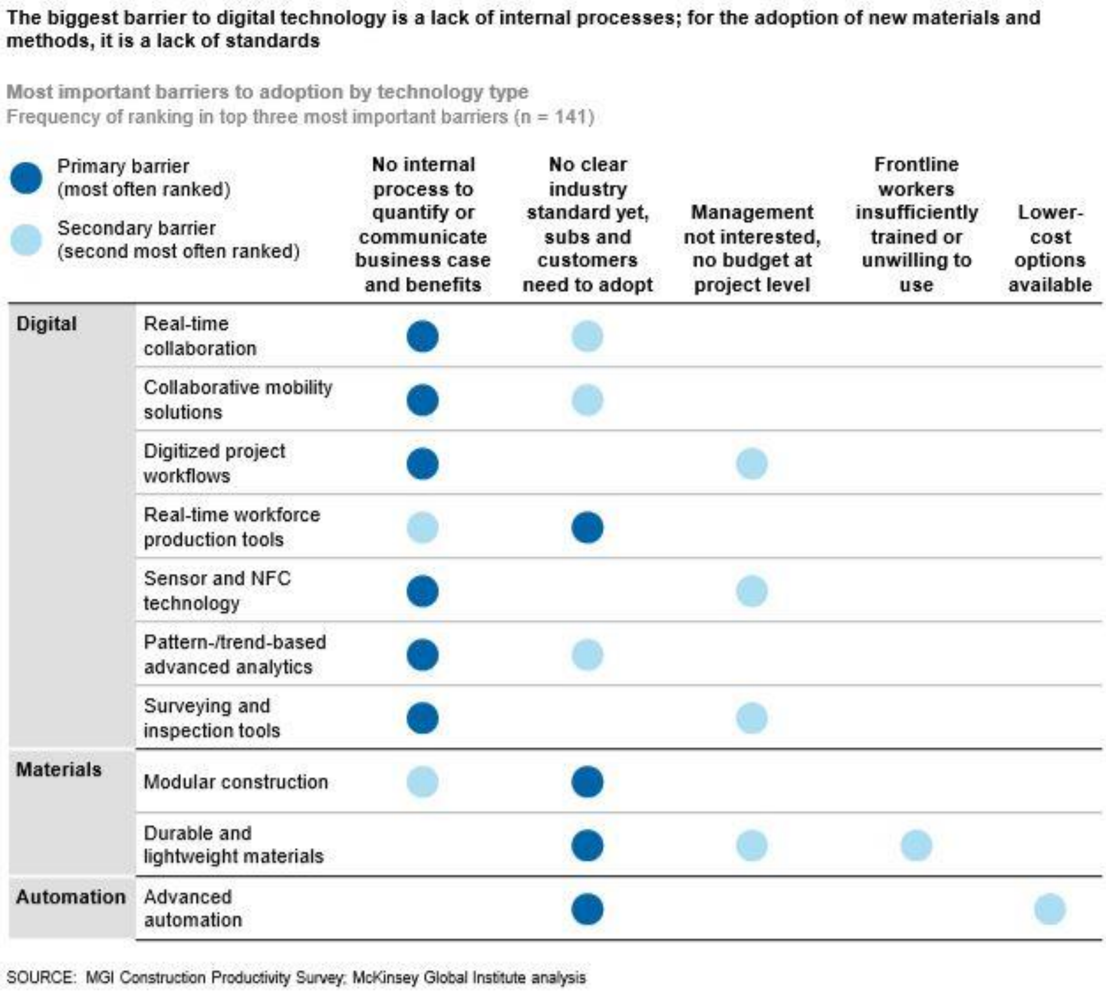
Innovation in the construction industry continues to be constrained by deep-seated barriers, including a lack of emphasis on R&D, a high degree of fragmentation, and widespread risk aversion. Considering this, three areas should be prioritized:

Embedding innovation throughout the organization and across the value chain
Construction organizations have not fully developed the fundamental capabilities they need to innovate. The MGI Construction Productivity Survey found that a lack of internal processes to quantify and communicate the business case for innovation was most often cited by respondents as the primary reason a given technology has not been implemented. Contractors should ensure that they have a dedicated function for seeking and piloting new construction technology, a chief technology officer or chief innovation officer.

One other notable aspect of embedding innovation into the organization is buying knowhow through acquisition.

- **Strengthening the link between technology suppliers and owners**

The link between suppliers and owners is important for innovation but is often weak. In the MGI Construction Productivity Survey, the factor cited second most often was a lack of adoption of agreed standards by suppliers and their customers, an indication that the two need to work more closely.



To improve this situation, owners can significantly revamp their procurement requirements to require the use of proven technologies, especially on large projects, for example by mandating the use of 5D BIM on publicly procured projects. Nordic countries were particular pioneers in this regard with several state-owned bodies requiring BIM use from 2007. Other countries such as the United Kingdom announced the mandate deadline in 2011, several years before implementation in 2016 to allow time for the transition.

- **Owners** should also adopt a reliability and life cycle-cost attitude, and work with contractors to understand the benefits of new materials and a greater array of sensors throughout the life of an asset. By taking a longer-term return on investment perspective, owners can begin to use fact-based and financially sound rationales to understand the full implications of innovations in the sector.

- **Suppliers** have an equally important role in strengthening their relationships with owners. They are often the players who are executing the most innovation, but this often goes unnoticed by the sector.

Together, owners and suppliers can work jointly on industry standards for new materials and methods, clearing the way for contractors to seamlessly take up the baton during the project.

Improving risk sharing of new approaches

Industry associations and regulators can facilitate an innovation transformation by working with owners, contractors, and suppliers:

- To define new standards for emerging innovations
- To assist in providing financial resources for pilots
- To showcase success stories

Grants and subsidies would be an effective way to support innovation. To further reduce risk aversion, owners should co-invest in technology pilots with contractors and share costs and rewards proportionally. Ideally, this could start with smaller scale projects to build confidence and experience before being deployed on larger projects. Contracting structures should also be used to ensure that the risk and reward from innovation are correctly allocated across the actors.

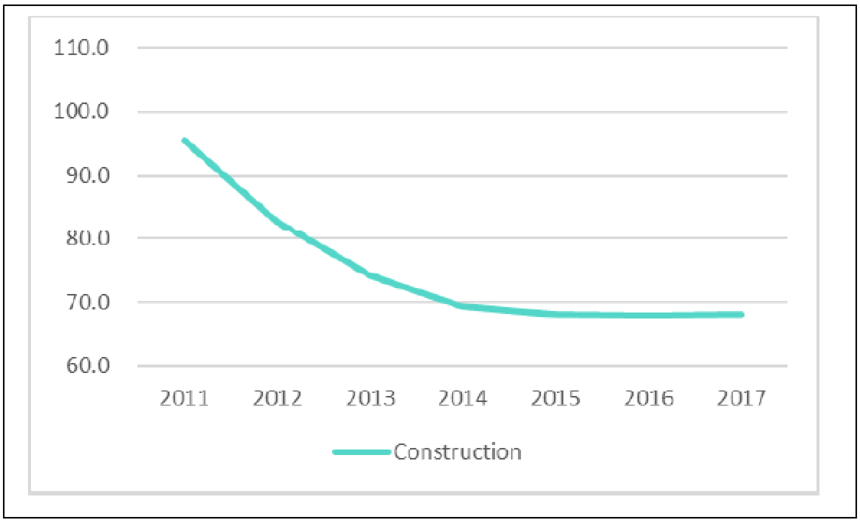
Source: REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY. McKinsey Global Institute. February 2017.

14.8 IDDS Scan - Situation in Italy

Local Context - Productivity in Italy and current state

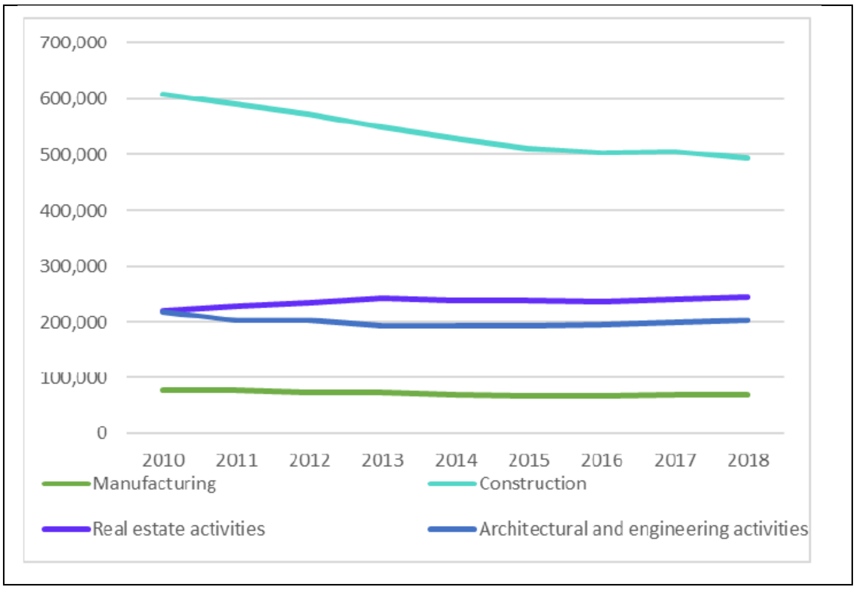
The Italian construction sector is a vital part of the national economy, with its gross value added accounting for 18.8% of Gross Domestic Product (GDP).

There was a costruction market decline from 2010 to 2017. It has been driven by a 16.7%, 10.7% and 8.8% decrease in the number of enterprises in the narrow construction, manufacturing companies, and architectural and engineering activities respectively. Conversely, the number of companies in real estate activities increased by 8.7% during that same period.



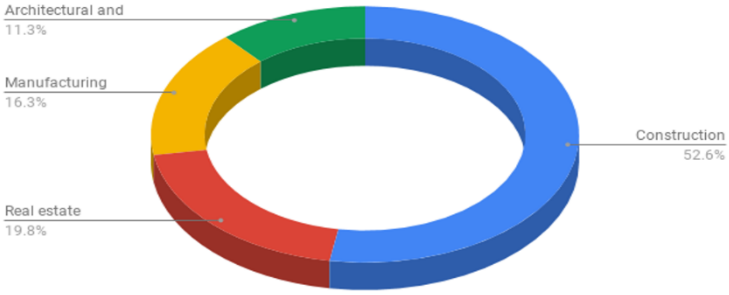
Volume index of production in the construction sector in Italy, 2010-2017

The total factor productivity in the narrow construction sector has slightly decreased in recent years, falling by 1.2% between 2010 and 2014. On the contrary, in the manufacturing sub-sector it has increased by 2.6% over the same period, thus implying a high efficiency of production. Labour productivity within the narrow construction as well as the manufacturing and real estate sectors has generally increased by 10.9%, 10.3% and 12.7% between 2010 and 2017 respectively. However, it declines by 5% in the architectural and engineering sector.

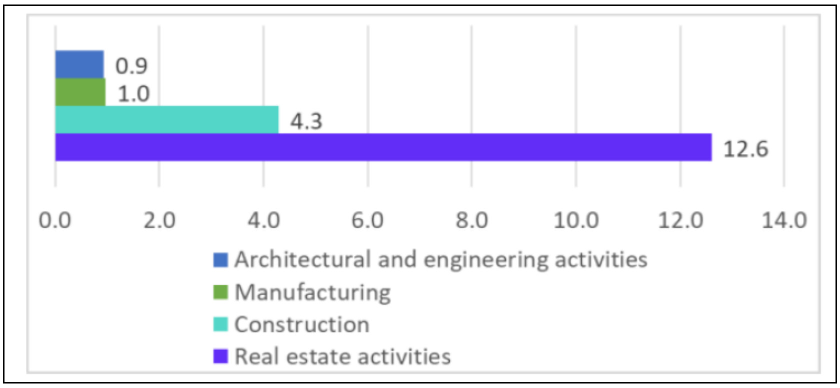


Labour productivity in the construction sector in Italy over 2010-2017(Eur k)

In 2017, the narrow construction sub-sector generated the largest share of total added value (52.7%), followed by real estate activities (19.8%), manufacturing (16.3%) and architectural and engineering activities (11.3%).

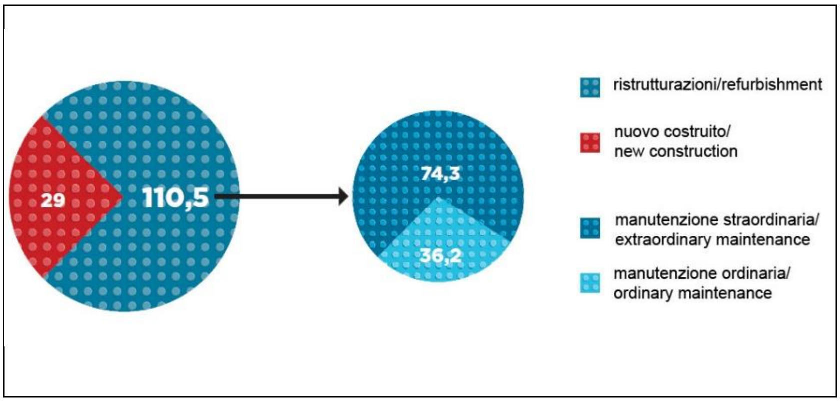


The share of gross value added of the broad construction sector in the GDP reached 18.8% in 2015, with real estate activities having the largest contribution (12.6%).



Gross value added as a share of GPD in the construction sector in Italy, 2015 (%)

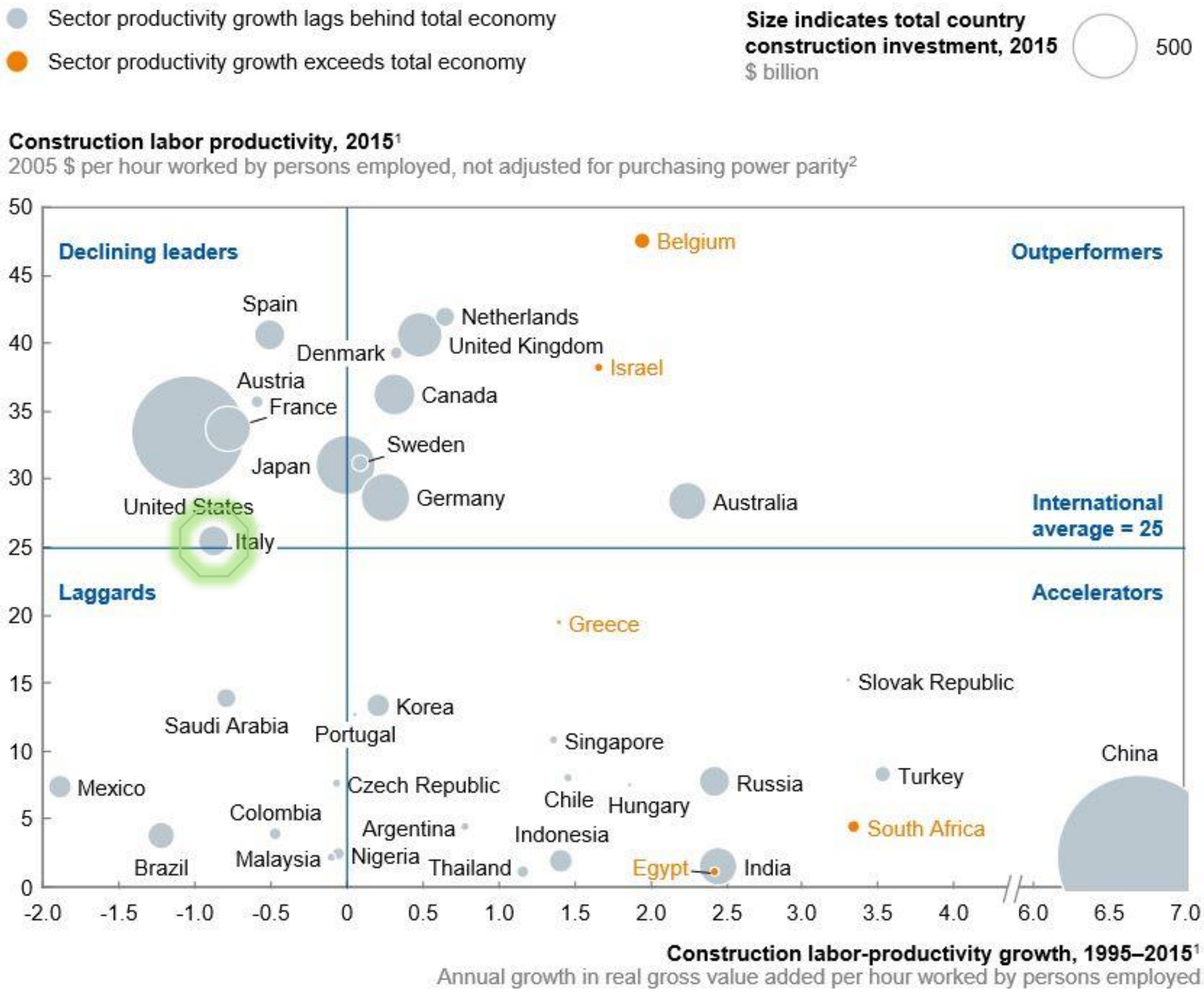
All in all, it seems that the Italian construction sector is showing some signs of recovery, with a modest growth in 2017. Investments growth was partly driven by restorations while the new residential building segment continued to decrease.



elaborazione CRESME sui dati del Ministero dell'economia/ CRESME elaboration based on Ministry of economy's data. **Valore della produzione nelle costruzioni, 2016, Mld € correnti. Value of construction sector, 2016 Mld € current**

Such growth seems however fragile, as shown by the production decline (see Figure 1). In fact, the workers employed in construction will continue to decrease, and the public administrations late payment and public procurement practices may discourage private investment in the future.

A small number of countries have achieved healthy productivity levels and growth rates

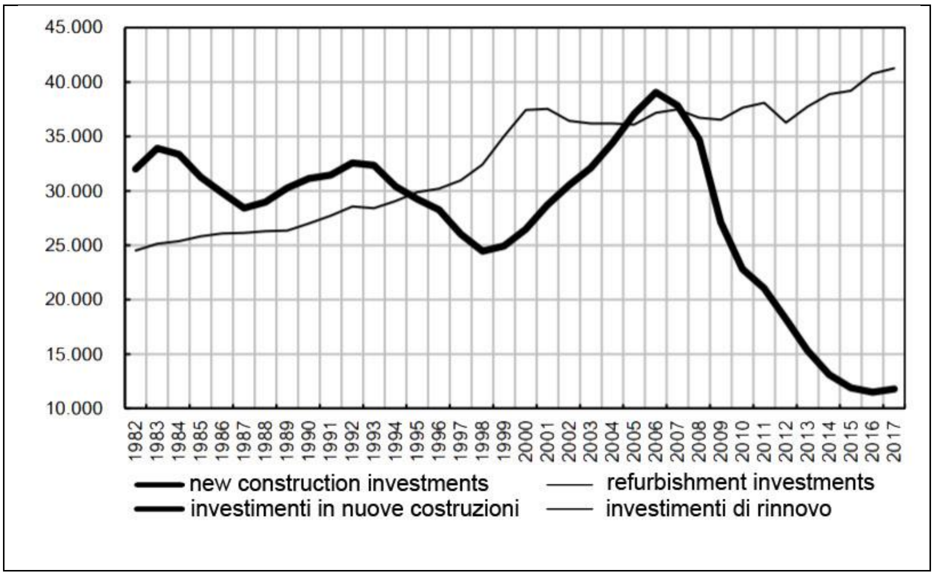


1 Countries with a shorter time series due to data availability: Argentina, Australia, Brazil, Chile, Ethiopia, Japan, Mexico, Nigeria, South Africa (1995–2011); Belgium (1999–2014); China, Colombia (1995–2010); Czech Republic, France, Israel, Malaysia, Russia (1995–2014); Egypt (1995–2012); Indonesia (2000–14); Saudi Arabia (1999–2015); Singapore (2001–14); Thailand (2001–15); and Turkey (2005–15).

2 Published PPPs are either not applicable (i.e., are not for the construction sector specifically or not for a value-added metric) or vary too widely in their conclusions to lend any additional confidence to the analysis.

SOURCE: OECD Stat; EU KLEMS; Asia KLEMS; World KLEMS; CDSI, Saudi Arabia; Ministry of Labor, Saudi Arabia; WIOD; GGDC-10; Oanda; IHS; ITF; GWI; McKinsey Global Institute analysis

) in order to increase the production in the construction sector. Clearly, tax deductions have brought good results. Renovation market increased from 2013 to 2017. In contrast, new building construction severly decreased.



Source: Camera dei Deputati,Il recupero e la riqualificazione energetica del patrimonio edilizio: una stima dell'impatto delle misure di incentivazione, 2019. **Investments in renovation sector 1982-2017 millions of euro**

Lean Construction. Situation in Italy

Lean Construction (LC) methodology has the aim to reduce waste of resources and it is able to joint all the effort in obtaining an optimized result. LC is one of the major development in management and on the other side, Building Information Modelling is the main revolution in Architecture, Engineering and Construction (AEC) field.

Nowadays Lean Construction isn't yet introduced and applied in Italy. However, Italy is trying to change its mindset.

A first step is torward to Building Information Modeling. The use of BIM technologies will become mandatory for all construction projects from 2025 in Italy in order to digitalize the construction industry and facilitate data sharing among stakeholders.

This introduction will have significant effects on the construction sector in the coming months and years. It will bring about major changes in the labour market and in the life of companies themselves since new skills will be needed and employments will be created. In addition, the introduction of new technologies in construction expected to create more new jobs for young skilled people.

Business as usual practices

In **private construction** contracts, procurement arrangements reflect the following phases of projects:

- Design phase, which involves professional designers
- Development phase, which includes obtaining all necessary licenses, approvals, authorizations and permits, involving the owner/developer, lawyers, construction manager, project manager, architects and so on
- Construction phase

In the design phase, the owner/employer can select and appoint the professionals involved (such as architects, engineers, interior designers and other professionals responsible for compliance with health and safety regulations) either directly or through a private tender procedure.

The development phase consists of setting out a detailed schedule of any project phases anticipating the construction phase, and include the following:

- Preliminary study
- Preparation of final design documents
- Issuance of the tender documents required for the construction phase

In the **public sector**, the most common public procurement procedures are set out in the new Public Contracts Code (Legislative Decree No. 50 of 18 April 2016) (new PCC), which conforms to EU directives on public procurement.

The new PCC transposes the EU directives and reorganizes the entire sector, simplifying and speeding up the procedures while reinforcing fundamental values such as transparency, prevention of corruption and infiltration of organized crime, environmental and social protection.

Source: Construction and projects in Italy: overview, Practical Law Country Q&A, 2019

In the Italy construction industry, several project delivery exist:

- Design-Bid-Build (D/B/B) (Appalto tradizionale):
    - Bidding phase: tender is launched in order to select a designer
    - Design phase: architect team starts by designing the project
    - Bidding phase: tender is launched in order to select a contractor (builder) considering price, technical feasibility, sustainability, etc. However main criteria of selection is the price
    - Construction phase: the selected contractor can begin the construction with a hopefully complete design and sometimes with a clear schedule
- Design-Build (D/B) (Appalto integrato):
    - Bidding phase: tender is launched in order to select a designer
    - Design phase: architect team starts by designing the preliminary project
    - Contractors prequalification: several information gathering and assessment process that determines a contractor’s capability, capacity, resources, management processes, and performance
    - Bidding phase: tender is launched in order to select a contractor (builder) considering executive project, technical feasibility and price
    - Construction phase: the selected contractor can begin the construction with his own complete design and with a clear schedule and budget

Applicable laws

To stimulate the construction sector, Italy has introduced the following legislation:

- The **Law 90/2013**, amending the decree implementing the EU Directive on the energy performance of buildings (2010/31/EU), defines:

- the concept of Nearly-Zero Energy Buildings, and the 2019 target.
- the methodology for calculating energy performance in buildings.
- the minimum energy performance requirements.
- the obligation for sellers or lessors to provide an energy performance certificate (Attestato di Prestazione Energetica – APE) when selling or renting a building. The document specifies the energy performance and energy class of the building, CO2 emissions and recommendations for the improvement of its energy performance. A new simplified APE was introduced in October 2015, identical throughout the entire country and with a standard calculation methodology.

- The energy efficiency strategies in Italy are governed by the national **Decree 102/2014** (*Decreto Legislativo 102/2014*), the Energy Performance in Buildings Directive (EPBD), and implementing the EU Energy Efficiency Directive (2012/27/EU). The Decree defines the main lines of action to be taken in order to achieve the 2020 energy saving targets. The most relevant to the construction sector are:
  - the establishment of a yearly energy upgrade plan for central government buildings by the Ministries of Economic Development and Environment. The plan will be supported by the National fund for energy efficiency (*Fondo nazionale per l'efficienza energetica*) and has a total budget of EUR 350 million for 2014-2020.
  - in the medium-long term, ENEA, the national agency for new technologies, energy and sustainable economic development, will be responsible for improving the energy performance of both public and private buildings, and increase the number of Nearly Zero-Energy Buildings (NZEB). Indeed, by January 2019, all new public authority buildings should be NZEB.

  - In line with the Decree, the national **Action Plan for Energy Efficiency 2014** (*Piano d'Azione per l'Efficienza Energetica 2014 – PAEE*) defines Italy's energy efficiency objectives for 2020 and suggests ways to strengthen and improve currently existing measures to achieve them. Namely, Italy set the goal of achieving total primary energy savings of 20.1 Mtoe (Million Tonnes of Oil Equivalent), by 2020, of which 5.1 Mtoe from the residential sector, and total final energy savings of 15.5 Mtoe by 2020, of which 3.7 Mtoe from the residential sector.

After PAAE 2014, the savings of energy consuption were 41.4% in 2016 in relation to 40% expected. The construction sector reached 84% compared to the final objective in 2020, the industry sector achieved approximately 40% , whereas the transport sector and the service industry sector were far away from the final result.

Risparmi energetici annuali conseguiti per settore, periodo 2011-2016 e attesi al 2020 (energia finale, Mtep/anno)PAEE 2014 /

Annual savings of energy consuption in each sector, period 2011-2016 and final objective in 2020 (final energy, Mtep/year)

Source: ENEA elaboration based on Ministry of Economic Development's data, ISTAT, GSE (Gestore dei servizi energetic), ENEA, FIAIP, GFK

Sector	Savings of energy consuption		Finale objective reached
	2016 achievement	2020 expectation	
Construction	3,06	3,67	84,2%
Service industry	0,19	1,23	15,4%
Industry	1,95	5,10	38,3%
Transport	1,18	5,50	21,4%
Total amount	6,41	15,50	41,4%

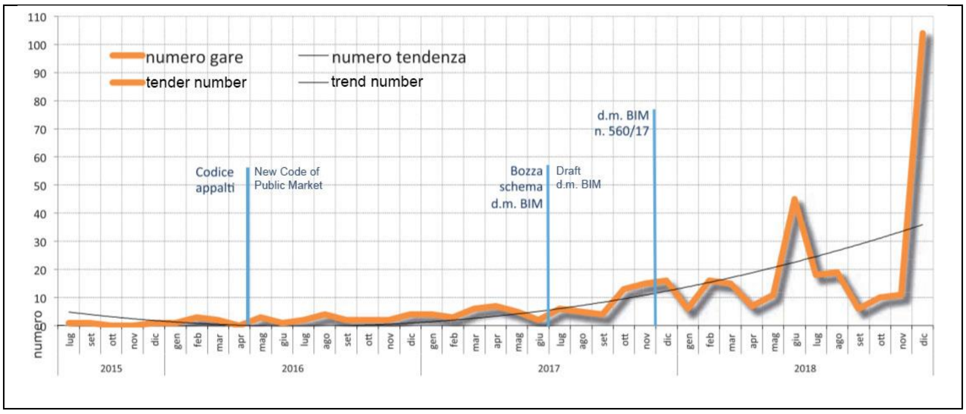
- In November 2014, the **Unlock Italy decree** (*Decreto Sblocca Italia*) officially came into force. It contains a 'Housing Package' (*Pacchetto casa*) encompassing a number of measures for the revival of the Italian construction sector. Namely, a standard construction permit (*Regolamento edilizio unico*) for all municipalities has been introduced to simplify administrative procedures, standardise the performance requirements of buildings and put an end to over 8,000 existing regulations which vary substantially between municipalities. Nowadays, this is not yet applied due to burocraty problems but this will reduce the cost and time of building procedures. Moreover, a building permit is no longer required for renovation and alteration works that do not change the volume and the facade's shape of a dwelling, being instead replaced by a simple communication to the municipality.
    - **Minister Decree No. 560 of 1 December 2017**

This decree will implement art. 23 paragraph 13 of the new Code of Public Market, drafted by the Baratono Commission (Decree No.246 of 15 July 2016).

Such transition will be done in three phases.

- By 2019, all complex projects worth more than EUR 100 million will be under obligation to adopt the BIM methodology.
- By 2020, all complex projects worth more than EUR 50 million will be under obligation to adopt the BIM methodology.
- By 2021, all complex projects worth more than EUR 15 million will be under obligation to adopt the BIM methodology.
- Finally in 2022, the BIM will be introduced at full capacity, becoming mandatory for all ordinary works, except for residential work and not presenting any particular problems related to security.
- By 2023, all projects worth more than EUR 1 million will be under obligation to adopt the BIM methodology.
- The last step, planned in 2025, is to expand BIM to all projects, (more or less complex, up to amounts of less than one million euros).

It seems that the application of this law is showing good results. As a matter of fact BIM's evolution is growing. In 2015 the calls for bids were just 4, in 2016 they increased to 26, in 2017 it raised to 86. In 2018 the calls for bids were 268.



*Source: BIM OICE study, 2018.*Evolution of the calls for bids BIM

- UNI 11337:2017: Building and civil engineering works - Digital management of the informative processes (BIM):
  - Part 1: Models, documents and informative objects for products and processes
  - Part 2: Methods and intervention tools
  - Part 3: Models of collecting, organizing and recording the technical information for construction products
  - Part 4: Evolution and development of information within models, documents and objects
  - Part 5: Informative flows in the digital processes
  - Part 6: Guidance to redaction the informative specific information
  - Part 7: Knowledge, skill and competence requirements of building information modelling profiles
  - **Parte 8: Processi Integrati di Gestione delle Informazioni e delle Decisioni/ decision and management information processes**
  - **Parte 9: Gestione informativa in fase di esercizio / information management in exercise phase**
  - **Parte 10: Linee guida per la gestione informativa digitale delle pratiche amministrative/ guidelines for digital management procedure**

- **Budget Law 2019** has confirmed and extended deductions until 2021 of the **Decree No. 201 of 6 December 2011**. The deductions are valid for renovations, energy efficiency upgrades and purchase of furniture and energy efficient appliances. The deduction from your tax is divided into 10 equal annual instalments, starting in the year in which the expenditure was started and thence into the following years.

  - thus, a 50% deduction from the Irpef (income tax), up to a maximum of EUR 96,000, applies to renovation works. This Renovation bonus is applicable to interventions such as maintenance, renovations and rehabilitations, including costs incurred for planning, hiring professionals and expert reports.

- energy efficiency measures on your house in Italy, such as installing solar panels and radiator valves, can benefit from Italian tax breaks. The installation of heat measuring systems and solar panels is included in the 65% deductions with eco bonus. If you install solar panels to produce hot water, you can take advantage of the 65% deduction of the IRPEF Italian income tax thanks to the ecobonus.This tax break scheme applies not only to homes, but also to companies, health facilities and sports centres.

- the Earthquake Bonus (*Sisma Bonus*) entails a tax deduction of 50% for works carried out to make a dwelling earthquake-proof. The deduction goes up to 85% if the interventions improve the property by two risk classes. This incentive will be in place until 2021.

Barriers in the construction sector

Company failure. The business demography in the broad construction sector has generally seen a 9.5% decrease in the number of company births and a 34.0% increase in the number of deaths between 2010 and 2015, despite some fluctuations. Company births in the narrow construction sector dropped by 24.0%, whereas the number of company deaths increased by 14.3%. Similarly, real estate activities experienced a 23.8% fall in company births and a 69.7% increment in deaths. Conversely, company births in the architectural and engineering activities sub-sector increased by 41.7%, whereas the number of company deaths also increased by 91.2%.Bankruptcies have been declining since 2014, with 2,935 companies filing for bankruptcy in 2017, which is 4.6% below the 2016 value. Bloomberg reported in October 2018 that the construction sector had one of highest default rates in Italy. The same article[24] also mentions that “three of the top six Italian builders are now either insolvent or negotiating with creditors”

Lack of Credit / Trade credit. The Italian construction sector has particularly suffered from the cut in bank financing during the past years. The total volume of outstanding loans advanced to the construction sector in Italy decreased since 2010, reaching EUR 133.4 billion in 2016 (-21.8%). In 2016, the construction and real estate sectors account for EUR 43.3 billion and EUR 20.8 billion worth of bad debt, i.e. 27.4% and 13.1% of the total bad debt in the economy (EUR 158.3 billion) and for over 40% of corporate non-performing loans (NPL). This has contributed to the risk-averse approach to lending and to the ensuing considerable reduction in the credit extended to the industry.

Source: European Construction Sector Observatory June 2018 Country profile: Italy

Late payment. The Italian construction sector reports one of the worst payment practices in the general economy.

24 https://www.bloomberg.com/news/articles/2018-10-11/italy-s-builders-add-118-billion-headache-to-banks-problems

69% of companies report delays in payment in 2017 averaging 156 days in comparison to the 60 days limit imposed by the EU Late Payment Directive (2011/7/EU).

According to ANCE, Public administrations (PAs) often request that contractors delay the issuing of invoices, so as to postpone the deadline for repayment, which is a breach of the EU Directive. As a result, in December 2017, the EU Commission referred Italy to the Court of Justice for failing to ensure suppliers are paid on time during the five years after the directive has entered into force.

The issue is further aggravated by the split payment practice, entered into force in January 2015, whereby PAs no longer reimburse the VAT on the received services directly to the contractors. Instead, contractors are only paid between 78% and 90% of their invoices by the PAs, with the remaining VAT amount being paid by the State.

The main reasons for payment delays by domestic Business to Business (B2B) customers in Italy are insufficient availability of funds (61%), intentional late payment (52%), and administrative inefficiency of customers (38%).

Time and cost of obtaining building permits and licenses. Italy ranked 96th out of 190 in terms of 'dealing with construction permits' in 2017, according to the World Bank's Doing Business 2018, significantly worse than the previous year (86nd).

According to a public consultation on the efficiency of Public Administrations (Pas) launched by the Italian government in 2013, obtaining construction-related licences is the second most complicated practice to simplify out of the 100 analysed procedures. For instance, to comply with safety requirements, over 60 procedures are needed. Furthermore, many regulations constantly change throughout the construction works, such as landscaping authorisation, which has undergone five amendments only in a year.

Construction procedures timing and costs in Italy

Procedure	Time to complete	Associated costs
Obtain nulla osta from the Regional Technical Office (Genio Civile)	30 days	EUR 1,275
Obtain geo-technical study of the land	15 days	EUR 2,000
Obtain topographic survey of the land plot	15 days	EUR 1,000
Obtain building permit	135 days	EUR 38,661
Hire an independent engineer to test structure	1 day	EUR 6,000
File certified notification of starting activity ("SCIA")	0.5 days	EUR 216
Receive on-site inspection by the Fire Department	1 day	no charge
Obtain occupancy certificate	30 days	EUR 468
Register the building	5 days	EUR 159
Apply for water and sewerage connection	1 day	no charge
Receive on-site inspection and estimation of water and sewerage installation costs	1 day	no charge
Obtain water and sewerage connection	29 days	EUR 600

Source: Doing Business overview for Italy, Word Bank, 2018

The value of time shown in the table above is only what reported in the laws. In Italy there is always a difference between what is written and what is effectively done.

Skills shortage There was a general increase of 69.6% in tertiary education in Engineering, manufacturing and construction between 2010 and 2016 not always increased of education corresponds to increased skills.

But, the industry is facing a shortage of different skills mainly due to the high decrease of labor force after the crisis and strong emigration flow from young Italian construction professionals.

Particularly, there will be a surplus in low skill occupations, mainly painters, building structure cleaners and related trades workers, and building frame and related trades workers. But high skill occupation construction managers, architects and professionals that have both technical and management skills, are also in shortage. Better interaction between higher education institutions (imparting technical knowledge) and companies (providing practical and managerial experience) is thus necessary to address the skills gap observed in the Italian construction sector.

Source : European Construction Sector Observatory January 2019 Country profile: Italy

Private sector vs Procurement-based practices

Local projects - Local projects Standard forms of construction contracts are drawn up and published by legal publishers and professional associations. The most relevant example is the model construction contract drafted by the Italian Association of Construction Companies (Associazione Nazionale Costruttori Edili) (ANCE). These standard forms can be freely adapted by the parties and do not have a specific legal status. They are drafted with the sole aim of assisting the parties, providing a variety of clauses that the parties can use and adapt when drafting their specific agreement. There is no prevailing standard form published by a particular body or organisation. In general, this lack of standardisation is closely linked to the reliance on the provisions of the Civil Code as the main method of settling differences.

However, the parties' autonomy is limited in public construction contracts, because the text of the contract must comply with the requirements of the public procurement rules on performance of the works. For anything not expressly provided for in the new PCC, the provisions of the Civil Code will apply to the terms of the contract and to the execution phase, and disputes related to the execution phase are decided before an ordinary civil law court or before an arbitration court.

International Contracts Considerations - No specific standard forms are used for international projects. In this context, the investor/employer usually chooses the model contract, using either an international standard (JCT, for example) adapted to Italian legislation and practice, or a "bespoke" form, tailored for the specific project. Italian players in the construction industry are increasingly aware of international renowned model contracts (for example, FIDIC, JCT, ICE, AIA and so on) but the use of such a model is in practice limited due to issues arising in relation to both their common law origin and structure, and their compatibility with the Italian norms and business practices.

Source: Construction and projects in Italy: overview, Practical Law Country Q&A, 2019

What should be changed in the construction industry?

It is important to improve and introduce new methods and tools for the improvement of the whole construction sector. Some suggestions could be:

- Reinforcing BUILDING INFORMATION MODELING (BIM): main tool
- Introducing LEAN CONSTRUCTION (LC) : management method
- Introducing INTEGRATED PROJECT DELIVERY (IPD): model checking

BUILDING INFORMATION MODELING

In Italy, according to “applicable laws” paragraph previously mentioned, BIM development is governed by Minister Decree No. 560 of 1 December 2017.

This decree defines a governmental BIM mandate compelling public client organizations to adopt a digital approach by 2025, with an incremental obligation which is started on 1 January 2019. As a matter of fact this decree presents a lack of technical rules in order to the right BIM application.

Nevertheless a UNI norm in 10 parts is also being written as guidelines: UNI 11337-1, UNI 11337-3, UNI 11337-4, UNI 11337-5, UNI 11337-6 and UNI 11337-7 were already published. But the following chapters aren't yet approved producing an average BIM technical knowledge.

Unfortunately, Decree No. 650 and UNI 11337 aren't linked creating two distincted entities.

Therefore, BIM knowledge should be reinforced in the legislation sector in order to have accurate guidelines to follow this intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure.

LEAN CONSTRUCTION

Lean Construction is a - respect and relationship - oriented production management-based approach to project delivery a new and transformational way to design and build capital facilities. Lean production management caused a revolution in manufacturing design, supply and assembly. Applied to the design, supply and construction of a capital facility, Lean changes the way work is done throughout the project-delivery process.

Optimize the whole:

- Continuous improvement
- Removal of waste
- Generation of value
- Focus on process e flow

INTEGRATED PROJECT DELIVERY

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. IPD principles can be applied to a variety of contractual arrangements and IPD teams can include members well beyond the basic triad of owner, architect, and contractor. In all cases, integrated projects are uniquely distinguished by highly effective collaboration among the owner, the prime designer, and the prime constructor, commencing at early design and continuing through to project handover.

To conclude LC may be empowered by IPD, because IPD instead of introducing appropriate processes of how to reduce waste and optimize efficiency, concentrated on multi-party contract and collaboration between all parties. IPD helps the project team to apply the LC to maximize value and minimize waste in the production process. BIM as a tool provides technological territory of information sharing between all parties.When BIM as a tool and LC as a process connect all people of project via IPD, the synergetic trilateral collaboration appears and all partners (owner, client, designer,..) get their benefit using synergies of them as a whole.

Source: How can Lean, IPD and BIM Work Together?, Conference Paper, 2016

14.9 IDDS Scan - Situation in United Kingdom

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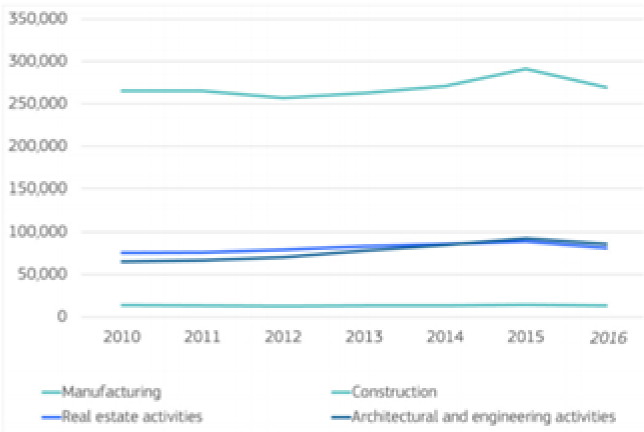
IDDS REGULATORY · SITUATION IN THE UNITED KINGDOM (UK) ·

Local Context. between 2010 and 2016 the broad UK construction sector experienced a 7.3% growth in number of enterprises, totaling 446,775 in 2016. This growth can be primarily accredited to a 32.1% increase in UK architectural and engineering companies. Production in the construction industry also experienced growth (11.3%) during this period, despite dropping initially in 2012. Declines within the sector were only reported in the number of construction workers, which experienced a fall of 4.8% between 2010 – 2016 (ECSO, 2018). The total added value of the broad construction sector totaled EUR 216.5 billion in 2016, with the construction sub-sector contributing to 53.2% of the total.

Figure 1: Number of enterprises in the construction sector in the United Kingdom, 2010-2016

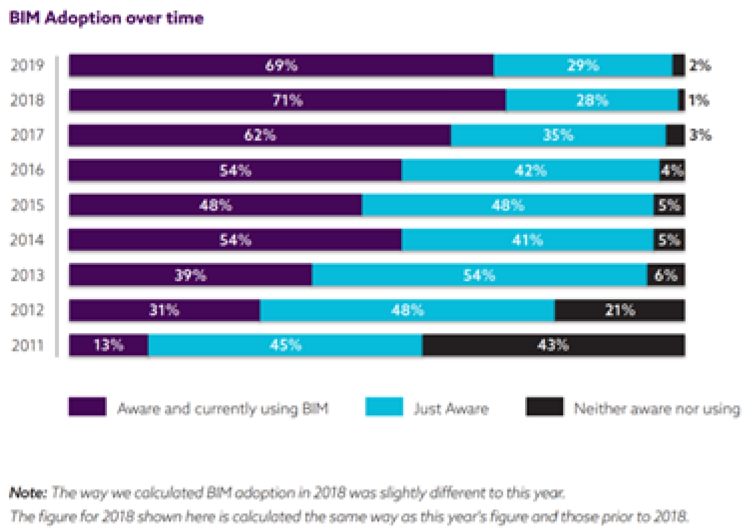


Source: Eurostat, 2017.

=The housing market in the UK remains in a boom and bust cycle, with the housing price index increasing by 24.3% between 2010 - 2016. The UK remains faced with issues of affordability and short supplies when it comes to housing. It has been estimated that approximately up to 300,000 new units are needed per a year to meet the current demand. The UK government have pledged to deliver 400,000 affordable housing units by 2021, 100,000 of which will be financed through a new Housing Infrastructure Fund on GBP 2.3 billion (EUR 2.7 billion).

In order to ensure continued growth in the sector the UK have issued a National Productivity Investment Fund (GBP 23 billion/EUR 26.8 billion) to finance investments in infrastructure, housing and R&D between 2017 – 2022. Additionally, the existing National Infrastructure Delivery Plan 2016 - 2012 allocates a total value of GBP 500 million (EUR 586, 000) to be invested in national infrastructure including 721 planned public and private infrastructure projects. The largest current construction project in the UK is the High-Speed Railway (HS2), with a predicted total budget of GPB 42.6 billion, the project will run from 2017 until 2033 (GovUK, 2019).

The UK considers itself to be a leader in sustainable construction methods and energy efficiency. Recently, there has been a particular focus on renovations of existing buildings, in 2016 total household renovation spending stood at 1.6 billion. This is supported by the Energy Company Obligation (ECO) scheme, which is now in its third renewal and continues to push for reductions in carbon emissions and fuel poverty. The introduction of BIM to aid these transitions has been supported by the government regulations. The Government's 2016 Level 2 BIM mandate saw levels of BIM awareness and use increase within the UK construction sector. However, the National BIM Report 2019 by NBS suggests that the extent to which BIM is embedded in common practice remains reliant on enforcement of the mandate and detailing the next stage of Level 3 BIM use.

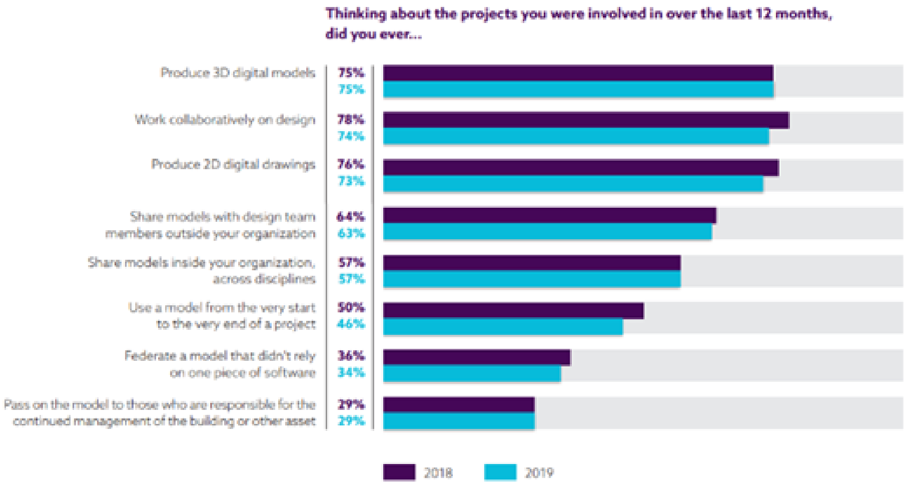


National 2019 BIM Report: BIM Adoption over time.

Overall, the survey suggests that attitudes towards existing and future BIM use in the UK remain positive. 48% of respondents stated that the adoption of BIM has increased their recorded profitability. There remains a growing awareness of the need to adopt BIM in practice, and whilst smaller firms remain more reluctant to do so, it is reported that 96% of all enterprises claim they plan to use BIM within the next 5 years.

National 2019 BIM Report: How BIM affects and benefits working practice.

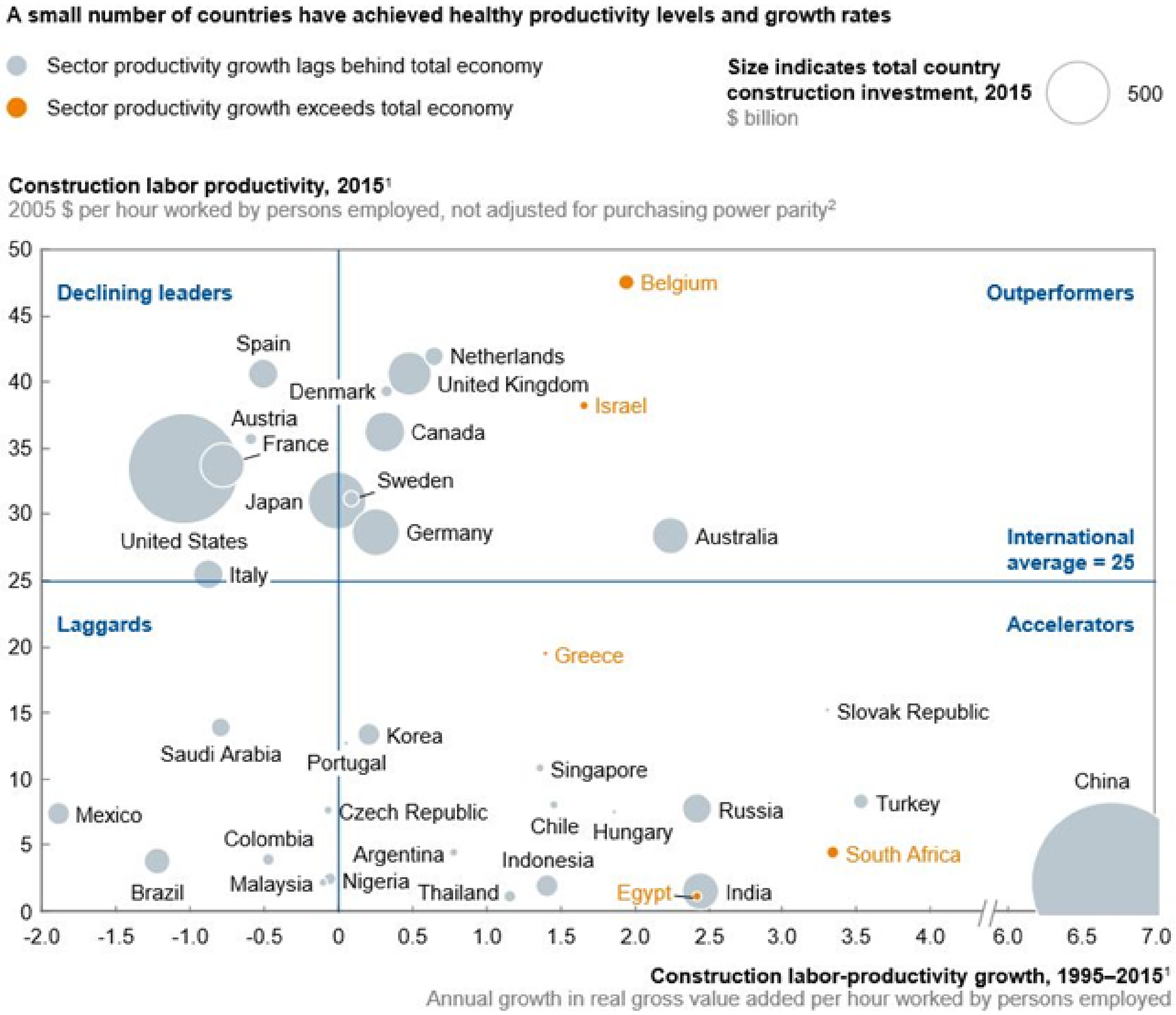
The report states that the current main uses of BIM in UK construction are to produce 3D models, work collaboratively on design and produce 2D drawings. Use BIM during the hand-over phase for continued management of the building and other asset is not yet common practice.



National 2019 BIM Report: How BIM is currently used in industry.

Currently the biggest challenge for the UK construction sector is its shortage of skilled labour. This deficit is becoming increasingly aggravated by the uncertainty surrounding Brexit. If the UK is to leave the EU single market, it is thought that this could lead to further losses of around 215,00 workers post-Brexit (ESCO, 2018). This will undoubtedly have a negative effect on the ability of the UK to deliver on its ambitious plans for increasing housing units and large-scale infrastructure projects. It is predicted that an exit from the EU single market could also lead to increased construction costs and lengthened time frames for completion of existing and future projects. It is thus not surprising that at this current time growth projections for the sector remain low, with the forecasted growth for 2019 at 2.2% and only marginally increasing to 2.5% in 2020. It is said the main divers of this growth will be residential building and infrastructure projects. Brexit could also aid explanations as to why the UK Governments drive towards BIM implementation across the broad construction sector has currently slowed.

Productivity in the United Kingdom and current state



1 Countries with a shorter time series due to data availability: Argentina, Australia, Brazil, Chile, Ethiopia, Japan, Mexico, Nigeria, South Africa (1995–2011); Belgium (1999–2014); China, Colombia (1995–2010); Czech Republic, France, Israel, Malaysia, Russia (1995–2014); Egypt (1995–2012); Indonesia (2000–14); Saudi Arabia (1999–2015); Singapore (2001–14); Thailand (2001–15); and Turkey (2005–15).

2 Published PPPs are either not applicable (i.e., are not for the construction sector specifically or not for a value-added metric) or vary too widely in their conclusions to lend any additional confidence to the analysis.

SOURCE: OECD Stat; EU KLEMS; Asia KLEMS; World KLEMS; CDSI, Saudi Arabia; Ministry of Labor, Saudi Arabia; WIOD; GGDC-10; Oanda; IHS; ITF; GWI; McKinsey Global Institute analysis

Lean Construction. Situation in the United Kingdom

The need for lean construction (LC) in the UK was highlighted in the Egan Report 1998, which aimed to change the processes of the industry. Initially, the concept made use of principles pioneered in other industries and applied them to the construction sector. Efforts toward encouraging the use of lean principles have been seen across the UK, through both academic and non-academic educational programmes and initiatives. The Construction Lean Improvement Programme (CLIP), created by BRE in 2003 continues to run a number of programmes tailored to assisting companies to make improvements. Additionally, the Lean Construction Institute UK (LCI-UK) heads the current drive towards lean construction practices in the UK. As a non-profit, independent charity, it aims to promote the use of lean thinking in construction and challenge existing practices.

Despite early recognition of the need for lean practice in the UK construction sector, there still remains a significant lack implementation. A survey by Common et al. (2000) revealed that the level of lean practice came far from meeting that which was professed. They accredited this deficit in application to a lack of understanding of lean thinking and a resistance to the use of fundamental techniques. Furthermore, it is believed by Common et al. (2000) the methods behind procurement and management of projects remain a significant barrier to the adoption of lean practice in the UK construction industry. Traditional procurement methods in the UK are said to undermine the concept of 'lean', as they favour building relationships and communication over the imposition of power by a single party. Additionally, a lack of top down management hinders the development of sufficient plans and directed management of changes.

Attitudes within the UK construction industry remain positive towards LC, however temperaments within the sector are thought to be prone to conflict and resistant to change (Rooke et al., 2004). Thus, changing behaviour within the industry remains a necessity for implementation of lean thinking. Furthermore, the initial invested needed for tools, equipment, training and wages/incentives to drive demand persists as a barrier to option of LC within the construction industry.

Business as usual practices

The UK Government 2016 BIM mandate insured that the use of Level 2 BIM in all projects irrespective of size, intending to ensure Level 2 BIM use as 'business as usual' by 2016. Despite the increase in BIM usage, the extent to which it is a 'business as usual' practice is often doubted. Level 2 BIM use is defined as a collaborative working environment where information exchange processes are possible from all design software. Common file formats include IFC (Industry Foundation Class) and COBie (Construction Operations Building Information Exchange).

Level 3 BIM is yet to be officially defined by the UK Government. Current intended definition include; the creation of 'Open Data' standards, contractual frameworks to ensure BIM consistency, incorporated training in BIM techniques. The implementation date of 2020 has since been extended and it remains unclear of when Level 3 BIM regulations will be published.

Applicable laws

Construction Law and Legal Frameworks

Within the UK, England and Wales, Scotland and Northern Ireland act under three different regulatory regimes meaning that laws and regulations can vary across the countries. The legal system in England and Wales is based on common law and at the present time European law is transposed into local law through statutes. This might be due to the change with the result of Brexit negotionations and it is predicted that this could have a knock on fiscal effect on Stamp Duty Land Tax (England), Land and Building Transaction Tax (Scotland) and Land Transaction Tax (Wales). In England and Wales, construction law consists of six main bodies; contract law, law of tort, legislation, breach of statutory duty, law of restitution, criminal law.

Insurance and Liability Regulations

Insurance and Liability Regulations remain a concern in the implementation of BIM in the UK construction sector as the nature of BIM usage alters responsibilities of actors and risk allocation. The current applicable regulations are as follows;

- All contractors are required by law to take out **Employer's Liability insurance (EL)** and **Public Liability Insurance (PL)** to protect against damage to employees and members of the public during construction works.
- **Professional Indemnity Insurance (PI)** is not compulsory but often taken out by those involved in design or giving professional advice to protect against claims of unprofessionalness by the client.
- **Contractors' all-risk insurance** is a policy that covers all risks usually associated with a construction project
- **Collateral Warranty** is a legally binding agreement which is ancillary to a separate contractual agreement between two parties and which forces an extended duty of care and a broader liability on those parties
- **Integrated Project Insurance** has been introduced to improve the distribution of risks among the distribution supply chain bringing about collective responsibility. Firm's participating in a construction project sign up to a new alliancing contract, under which they are jointly liable.

The Limitation Act 1980 defines the time limit within which legal action can be taken in relation to construction defects, limitation periods are roughly 6 or 12 years.

<u>Building Permits</u>

The main regulations governing construction activities in England and Wales are the Building Regulations 2010. The following actions or exempt needing to comply with these regulations:

- most repairs, replacements and maintenance work (except heating systems, oil tanks, fuse boxes and glazing units)
- new power and lighting points, or changes to existing circuits (except around baths and showers)
- like-for-like replacements of baths, toilets, basins and sinks

Any other modifications, demolitions, construction or new builds require planning approval.

There are three time of applications:

- Full plans: most thorough option and you will receive a completion certificate within 8 weeks of the building work if it complies with the regulations
- Building notice: only for smaller projects, no formal approval given.
- Regularization – can be applied for retrospectively after building works completed. You may have to change works or pay a fine if it does not meet regulations.

The national requirements for an application include; completed standardized form, local plan, site plan, ownership certificates, design and access statements. In addition to the national list local level requirements might be in place. Scotland's regulations primarily mirror that of England and Wales, the full details of Scottish Building Regulations are set out in the Building (Scotland) Act 2003. Northern Irish building regulations can be seen to be much more in line with that of the Republic of Ireland.

<u>Health and Safety</u>

The Construction (Design and Management) Regulations 2015 is most commonly referred to as "the CDM Regulations". Two documents are required to be created: first, a "construction phase plan" which needs to be maintained throughout the duration of the construction work on site (until completion of the project) and, second, a "health and safety file". This plan details the health and safety arrangements on site for the project aswell as all information relating to the structure "as built" for future owners/occupiers and contractors who carry out work on the structure. Following the Grenfell Tower fire in June 2017, health and safety regulations remain under scrutany, especially Part B of the Building Regulations 2010 which covers fire safety in England. There is a current demand for it to be reviewed as a matter of urgency.

Environmental Assessment and Sustainability

Environmental Impact Assessment

The UK Town and Country Planning Association implemented regulations for construction projects which are due to have a significant environmental impact to complete an Environmental Impact Assessment before applying for planning permission. For example; the construction HS2 is currently undergoing a vigorous EIA. The EIA has five broad stages;

- Screening – does the project fall within the remit and require an EIA
- Scoping – determining environmental issues caused by the project
- Preparing an Environmental Statement - the Environmental Statement must include at least the information reasonably required to assess the likely significant environmental effects of the development listed in regulation 18(3) and comply with regulation 18(4) of the Town and Country Planning Regulations 2017.
- Making a planning application and consultation
- Decision making – the local planning authority and/or the Secretary of State will decide whether to grant consent and make a public notice

Clean Air Strategy

In 2019, the UK Government released a new Clean Air Strategy which encompassed means to empower local action to curb heavily polluted areas. Building upon the Clean Air Act 1993 and the Climate Change Act 2008, this Strategy promotes transitions towards sustainable transport and equipment in the constructor sector but doesn't impose strict guidelines.

Site Waste Management

Site Waste Management Plans initially introduced in 2008 for construction projects over the value of £300,000 have since been repealed in 2013 as part of a Government Initiative to reduce red tape in the sector. Despite being removed from England the plan remains in use in Wales. The Plan recommends the adoption of reporting and measuring waste arising from construction, demolition and excavation activities for all projects. Across the UK landfill taxes and levies on virgin aggregate remain to reduce the amount of C&D waste.

Energy Performance of Building (England and Wales)

- Energy performance certificates (EPCs) are produced for certain domestic dwellings and nondomestic premises An EPC provides residential and commercial buildings with an asset rating and is a calculation based on the Reduced Data Standard Assessment Procedure (RdSAP)

software. EPCs show the energy demand of a building on a scale between A–G, and provide recommendations to occupants on how to improve the rating
- Display energy certificates (DECs) are produced for public buildings with a total useful floor area of 500m^2 or more. DEC's use the same A-G scale as EPCs however they differ in showing the actual energy use of a building and the associated carbon dioxide emissions. A DEC additionally provides a comprehensive Advisory Report (AR) that details how to reduce emissions from the building further.
- Air conditioning inspections are carried out for systems above a certain size.

Sustainability Planning Regulations

Code for Sustainable Homes (CSH) or BREEM ratings are integrated into local planning regulations making them a necessity for new builds in the UK. Both systems aim to review and improve a range of environmental impacts associated with a building. BREEM remains the most widely used system and more details can be found at www.breeam.org.

BIM Regulations

The 2011 Government Construction Strategy stated that 'fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic – Level 2) as a minimum by 2016'. The 2016 BIM mandate led to a rise in BIM usage across the sector. However, the National 2019 BIM Report suggest that issues of knowing how to comply with mandate remain and 57% of the respondents believe that the UK Government is not doing enough to enforce the mandate, leaving many doubting the Governments commitment in BIM implementation.

Currently, BS 1192 and PAS 1192-2 were until recently the most commonly used definition standards/publications for regulation BIM use in UK construction organizations. BS 1192 series is still in existence; however, the latter aforementioned standard has been overtaken by the ISO 19650 series, released in January 2019. The ISO 19650 is an evolving series of 'international standards that define the collaborative processes form managing information when BIM is used' (National BIM Report 2019). The ISO 19650 is designed to be used throughout the delivery and operational phases of assets.

Whilst the initial Government intervention accelerated the adoption of BIM in practice, there is a growing consensus that the UK Government has failed to maintain the momentum. Despite aims of introducing a 2020 mandate and continued support for BIM standardization in the recently published information standard ISO 19650, BIM Level 3 is still to be defined. Over half of those involved in the report believe that it is taking too long and there is little confidence that it will be defined soon, with only 27% thinking that it will be defined by 2020.

Barriers in the construction sector

Company Failure

The UK saw a net increase across the broad construction sector between 2010 – 2014. With the largest increase resulting from the architectural and engineering activities sub-sector which experienced a 121.9% increase in company births (ESCO, 2018).

Sub-Sector	Company Births	Company Deaths
Construction	49% increase (27,345 in 2010 to 40,990 in 2014)	18.9% decrease (39,095 in 2010 to 31,715 in 2014)
Architectural and engineering activities	121.9% increase (from 6,315 in 2010 to 14,010 in 2014)	17.1% increase (from 6,475 in 2012 to 7580 in 2014)
Real estate	31.4% increase (from 8,180 in 2010 to 10,745 in 2014)	3.3% decrease (from 7,145 in 2010 to 6910 in 2014)

In 2017, the second highest number of new company insolvencies where reported in the construction sector, totaling 2,616 companies. It is said that, bankruptcy in the construction sector can primarily be accredited to problems in the security of contracts, low bidding prices in the economic downturn and the rise in labour costs and materials which followed.

Trade Credit

Trade credit is used more abundantly in the construction sector compared to other sectors in the UK economy. The 'cascade' system which has been created among various tiers of subcontractors leave the upper tiers vulnerable in the event of the low-tier contractors experience problems in accessing external credit. It is reported that 25% of building and construction companies in 2017 experienced an increase in the risks they were experiencing due to the use of trade credits. According to the Survey on the Access to Finance of Enterprises (SAFE) report the demand for the use of trade credit in the UK construction sector is increasingly disproportionally to that across the rest of Europe.

Late Payment

Late payment remains the most important barrier in the construction industry and most often a result of inefficient administration. The introduction of the European Late Payment Directive was said to have had a greater success in increasing the speed in which payment are made in the UK compared to the average increase across Europe. Averages for business to business (B2B), customer to business (C2B) and PA to business (PA2B) all showed an improvement in time taken to pay between 2016 and 2017. However, a more recent European Payment Risk Index shows a deterioration in the situation post 2017 with a greater number of payments taking over 30 days to be settled.

Time and Cost of Obtaining Building Permits and Licenses

According to the Work Bank's Doing Business Report 2018 the UK has moved up 3 places to the rank of 14th (out of 190 countries) in 'dealing with construction permits.' Licensing requirements to work on construction projects vary locally across the UK and are dependent on the local Councils. However, as an example; to build a warehouse anywhere in the UK, 9 procedures and 86 days are required to complete administrative formalities which remains shorter that the OECD average for high income countries. An Approved Inspector (AI), is a mandatory requirement to oversee any construction project. An AI can complete the inspection in as little as 1 day and will cost on average GBP 2.964 (EUR 3,490)

Table 3: Construction procedures timing and costs in the UK

Procedure	Time to complete	Associated costs
Obtain planning permission	56 days	GBP 6,676 (EUR 7,763.5)
Hire an Approved Inspector	1 day	GBP 2,964 (EUR 3,445.5)
Approved Inspector files the initial notice to the Local Authority	5 days	no charge
Apply for water and sewage connection	1 day	no charge
Receive inspection from the water and sewage provider	1 day	no charge
Submit application to local Fire and Rescue Authority and obtain approval	21 days	no charge
Obtain water and sewerage connection	20 days	GBP 5,321 (EUR 6,187.8)
Request and receive energy performance certificate from Accredited Energy Assessor	1 day	GBP 78 (EUR 90.7)
File completion certificate with the Local Building Control Department	1 day	no charge

Source: Doing Business overview for the UK, Word Bank, 2017

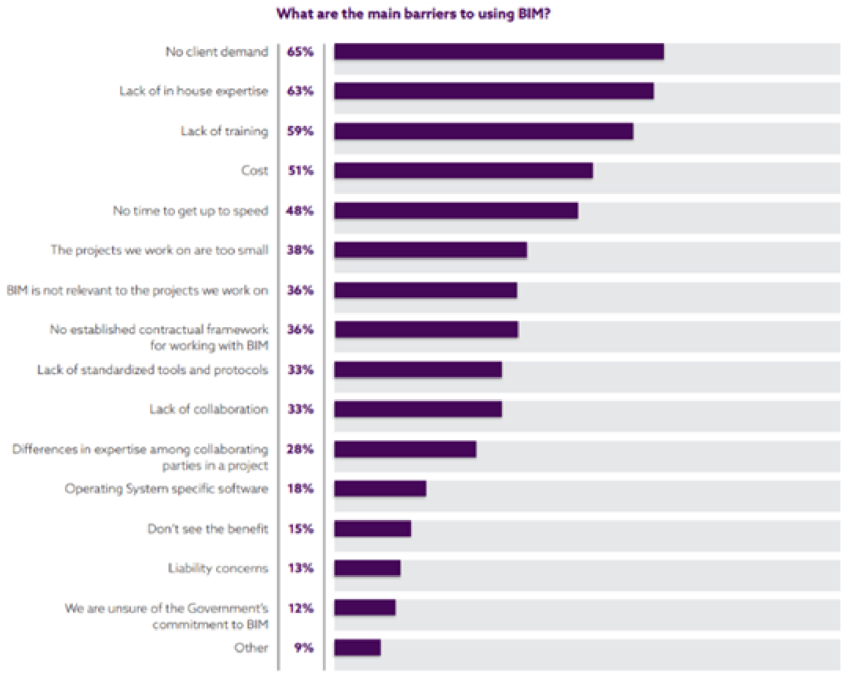
Construction procedure timing and costs in the UK.

Skills Shortage

The UK construction sector currently suffers from a labour shortage, with reported 182,000 jobs needing to be filled by 2018. Whilst job vacancies in the construction and real estate sub-sectors have grown since 2010, adult participation in education and training in these sub-sections had decreased. Furthermore, the number of tertiary students in engineering, manufacturing and construction decreased from 2010 – 2015 by 11.8%, from 29,650 to 26,144. It is thought that these reductions are perhaps due to the industry being seen as old-fashioned and unappealing by young students. It is the opinion of the NFP that current initiatives in the UK to counteract this downturn lack long term vision and fail to place sufficient importance on acquiring skills not only for a specific trade but to allow for career development and upskilling. Inadequately skilled workers and poor English skills are said to be increasingly threatening the safety of construction sites.

This is due to be aggravated further by 400,000 skilled reported by the Construction Industry Training Board (CITB) to be due to reach retirement age in the next 10 years. Shortages are predicted to be most severe amongst bricklayers and carpenters. With the UK's current forecast for new construction projects it is predicted that 230,000 new construction jobs will be created by 2020. It is stated that there will be an approximate need for; 9,400 non-construction professionals (eg. IT, technical and office-based), 4,320 wood trade professional, 2,870 bricklayers, 2510 envelope specialist and 2,120 senior executives/process managers. The path which Brexit negotiations take will have a particular importance in the UK meeting this demand with one out of three SMEs in UK noting that the end of free movement would trigger major constraints on the construction industry.

Barriers to BIM use



National BIM Report 2019. What are the main barriers to using BIM.

Reluctance to modernise

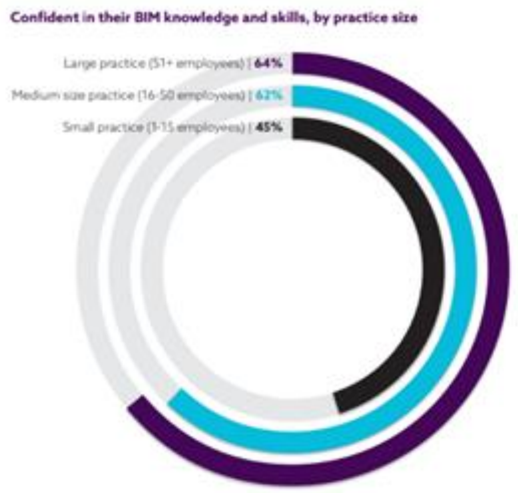
The 2016 mandate was introduced by the UK Government in order to overcome the reluctance to move away from traditional practices in favour of modernisation. However, 65% of respondents to the National 2019 BIM survey stated that a lack of client/market demand remains a significant barrier to BIM adoption in the UK. Despite the initial drive following the 2016 mandate, a lack of awareness of the benefits of BIM and its full potential is becoming increasingly evident in the UK, with 66% of the survey believing that clients don't understand the benefits of BIM. This trend is apparent within both the public and private projects. The initial investment cost of BIM remains an additional barrier, resulting in higher recorded BIM use in larger, more established enterprises.

Human and organizational barriers

Despite an overall awareness of the existence of BIM across the UK broad construction sector there remains a shortage of expertise and access to in-house training. The lack of initiatives and training hinders the application of BIM use in practice and has created inconsistencies in BIM experience within an enterprise.

Ambiguity in data ownership and legal risks

In its initial introductory phases BIM caused misunderstandings around its compatibility with existing contract formats. Despite the recent improvements, it is still not universally accepted that contracts are compatible with BIM. Furthermore, 13% of respondents to the National 2019 BIM survey stated that they held concerns over liabilities when using BIM, suggesting a lack of clarity regarding the impact of BIM on legal risks remain a barrier to BIM adoption.



National BIM Report 2019. Confident in their BIM knowledge and skill, by practice size.

Scale

It is a common opinion that most BIM advancements are primarily designed for large scale projects and not for small organisations (Walley, 2017). This is reflected in the National BIM Report which shows a strong negative correlation between the size of a practice and their use of BIM. Whilst larger practices state an awareness of a need to embrace BIM practice, fewer smaller firms are concerned that they will be left behind in the market if they resist adoption.

Standardisation and Definition

Despite the overarching 2016 mandate, the level of BIM use within UK construction enterprises differs. The main uses of BIM in practice are stated in order of frequency to be; production of 3D designs, collaborative work on design, production of 2D digital drawings, sharing models outside of the organisation, sharing models across disciplines, use of model from start to end of project, federation of a model, handing over of a model. In addition to differences in BIM use, within projects there remains inconsistencies between the tools used when producing drawings or models. The lack of standardization in practice is said to hinder BIM reaching its potential in enhancing communication and collaborative methods. Thus, suggesting that interoperability between various BIM software needs improvements.

Private sector vs Procurement-based practices

Public sector procurement practices vary widely across England, Wales, Scotland and Northern Ireland, as well as varying significantly within England itself. Model-based information sharing is currently being itegrated in exsiting procurement practices. However it is believed that as BIM use becomes habitual, more appropriate methods for managing common data with elvolve. The general evolution of procurement practice in the UK broad construction sector can be seen in the table below, where there is evidence of continued progression towards collaborative practice (Constructing Excellence, 2019)

- **Traditional or Design-Bid-Build**– Separation of design and contracting. Designer is tasked with leading the procurement and the contractor responds to decisions made. In the 1970's the introduction of ICT left this procurement practice weak and inefficient. It was the long-standing practice in the UK but is increasingly being phased out. A possible refinement within this practice would be a Two-Stage tender, with the initial tender being based on a partially developed design and the contractor assisting with the second stage of tenders for construction works.

- **Design-Build** - Introduced in the 1980's the Design and Build practice became popular with clients in UK construction, mainly because the risk lies with contractor. It involves integrated approaches between design and construction phases, assigning all responsibility to contractors. BIM models have the potential to reduce misinterpretations and provide early warning of mistakes that occur during this collaborative practice. Variations on this practice include:
    - Develop and Construct: the client prepares the initial design and the contractor takes on "finishing" off the design
    - Package Deal: contractor provide a simple replicable design that can vary in size. Typically, most suitable for warehouses and straight-forward office buildings.
    - Prime Contracting: use of a prime contractor who is expected to coordinate supply chain.

- **Management Consulting** – This practice remains most suitable for use in fast track projects and complex, developing buildings. A contractor (management contractor) and design team are appointed separately by the client. The contractor is paid an extra fee to oversee the management of the project ad will not be responsible for the contraction works. In this practice collaboration requirements during the over-lap between design and construction stages could be benefitted by the ease of knowledge-transfer of BIM.

  Construction Management, Originated from the US system and not widely used in the UK broad construction sector. It was recently was used on Heathrow Terminal 5 procurement where a construction manager acted as a point of contact and headed the design team and coordinated construction operations.

- **Private Finance Initiate/Public-Private Partnership Project (PFI/PP)** – Designed specifically for large scale projects. The effectiveness of the methods is currently debated. National Audit Office report of project that describes PFI as wasteful and on the whole projects under PFI are often late and over budget.

Pre-qualification schemes are used by both private and public sector clients to carry out initial evaluation and assessment of potential suppliers. Despite the benefits of conduction Pre-qualification Questionnaires (PQQs), their introduction has led to a reduction in access for SMEs to contracts due to an increased cost and time burden. There are current issues in the UK broad construction sector with smaller enterprises encountering difficulties winning public sector work. In a recent government survey, it was found that 41% of construction SMEs are only successful 10% of the time or less when bidding for public sector contracts. Contracting the totality of the project to the biggest single organisation is becoming increasingly favoured. It is believed that allowing on big organisation to them transfer the work throughout their own supply chain is not only a more productive method but shields smaller organisation from the risks and professional indeminities associated with big government contracts.

Public sector procuremnet managements tends to entail extensive procedure and bureaucracy, hindering the effiency of procurement methods. A legistlative body is responsible for over seeing the process of the procurement and decisions remain consistent with regulations and are thus more transparent that the procuremnet in the private sector. The UK government encourages the use of BIM as an opportunity to bring in the right system factors and drive more consistent behaviour. It has already been used in projects by The Ministry of Justice. These projects have continued to use the PPC20000 form of contract without making any amendments for the use of BIM.

Local projects

Despite recent cuts to spending in the UK, local authorities retain significant spending power for contruction projects. This continues to be driven by support for localism and an increase in automous decision making power. Efficiency in projects funded by local authorities is reduced due to a lack in use of contract clauses to ensure that their payment policies, and especially those on prompt payment, are passed on by tier one suppliers through their own supply chains.

International Contracts Considerations

Contracting authorities are currently tied into EU procurement regulations. In the event of no-deal Brexit, procurements that have commenced before the leaving date will need to comply with the new regulations from then on. In some circumstances, former rules will be preserved to ensure consistency throughout a procurement. In the event of a no-deal exit, all procurements across the UK broad construction sector will be subject to the amended regulations. The current types of construction contracts in across the UK broad construction sector are as follows:

- Joint Contract Tribunal (JCT): most widely used standard contracts for the construction of buildings in the UK. Available in difference versions for private sector and local authority projects.
- The Association of Consultant Architects (ACA): more flexible and concise than other forms of contracts. Includes clauses that can be customised by parties for design and build projects.
- ICE: suitable for public or private projects that entail major civil engineering. The contract assigns extensive power of direction and control to the engineer.
- FIDIC: the conditions of contract produced by The International Federation of Consulting Engineers are suitable when the engineer is employed under that control of the client. Includes the possibility of enlisting sub-contractors and requesting extensions to the contracted period.
- NEC: The NEC’s Engineering Construction Contract is user-friendly and easy to be used by all partners on the project. Entails a set of standard clauses as well as scope for extensions to meet the needs of the project. NEC Supply Contract and NEC Supply Short Contract were introduced in 2010 for the supply of items in the UK construction sector. The Supply Contract is most commonly used for both local and international procurement of high-value goods and services including design, whilst the Short Supply Contract for commoditised products/batch supply.
- GC/workd/1 (1998): primarily used for public sector procurements but can also be used in the private sector. Being phased out in public use in favour of more user-friendly contracts.

What should be changed in the construction industry?

Innovation

Despite the UK's recent investment in R&D, it is reported that two-thirds of construction firms do not carry out innovation at all. This is most commonly accredited to the existing market barriers. A recent government initiative in the form of tax credit incentives worth GBP 1 million resulted in a claim merely totalling 23 million (EUR 26.1 million) due to a lack of awareness of the scheme and misinformation surrounding eligibility. There is a growing need for the expansion of training programmes within schools in order regain support for the construction sector and aid the transition towards digitalisation in order to help meet the demand for labour of the industry.

Collaboration

The narrow fields of specialists in the construction sector criticised for limiting collaborative approaches. Thus, support for digitalised communication as well as broad specialists across the sector could positively affect knowledge transfer and increase innovation.

Technological Advancements

Whilst the UK Government continues initiatives to expand it Digital Built Britain network, further commitments and expansions are needed to meet the position of leading force in BIM technology which it strives for. There is an implication that Government inaction has led to a loss of momentum in BIM promotion and adoption. Thus, further regulations for use of higher levels of BIM might be needed to move the industry forward. This would need to be coupled with incentives for the change and education programmes.

Standardisation

Despite attempts by the government to standardize BIM use through the introduction of the BIM mandate, BIM use not only falls below this standard due to inefficient enforcement but the tools and uses of BIM also vary. Standardization across the sector would aid collaboration and communications.

Efficiency

Most insolvencies within the construction sector are caused by late payments and uncertainty due to inefficient administration throughout the supply chain. There remains a growing need to improve communication and administration measures in order to curb the number of insolvencies.

Green Practices

The difference between designed performance and that achieved by the completed building currently hinders the UK's ability to meeting its national carbon reduction objectives. Energy literacy and training of construction workers is being promoted in attempts to close this gap.

15 Appendix C – Workshop and Interviews Facilitation Materials

Some general tips on how to relate with participants-prospective users: Appropriate common phrases to use

Welcome and Purpose

Thank you for agreeing to participate in this meeting/evaluation/encounter. Today we are asking you to serve as an evaluator of this project. We need to extract information about your needs and expectations. We are trying to extract system requirements in order to properly develop the application. Our goal is to see how easy or difficult you find the application to use. We will record your reactions and opinions; so, we may ask you to clarify statements that you make from time to time.

Test Facilitator's Role

I'm here to record your reactions and comments over the project presentation you'll view. During this session I will not be able to offer any suggestions or hints. There may be times, however, when I'll ask you to explain why you said or did something.

Test Participant's Role

I will ask you to search for information on this site to learn if it works well for you. We'll do this by giving you scenarios or tasks to complete on the site. You also will be asked a series of questions about your experience at the end of this session.

Things to Keep in Mind

Here are some things that you should know about your participation:

1) This is not a test of you; you're testing our application/development/program. So don't worry about making mistakes.
2) There is no right or wrong answer. We really just want to know if we made a good design, whether it is good for you.
3) If you ever feel that you are lost or cannot complete a scenario or a taks with the information that you have been given, please let me know. I'll ask you what you might do in a real-world setting and then either put you on the right track or move you on to the next scenario.
4) We will be video recording this session for further study if needed. Your name will not be associated or reported with data or findings from this evaluation.
5) Finally, as you use the application/development/program, please do so as you would at home or in your office. I do ask that when looking for information, you do so as quickly and as accurately as you can.
6) Do you have any questions before we begin?

Preparation/General tips

- Simple wording should be used so the participant understands all information transmitted.
- Be polite and answer any relevant questions prospective users-participants might have. In case answering such questions is time consuming, inform the participant that you might continue your discussion after tests/tasks are completed (i.e. debriefing should focus on such matters).

- Hard copies of the questionnaires should be available, in case participants choose to complete the questionnaires on paper (i.e. paper and pencil procedure).
- Give time and space to participants for questions at any possible time (i.e. they can take as many breaks as and as often they feel they need to do).
- Familiarise with the testing venues/premises/lab where tests will be conducted and be ready to give participants all possible information. Environmental awareness affects stress in both facilitators and participants.
- Familiarise with the scenarios that will be tested and the demos that will be presented related to demonstrate applications.
- Ensure users understand the project-research-pilots' concept.
- Make sure you have translated all the documents you will use at the pilots´ local languages.
- Questionnaires, interview script, websites, video, and any other material can help to validate the SPHERE concept.
- Make sure you have all equipment prepared and running and you also have the consent form ready.

Please use the following checklist to ensure you complete all necessary actions based on the common agenda. Times can vary according to circumstances, thus adapt adequately. Tests, questionanaires and pre-test will be used once the project has develop its tools, during its latest stages.

Task	Time (min)	Done
1) Welcome and introduction (5 minutes)	**10**	☐
a. Welcome participants	1	☐
b. Inform participants about testing venue/premises, e.g. toilets, exits etc.	3	☐
c. General description of main objective and test purpose (i.e. we are here to explore the possibilities of integration presented by the SPHERE project, or we are here to test the preliminary outcomes of SPHERE system, etc). It is very important, to explain that the system is to be tested not the participant (i.e. test person)!	2	☐
d. Agenda presented (hard copy should be included in the diary as a checklist).	1	☐
e. Short explanation of data collection methods adopted (e.g. Thinking Aloud, observational protocol, video, etc.).	3	☐
2) Signing consent forms	**3**	☐
a. Hand the consent form to the participant and ask from him/her to read and sign it (if this has not happened already). If the participant is not able to read the consent form assists him/her to read and sign it.[25]		

[25] The consent form will have been sent to all participants prior to the trials, so they will have read them beforehand and even sign them beforehand.

Task	Time (min)	Done
3) Pre-test questionnaire (if necessary)	**15**	☐
a. Ask the user the questions of the pre test		
4) Present the concept of SPHERE with the video	**5**	☐
a. This video will allow you to provide the participant with the basic information of the project. Since the video of the project is in English you have to be prepared to explain to the native language of the users what is being done at the vide.		
5) Showing the demos	**10**	☐
a. Inform the user that he/she will see a demonstration of the implementation of SPHERE	10	☐
6) Communication and interaction	**30**	☐
a. Participants will be encouraged to express freely their ideas on the project, topic or area to be explored. This can be done by using several techniques: focus groups, interviews, brainstorming, questionnaires, prototyping, etc.	30	☐
7) Training	5	☐
a. The participants of the pilots will receive a short training session before the actual tests in order to be informed about the tools that they will use and the specific tasks they will realise.	5	☐
8) a. Performing tests – end users (if necessary)	**30**	☐
a. Keep notes at the facilitator’s diary about the user performance per task	-	☐
9) Post-test questionnaire (if necessary)	**15**	☐
a. Ask the user the questions for the post-test questionnaires and fill in the answers of the participants		
10) Compensation (if applicable) and farewell	**10**	☐
a. Thank the users for their participation	**5**	☐
b. Give them their compensation for their time.	**5**	☐

16 Appendix D – Workshops and Interview Results

16.1 Workshop Findings: Caverion/VTT

Finish pilot coordinator Caverion is a construction company that designs, builds, operates and maintains intelligent and energy-efficient solutions for buildings, industries and infrastructures in Northern, Central and Eastern Europe. Caverion's services cover the entire life cycle of real estate. Tha company aims to provide users with the financially, technically and operationally best solutions. Caverion uses Building Information Modelling to provide more detailed analysis for specific purposes such as energy analysis, lighting analysis, building automation and site activities in new construction production. BIM use has been a part of Caverion business as usual for two decades. Caverion is providing the pilot building in Finland. The building will be renovated during the project duration and will be used to demonstrate the Sphere tools.

Throughout the intensive workshops with Caverion and the meetings in parallel, the project team identified their workflows throughout the lifecycle of the project. The following barriers for the IDDS and BIM implementation that will enable the digital twin approach have been identified within these workflows specific to the different stages of the project:

Preparation and Brief Stage

- Working practices are too stagnant and might limit new technology uptake.
- BIM practices do not meet the current tools and theory.
- Miscommunication and potential lack of collaboration among the project actors.
- Different stakeholders work with separate documents and tools which can result in problems with integration of data and works.

Concept Design Stage

- BIM practices do not meet the current tools and theory
- Design quality – clients are not prepared for higher cost of using BIM
- Often staff is not skilled enough for BIM and there is a culture of mistrust

Construction Stage

- BIM models require too much computing power at construction site

16.2 Workshop Findings: CREE/EKO

Cree, a 2010's spin-off by Rhomberg, Austria, is a worldwide recognized leader in the design and construction of wood based multi-story, multi-use structures. Cree has constructed one of the tallest wood commercial buildings in the world, the LifeCycle Tower ONE (LCT ONE) in Dornbirn, Austria. The LCT ONE is eight stories high and is based on the LifeCycle Tower system design which has the potential to reach thirty stories. Cree's LifeCycle Tower system was conceived as a way of constructing with the least impact on scarce resources, as well as the lowest emissions of waste and CO2, and has been nominated for the Austrian Federal Ministry of Economy, Family and Youth's National Award for Innovation. Cree's parent company, the Rhomberg Group, has been in the real estate development and construction business for over a century. Rhomberg is acknowledged as a leader in Life Cycle Assessment and ensures that projects will perform over the complete life cycle of the building from concept to recycling. Rhomberg and Cree are ISO 9001 (quality) and ISO 14001 (environment) certified. Before starting the LCT development and the Cree business, Cree's team members were involved in turn-key and design/build projects of up to 100M Euro.

Cree is the Austrian Pilot case provider, residential building, new construction, prefabricated timber-based system, BIM method for virtual design and construction, operation and building occupation changes. The building will be Built during the project duration and will be used to demonstrate the Sphere tools. Throughout the intensive workshops with Cree and the meetings in parallel, the project team identified their workflows throughout the lifecycle of the project. The following barriers for the IDDS and BIM implementation that will enable the digital twin approach have been identified within these workflows specific to the different stages of the project:

Preparation and Brief Stage

- Miscommunication, lack of collaboration among the project actors
- Separate documents and tool usages across stakeholders resulting in problems with integration

Concept Design Stage

- Typically the skills are not available for the use of BIM in the sector

16.3 Workshop Findings: DE5/EKO

De Cinque Group was founded on 1981 from initiative of Angelo De Cinque. The company became and is a reference point for the professional building sector in the Abruzzo and Molise regions. In the 90s is the first company in the area of Vasto to give innovative solution to build with dry construction systems to create partitions and ceilings and is expert in waterproofing and thermal and acoustic insulation. De Cinque Group operates in the building sector where it is able to offer a 360° service and lead the client reaching his goals in the building environment. The offered services are: purchase consulting, technical consulting, quotations, delivery service, design, installation/realization, building site supervision, cranes rental, wood and steel structures, post-purchase consulting, warranties, commissioning. DE5 is the Italian Pilot coordinator and offers the consortium the possibility to test the developed BIM methodology in field; specific resources: implementation of BIM methodology in a residential building with 2 underground floors and 4 above ground floors; the housing contains 11 apartments and 20 garages. The building will be renovated during the project duration and will be used to demonstrate the Sphere tools.

Throughout the intensive workshops with DE5 and the meetings in parallel, the project team identified their workflows throughout the lifecycle of the project. The following barriers for the IDDS and BIM implementation that will enable the digital twin approach have been identified within these workflows specific to the different stages of the project:

Preparation and Brief Stage

- Miscommunication, lack of collaboration
- Separate documents and tools resulting in problems with integration

Concept Design Stage

- Unskilled staff for BIM, culture of mistrust

Developed and Technical Design Stage

- Resources limited/not compulsory to carry out ventilation / daylight simulations

Construction / Renovation Stage

- GANTT chart updating based on construction site development (critical path), with information updates provided by the construction manager or general contractor (depending on approach) in a simple way to parties in a way that can be interpreted/helpfully sent to contractors (e.g. plumber) to make sure construction activities happen on time

Handover and Close out Stage

- Lack of information from previous works / history on the building --> Update information in a "building maintenance book" [FASCICOLO DEL FABBRICATO] that contains the history of the building (concrete used in a good day with a good temperature)

In Use Stage

- Barrier: not known /what should be monitored and how it relates to the design phase

16.4 Workshop Findings: EKODENGE

Ekodenge is a sustainability focused SME based in Ankara, Turkey and London, UK that provides services cross cutting research, consultancy, design and engineering. For the building sector, Ekodenge delivers complete building designs covering all stages from concept design to tender documents, along its consultancy services including: life cycle assessment, building energy modelling, energy efficient systems' consultancy and consultancy for any design phase. Ekodenge has a record of using state of the art technologies and approaches in its architectural & engineering designs for sustainable buildings in Turkey. A leading example is the "Promoting Energy Efficiency in Buildings in Turkey Project" by UNDP, where Ekodenge provided the designs of two lighthouse energy efficient demonstration buildings. Becoming the first green public buildings designed by the integrated building design approach in Turkey, the school and office buildings in this project provide highly relevant experiences for SPHERE project.

Ekodenge held workshop and meetings with the contractor of the lighthouse energy efficient designs developed under "Promoting Energy Efficiency in Buildings in Turkey Project" by UNDP. The manager and engineering team of the construction site of this project attended the workshop session. Under this workshop session and follow up communications, the contractor provided the following insight.

Business as usual changes depending on the scale of the construction project. Larger firms use ERP systems, smaller ones use written forms that are standardized. Responsibility also depends on project scale, some only have a structural engineer as the site chief and some have mechanical and electrical counterparts as well.

Technical barriers also vary greatly depending on the project at hand. A major barrier is lack of documentation. One must first have a detailed documentation of the building to be refurbished. Sometimes the building has fulfilled its economical lifespan- this should be studied before the project. One particular problem in Turkey given as an example was disposing demounted materials and finding recycling opportunities. Things that do not have scrap value are very hard to dispose of.

Regulatory and contractual rules for collaborative working and responsibility sharing are limited. Administrative specifications in tenders enforce a team structure, however: this is limited and not inspired by **project complexity and technical quality, uses financial thresholds instead**. Administrations have the authority to change the tender procedures to achieve better quality however, the general practice is mainly based on the comparison of the financial offers by the tenderers.

Technologies / data and design management tools already being used are:

- ERP and related applications: (Workflow, project management, file sharing)- they have a bad experience with most ERP softwares. A product named Lotus they used in Russia was better among them, but still not efficient.
- Construction site: Primavera is the most common, then Ms Project (Scheduling)
- A lot of other tools are used per site. Merging these and getting all stakeholders to understand interfaces is a major issue.

The starting point to shift towards more integrated project delivery as pointed out in the workshop, should be integrated design. Already superposed projects will accelerate construction start and minimize problems: the problem they face most often is inconsistency between different projects such as the architectural and mechanical drawings. As built projects can be monitored with the design and construction teams if there is a superposed base document on BIM. For the contractor team it is important to establish a memory for the project. How and why design decisions were taken should be accessible to the team building them.

For the transition to BIM, lack of know how in the industry has been pointed as the main barrier. For general adaptation of technology and tools already in use, numerous tools are used and this makes the process more complicated. Tools like ERP software for construction management, MS Project for time management and other document and file managers are used. The construction experts in the workshop pointed out that “the costliest thing in construction is time” and losing time through this bulk of softwares and tasks to be done on them is a major problem. Another important point is that not every actor in the process is competent on the complicated interfaces of large construction management softwares such as ERP. The incompetency of one actor may disrupt a whole process.

To develop a tool have to be useful and that could make their workflow better to close the gap between, design, construction, commissioning even operation, one should provide the following:

- This tool must be user friendly, provide intuitive use along with user specific interfaces. Something web based and accessible, like dropbox, with different access levels for different user groups and interfaces focused on the tasks these groups would handle will be practical.
- The current and past versions of the project shall be kept in the system along with the work schedule, while reporting works completed and managing payments.
- Some sublevels of authority would be practical to be able to approve some smaller works, unlike ERP where the smallest purchase is approved at all levels, being time consuming.
- This tool must be an add on to established softwares or be able to import from them. Double work should be avoided and it is almost certain that major players will be doing their workplan on Primavera, this should sync with it. Even if it is a Revit plugin or BIM component it should be part of these as well.

16.5 Workshop Findings: BASF

Dobrindt – Federal Ministry of Transport and Digital Infrastructure (freely translated) *“We‘re starting an offense on the digitalization of the construction industry. With the help of the most modern digital methods construction projects will be efficiently realized within time and cost frames. Beginning 2020 we will require design and construction infrastructure projects to be delivered in BIM. We‘re optimizing the use of this design method with pilot projects. This is a modernization campaign for the worldwide operation of the German construction industry.“* (December 2015)

In this chapter, we only attach the most important statements from the several interviews that have been held in Germany (the interviews are accurate and typical for the German construction industry). Four workshops were held by the BASF team with large German construction and engineering firms including Züblin BIM, Scherr+Klimke, Wolff & Müller, and Heidelberg Cement.

Key findings across the interviews include:

- BIM Objects are not used due to missing standards
- Building data model is **not maintained** during construction
- BIM calls for a **rethinking** of the whole construction industry
- **Missing tools** and interface losses hinder the progress
- **BIM will be standard** for all partners of the construction industry
- **High acceptance** and will for change
- Great potential in **automating the supply chain**/procurement (TAI

Meeting Züblin BIM 5D. Largest German engineer office in terms of BIM (60 people)

BIM takes place in the office […] the construction industry is not yet ready for BIM 5D“

- Missing tools for construction manager to easily handle the model on the construction site, BIM is rarely used (model is not updated).
- Selection of building materials during construction is done independently and outside the model (by construction manager)
- BIM objects are not or rarely used, because of the lacking unity of the attributes
- Building operation data are often not requested and there are no standards
- Evaluating cost-benefit equations before connecting data
- Currently, it’s important to provide construction material data for BIM models: Digital concrete demand - supply chain digital: Digital delivery of the concrete plant to the construction site (compatible data format, easy to use, ...)
- Current Focus: digitalization of construction processes, such as component tracking (precast).
- How do I check the quantities used on the jobsite? → Next step: digital recording. At the construction site, the data processing must be fast and easy.

Drawback: only standardization leads to process optimization; not available yet

Meeting Scherr+Klimke

“The construction processes need to change to gain the full potential of BIM.“

- Prefer closed BIM (obvious, because they are general designers)
- Improvement of the interface communication is crucial for the BIM potential
- Complex models are linked to intensive maintainance.
- Difficulties in transferring IFC Revit. Required Know-how.
- Designers do not get enough information back from the contractor to optimize their planning/complement the model
- In Germany: neutral construction tendering
- BIM objects are not or rarely used, because they are not neutral (search via google)
- Building operation data are often not requested

- Cost / benefit balance should be done: Added value from additional information in the model should be clarified. For example:
    - No interest of facility management model data → had existing systems, would not work with the BIM model → Facilities Management difficult.
    - Useful data for operational phase overestimated: z. B. heat exchanger comes after ten years of breaking → How valuable is the information from whom the heat exchanger comes and who has installed it after ten years due to bankruptcies and technological progress?
    - Complex models need care. LOD 200 (preliminary design) are
        - As-built (LOD 500) - the cost does not justify the benefits
        - Builder has no interest in or lacks the options (know-how)
        - Who cares in 5 years (expiry of warranty) what about the building? → In the future they will not invest.
        - So they see the biggest advantage of BIM methodology not with facility management but with construction company (but construction industry is far from the extent)
        - Great potential in the supply chain
        - Building process has to change, otherwise the BIM not access benefits
        - Great advantage for planners: collision check
        - Scherr + Klimke favors closed BIM (Example Bosch Health Center). Open BIM does not lead to the desired result. Closed BIM works very well (all in-house designed by a company), major problems with open BIM - project with external stakeholders. IFC Revit +→ had great difficulty: IFC impractical for planning.

Key: Greatest potential lies in the automation procurement processes

Meeting Wolff & Müller

Change comes fast […] BIM will be standard in 3 to 5 years.“

BIM: Building Information Management

- First operative BIM, then change to a more strategic aproach
- Huge need for standardization
- Good experience with IFC format
- Need for complete rethinking of the current workflows
- Project design and planning with current HOAI phases do not work with BIM (honorarium moves into early project phases)
- Products and BIM objects are searched via google. SEO is very important!
- Building model is especially interesting for maintenance and use change purposes
- Maintenance of the data on the construction site is still critical
- Designers for public infrastructure projects are not yet ready
- In the future there will be no more tender specifications (up to 5 years from now)
- Perhaps suppliers will get access to the BIM model to make their tenders.

Heidelberg Cement

- BIM object databases are far from digital supply chain (digital delivery notes, truck tracking ...)
- Improve communication between manufacturers / factory and construction site.

16.6 Workshop Findings: COMSA/OPY/COMET

COMSA Corporación is the first largest unlisted Spanish group in the infrastructures and engineering sector. With more than a century of experience behind it, COMSA Corporación mainly operates in the fields of Infrastructures and Industrial Engineering; Services and Technology; and Concessions and Renewable Energy. One of the pillars of COMSA Corporación's progress is its international operations. The company is currently present in 24 countries: Andorra, Algeria, Argentina, Australia, Brazil, Chile, Colombia, Croatia, Denmark, France, Latvia, Lithuania, Morocco, Mexico, Paraguay, Peru, Poland, Portugal, Romania, Spain, Sweden, Switzerland, Turkey and Uruguay. The company has a turnover of €582 million in this area. COMSA Corporación, which is the seventh largest Spanish company in the sector, has a turnover of €1.080 million and over 7.700 employees.

COMSA participates in many national and international research projects. In recent years, it has joined the new trends in the construction sector and has incorporated BMI, LPS, Lean Construction and IPD techniques into its internal protocols. In this objective they are involved from the CEO, the department of projects, the people in charge of work, etc.

In the last six months, we have conducted several workshops and interviews with managers of the different internal departments of COMSA. To enrich our contribution to the SPHERE Project, we have also held face-to-face external meetings with various agents in the construction process:

- La Salle School of Architecture (Ramon Llull University - URL)
- Official College of Industrial Engineers of Catalonia (COEIC)
- MEP and Structural Engineering firms
- Architectural offices.

As a result of these more than ten interviews, workshops and RFI sent by mail, we report the following twenty conclusion points:

1. BIM is still in evolution. This often causes misunderstandings between the parties when agreeing on a project in BIM, concluding in mutual distrust

2. In projects with BIM it is essential to specify the maximum detail, in order to avoid confusion in the LOD and the scope with which the project will be developed (4D, 5D, 6D, 7D, etc.).

3. BIM has been used excessively as a marketing tool, to sell the project to the client, rather than as a technical resource, and this has reduced its value. This discredited the BIM as a useful tool and made him lose credibility and confidence.

4. Object libraries are still under construction, and this leads the designer to simplify the project to products that are available in libraries, or requires manual labour to create new objects (project cost overrun), if he wants to give free rein to his creative abilities.

5. BIM can simplify the construction process rationalizing it for good, but also for bad, slowing down the creativity of designers.

6. The public administrations, which in Spain already require the presentation of projects in BIM, will give a good impulse to normalize and update the use of BIM.

7. BIM is already a frequent work tool in the most important architecture bureaux and engineering offices. The Owners, following the process that prescribe the public company, also begin to use and prescribe BIM

8. The BIM>4D dimensions are just beginning to emerge. The most advanced is 5D. The 7D, which links the building to its life cycle, is the necessary tool for the development of IPD contracts and the IDDS itself.

9. Construction managers of contractors are very reluctant to incorporate BIM into their daily work, because today it represents more of an additional cost than a benefit. Although this will change, there is still a way (time) to go.

10. There is a great lack of specialized personnel to handle BIM and take advantage of it.

11. Maintenance companies, such as the one of our COMSA group, are already working to adapt and integrate their CMMS to BIM.

12. The current cost of the BIM tool is only amortized for large projects.

13. Currently, virtually no one introduces maintenance protocols to build equipment and technical systems on BIM, and without it, 7D cannot be executed.

14. The ability to import and export files from/to BIM has not yet overcome all the technical barriers.

15. In rehabilitation projects, working in BIM requires an additional previous task of scanning and digitizing the pre-existences, that if you want to do properly, it has a very high cost

16. The BIM in the residential sector of single-familiar dwellings is not economically justified, except for multi-family buildings with some technical complexity.

17. The feasibility of using BIM on construction sites is subject to the capacity limitations of the resources available on the sites.

18. The performance of existing simulation tools compatible with BIM (Digital Twin) does not offer more attractiveness than others that already exist on the market, even if they are not compatible with BIM.

19. The cost of projecting a building of outstanding architecture in BIM can be very high and is only available to great experts in the management of the tool.

20. In Spain, BIM training in Universities and Schools of Architecture and Engineering is very recent, even not mandatory, which means that there is very little supply of truly BIM experts in Spain.

16.7 Workshop Findings: R2M

During different days of August 2019 R2M hold one-by-one interviews in Northern Italy, Milan area, with four professional profiles related to Architecture, Engineering and Construction. The interviews were mainly focused on understanding the knowledge and usage of key terms and ideas related to Sphere.

The Questions were:

- Which profile best depict you?
- Number of employees in your company?
- Headquarter Location
- BIM: Are you aware of its existence?
    - What does BIM suggest to you in the first instance?
    - Do you have it implanted in the company? If yes, indicate the year of implementation
        - In case you know it but don't use it. Are you planning to incorporate BIM?
    - Do you use Autodesk Revit software? Which version? If not, what program?
    - Do you use additional plug-in software for the functions 4D (planning), 5D (costs), 6D (sustainability), 7D (maintenance)? Please specify
    - In the BIM projects you are involved, indicate whether any of the following attributes (non-geometric) of the work units have been entered when defining each of them, in addition to the 3D data:
        - Description of work units,
        - Position in the chronogram (4D)
        - Unit price (5D)
        - Energy traceability (6D)
        - Manufacturer (Brand, Model)
        - Associated maintenance operations (7D)
    - Currently, which % of the projects/constructions in progress you are involved in, are being executed in BIM?
    - In how many projects have you participated in 2018 in which BIM-based software has been applied?
- LEAN Construction: Are you aware of its existence?
    - In case you know it but don't use it. Are you planning to incorporate LEAN?
    - Do you have it implanted in the company? Indicate the year of implementation

    - In how many projects have you participated in 2018 in which LEAN Construction methodology has been applied?
    - What software tool do you use for LEAN Construction purposes?
- Last Planner System: Are you aware of its existence?
    - In case you know it but don't use it. Are you planning to incorporate LPS?
    - Do you have it implanted in the company? Indicate the year of implementation
    - In how many projects have you participated in 2018 in which LPS criteria has been applied to control the temporary program?
    - What software tool do you use for LPS?
- Integrated Project Delivery: Are you aware of its existence?
    - In case you know it but don't use it. Are you planning to incorporate IPD?
    - Do you have it implanted in the company? Indicate the year of implementation
    - How many contracts have you signed/participated in 2018 under IPD format?
    - What barriers or legal difficulties have you encountered when signing such contracts?
    - Do you use any specific software tool to manage IPD contracts? If yes, which one?
- Digital Twin: Are you aware of its existence?
    - In case you know it but don't use it. Are you planning to incorporate Digital Twin concepts?
    - Do you have it implanted in the company? Indicate the year of implementation
    - How many projects have you been involved in 2018 in which Digital Twin was applied?
    - What software tool do you use for Digital Twin?
- Please, feel free to add any comment regarding your use of IPD, BIM, LEAN, LPS, Digital Twins

Interview 1: Real Estate Consultant (Pavia), Company size: 30 Persons

The interviewee was only aware of **BIM** and **Digital twin**, thus, the questions were focused on these technologies. The interview 1 defined BIM as: **a new way of project, develop and maintain buildings in a more sustainable and efficient way.** He is not always using BIM (he has been involved in 2 BIM projects so far) but he considers to utilise it in the future. Regarding Digital Twin, he understands the term, but so far is not something that he has worked with. He might consider using it in the future.

Interview 2: Architect - Engineer (Pavia), Company size: 50 persons

The interviewee is aware of all the five terms presented in the interview. He has been using BIM **for 3 years** and it suggests him: **Models - modelling - management** . He is using Revit 2019, and he mainly uses description of **work unit attributes** and doesn't require extra plugins since "*The current BIM application in the company doesn't require other BIM dimensions*". He has been involved in **10 different BIM projects**, and around **80% of the projects/constructions in progress in which he is involved in, are being executed in BIM**? The interviewee **knows and understands the terms related to Lean Construction, including LPS and IPD**, and plans to incorporate them in the future depending on the projects. Regarding **Digital Twin**, he understands the term but he is **not sure that he will use it in the short term**.

Interview 3: Engineer (Milan), Company size: 280 persons

The interviewee was aware of **BIM and Digital twin,** and has some light knowledge of some Lean construction methodologies. For him "**BIM is the baseline for creating Digital Twins**", "**LPS is a collaborative process between different parts to reach agreements - far from the construction market in this phase**" and that "**LEAN cost control is the future of construction real estate even if it is not already in the italian market**". He believes BIM is a **collaborative tool to improve the construction process,** and he has been using BIM since 2016 (3 years). Regarding BIM attributes he is using: Description of work units;Position in the chronogram (4D);Unit price (5D);Energy traceability (6D);Manufacturer (Brand, Model); Associated maintenance operations (7D). He has participated in **10 BIM projects in the last years**, but believes that **not more than 40% are being executed in BIM**. With respect to Lean Construction and LPS, still they are **not common in the Italian market** but he would consider using them. He had some past experience with **Digital Twin in one project in 2018.** He used **Revit and Autodesk Forge.**

Interview 4: Project Manager Real Estate (Milan), Company size: 700 persons

The interviewee was only aware of **BIM** and **Lean Construction**. For him **BIM is synonym of Data Management,** and even if he has not been involved in BIM projects directly he believes he will incorporate it in the short term. Regarding Lean Construction he doesn't think he will use it in the italian market in the next few years. In the open questions, he commented that there is a lack of knowledge of these terms, methodologies and technologies in his sector and that "**more information and communication about this matters**" is needed.

Table X. Term Knowledge Matrix

Profile	BIM	LEAN Construction	LPS	IPD	Digital Twin
Real Estate Consultant	**Yes**	No	No	No	**Yes**
Architect; Engineer	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Engineer	**Yes**	**Yes**	No	**Yes**	**Yes**
Project Manager Real Estate	**Yes**	**Yes**	No	No	No

Conclusion (For North Italy)

As a summary of the interviews with the italian partners, we can say that BIM, at least the term, is known but only used in part of the projects. Lean construction and related methodologies are not planned to be used in the short term, and for Digital Twin there is still work to be done to reach user engagement. In general interviewees knew the terms but they have not pursued yet the use of technologies/methodologies.

16.8 Workshop Findings: Neanex

Neanex works together closely with BESIX, a construction company based in Brussels, Belgium. BESIX operates all over the world in most sectors of construction, including building, marine works, environmental works, sports and leisure facilities, industrial buildings, road, rail, port and airport infrastructure. Interviews with BESIX were conducted in five workshops, resulting in the following condensed conclusions:

- The learning curve for working with BIM is too steep.
- BIM does not help to think ahead (as an engineer), it is a tool to check design. The required technical expertise is sometimes underestimated.
- Collaboration with other disciplines has become easier and more information and the process is better documented. Projects of the size and scale that we are doing right now would have been more difficult without the use of BIM.

- Accessibility of 3D models should be improved, especially on site. However, also for non-modelers during the design phase an improvement is necessary.
- Requirements for projects are rarely received linked to objects. In many projects requirements are still given in a very old-fashioned big PDF document.
- Knowledge sharing is difficult. Currently we do not have a good system to manage all knowledge from previous projects. This is a risk as it is possible that problems are repeated in future projects.
- We should do more validation of the process during the project. In difficult projects, where a lot of external parties were involved, we have successfully implemented evaluation meetings. These meetings helped to align processes and be a way for the team to share frustrations. We are making steps to implement this as a standard process for all our projects.
- Because information is stored in a reusable way, the assumption is that different people can easily start working with it. However, transferring projects from one person to another often will result in unnecessary time loss.
- Much more information is stored within a model than within a 2D drawing. Therefore a lot more information can be shared with other parties/disciplines, but also received from those parties/disciplines. This increase in information flow is important to manage, because too much unorganised information can easily do more harm than good.
- Create more value for the client, especially towards operation and maintenance phase. We can help our (private and public) clients to make better use of the information that we put inside of the models.

- Currently our administration and invoicing system is slow, resulting in unnecessary time loss.

17 Appendix E – Workflows developed for SPHERE Pilots

SPHERE Austria Pilot Workflow Developed by Ekodenge and CREE – V3

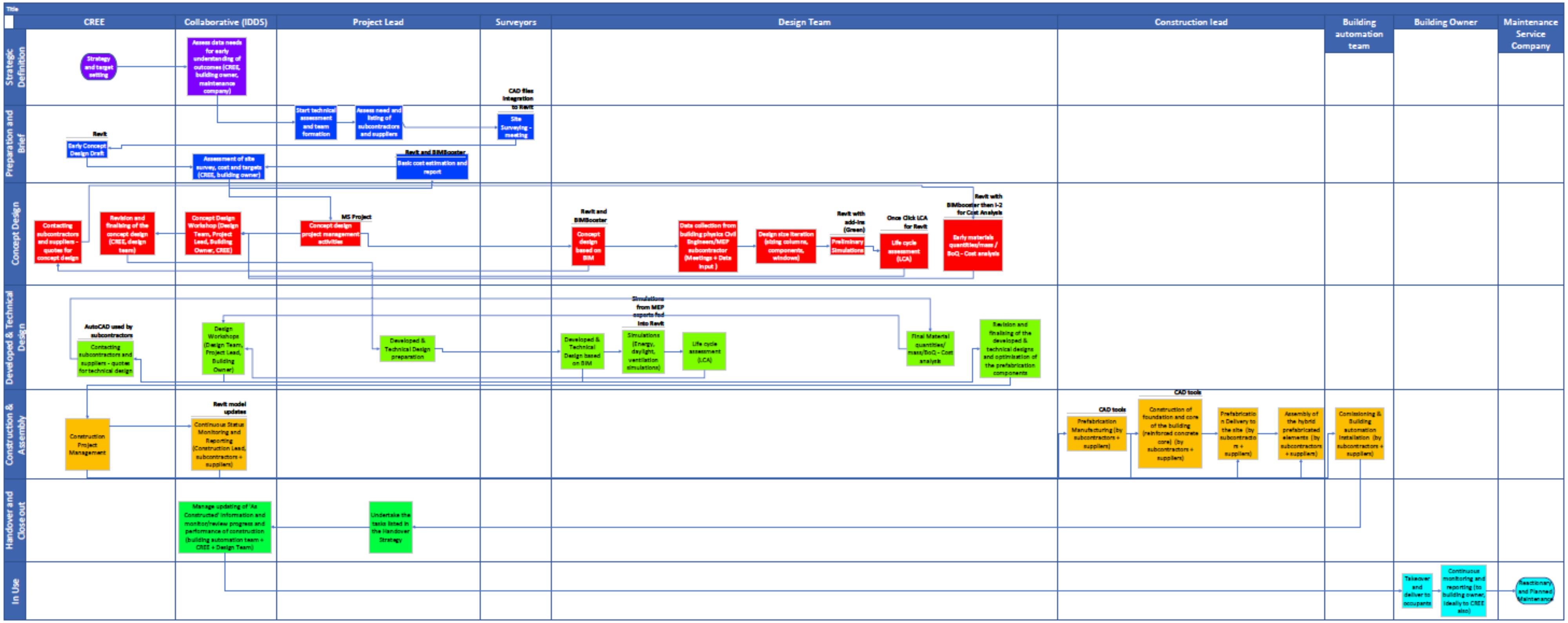


Figure X. Pilot workflow developed in the SPHERE project for the Austrian Pilot by Ekodenge and CREE

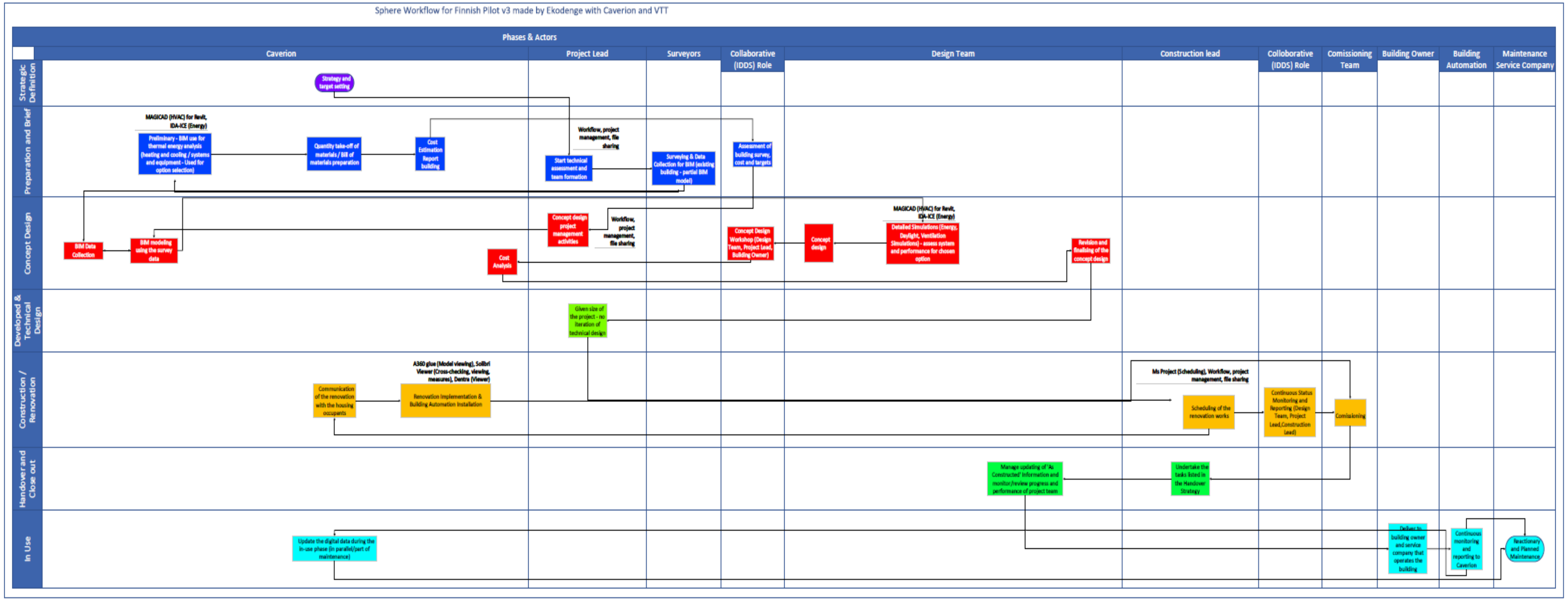


Figure X. Pilot workflow developed in the SPHERE project for the Finnish Pilot by Ekodenge and Caverion

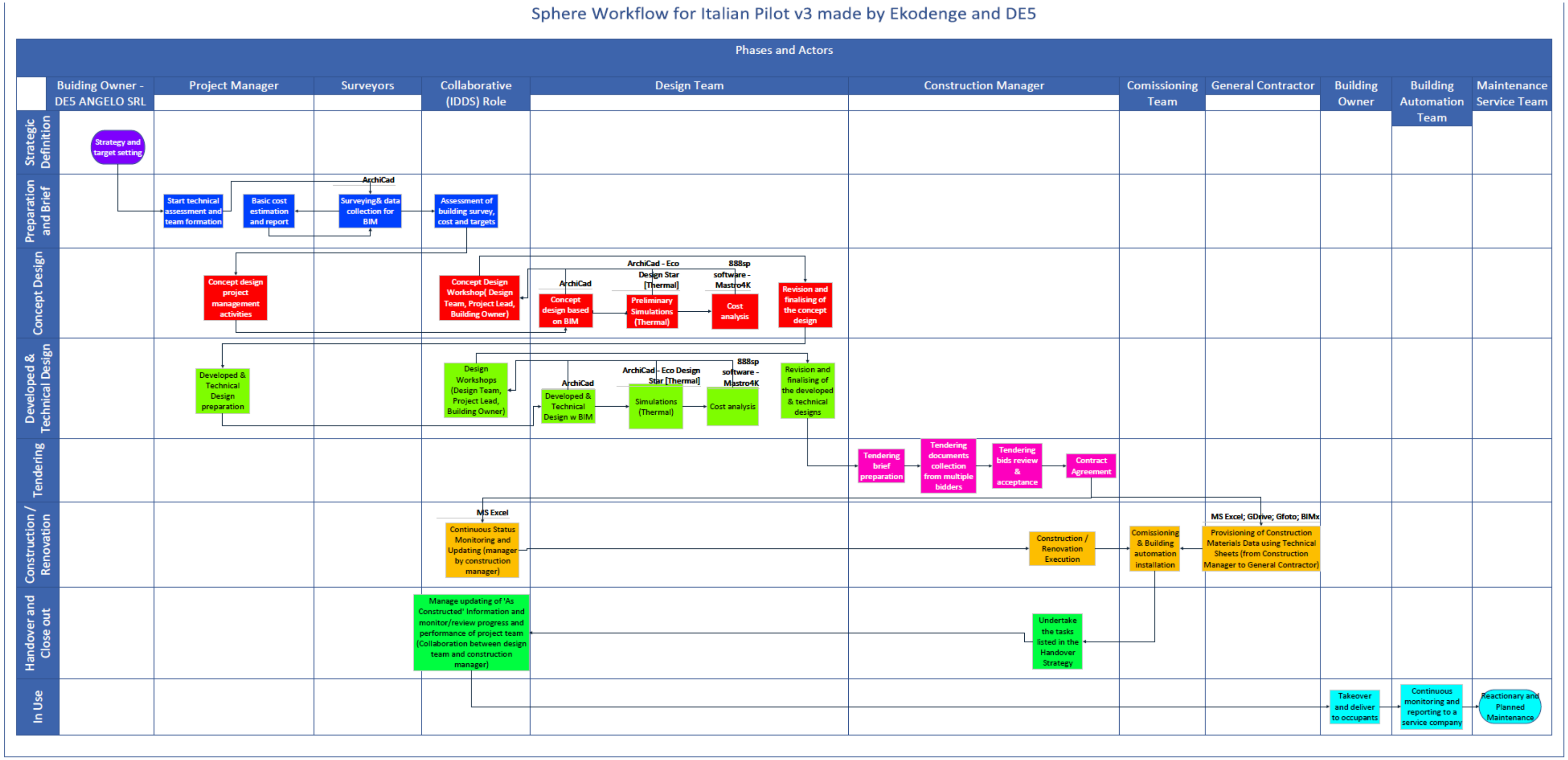


Figure X. Pilot workflow developed in the SPHERE project for the Italian Pilot by Ekodenge and Caverion

[TBD]

Figure X. Pilot workflow developed in the SPHERE project for the Dutch Pilot by Ekodenge and TNO

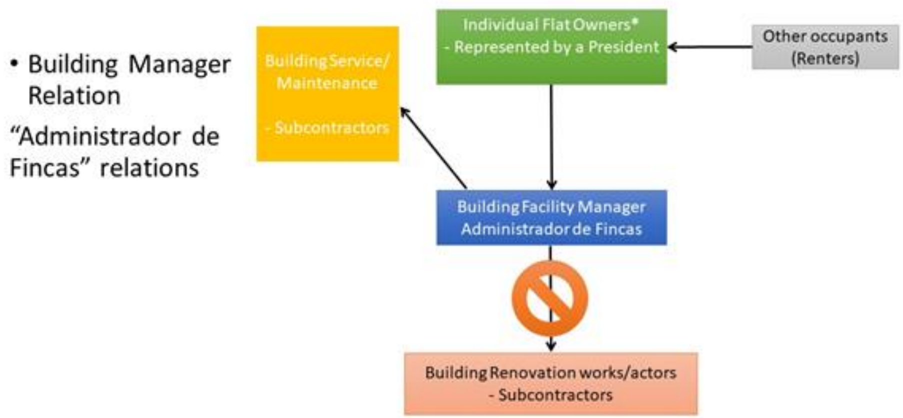
18 Appendix F - Residential Users and Actors Relationship Cases

18.1 Community owned with a Building Manager Relation (Administrador de Fincas)

Contracts gives responsibility:

- Current Expenses: Owners pay service fee for operational costs + maintenance + minor repair works.
- Extraordinary Expenses: additional fee increase for corrective maintenance & substitution (ITE: Building Technical Inspection; RDL 8/2011. SpanishLaw, DECRETO 67/2015, Catalan Law retrofitting).
- Owners community meeting with President.
- Administrador de Fincas meets with President to decide on carrying out any repair or maintenance works.

Renovation: typically, no significant renovation is carried out in the duration of ownership, renovation only occurs when building or individual flat switches ownership.



Applicable in Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Share of occupancy	Typical for 99% of housing – 78% owners, 21% renters	Common	Uncommon	88,5% of housing including 56,8% owned and 31,7% rented in 2017. Flat ofnership system is different in Finland, please read neighborhood association cell below for further information. Tried to explain differences.	Very common: the president is an elected resident or there are external building maintenance companies that act like the president.	83% of housing (57,6% owners, 25,3% renters)		Every flat owner owns a percentage of the building. The percentage is related to the surface of the flat. All the flat-owners are part of a "owner association" led by a "president". That preseident can be an owner (restrictions apply) or an external firm. The owners pay a monthly contribution to the "owner association" to pay the president's services and to gather a budget for maintenance & renovations.		Common

Below is a summary the analysis of each key actor in the relation, the summary has been created by taking the most common response for the relationship from the 10 countries. A break down of the response for each country can be found in the final section in this chapter.

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
Building Facility Manager	Signalling needs, preparing brief, investing and implementation	YES	Medium	High	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High
Individual Flat Owners	Signalling needs	YES	Low	Low	They will have more efficient solutions in renovation works in shorter time and lowest prices. Information about the state of the building	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	Low
Subcontractors for Building Renovation Works	Preparing brief, investing and implementation.	NO	Medium	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to do the renovation works	Medium

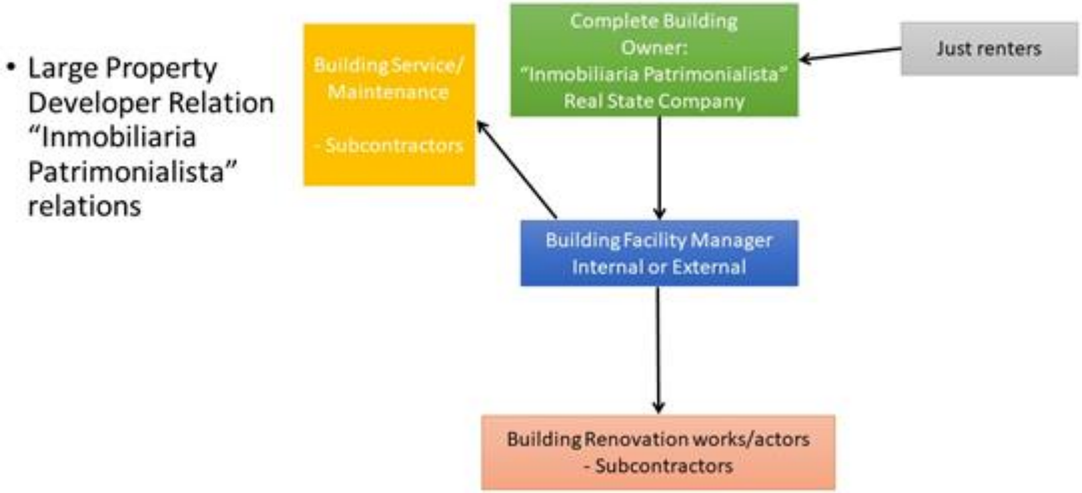
Renters	Signalling needs	NO	Low	Low	They will have more efficient solutions in renovation works in shorter time.	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low

18.2 Large Property Developer Relation (Inmobiliaria Patrimonialista)

Contracts gives responsibility:

- Expenses: Owner assumes all operational costs + maintenance + minor repair works.
- Extraordinary Expenses: Owner assumes additional fee increase for corrective maintenance & substitution (ITE* retrofitting).
- Owner can attribute to renters just minor taxes (RDL 7/2019).

Renovations: Being the same ownership, major renovations can be carried out when necessaryas to avoid depreciation of the property and ITE.



	Spain	Italy	UK	Finland	Turkey	France	Netherlands	Belgium	Germany	Austria
Applicable in Country	Yes	Uncommon	Yes	Uncommon	Yes	Uncommon	Yes	Yes	Yes	Yes

Share of occupancy	1% currently, due to increase	Unknown	Common	Professional investors own 21% of rental apartments (non-subsidesed) equaling to 7 prosent of housing in FInland. This means that they own the whole building. There is also 35% of ownership by households /private investors who are renting apartments.	Less common, but does apply to cases where there is a single building owner and the occupants are the owner, other family members or tenants	Unknown	Unknown	Unknown	Unknown	Common

Below is a summary the analysis of each key actor in the relation, the summary has been created by taking the most common response for the relationship from the 10 countries. A breakdown of the response for each country can be found in the final section in this chapter.

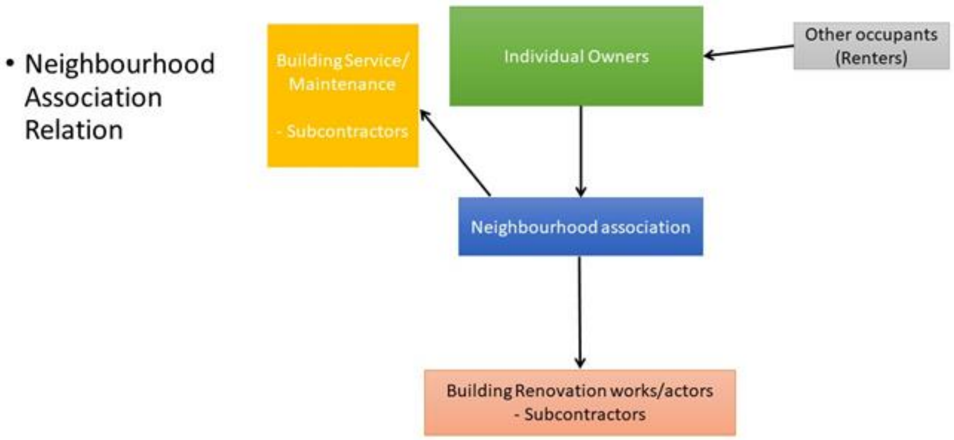
Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
Building Owner	Signalling needs, preparing brief, investing and implementation.	YES	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
Internal Building Facility Manager	Signalling needs, preparing brief, and implementation.	NO	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
External Building Facility Manager	Signalling needs, preparing brief, investing and implementation.	YES	High	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	Medium
Subcontractors for Building Service & Maintenance	signalling needs, preparing brief, implementation	NO	Medium	Medium	success of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	High
Subcontractors for Building Renovation Works	preparing brief, implementation	NO	Medium	Medium	energy efficient building, success of design in meeting standards and regulations	Easy access to rich inventory of the materials and dynamic design tools, facilitated data flow	High

18.3 Neighbourhood Association Relation

Contracts gives responsibility:

- Expenses: Owners pay a monthly fee to association for operations costs and maintenance and saving for future repair works
- Extraordinary Expenses: addition fee for extraordinary repair or renovations works
- Neighbourhood include typically a group of buildings (sometimes similar buildings that were built together)
- Neighbourhood association board typically involved a representation of all buildings

Renovations: Renovations can be carried out when and if necessary.



Below is a summary the analysis of each key actor in the relation, the summary has been created by taking the most common response for the relationship from the 10 countries. A breakdown of the response for each country can be found in the final section in this chapter.

	Spain	Italy	UK	Finland	Turkey	France	Netherlands	Belgium	Germany	Austria
Applicable in Country	Yes	Yes	No	No	No	Yes	No	No	Yes	No
Share of occupancy	Uncommon	Uncommon	0%	*	0%	Uncommon	0%	0%	Uncommon	0%

* We have different structure of ownership in Finland. Apartments are part of housing company, that is regulated by the law. The housing company has board (about 5 members selacted from owners). The board hires company to keep building in shape and handle running things and other company to take care of finances. The law says that people have "limited liability". Each owner of apartment is threated democratically and decissions are done for the general good of the housing company in general meeting where all owners vote. Housing company is responsible in planning and implementing renovations in time etc. and keep everything in shape.All renovations, even smallest, need permission from housing company. Apartment owner has right to use the apartment and owns it, but housing company is responsible for common spaces around apartment, facades, roofs, windows and HVAC and electiricity systems.

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
Individual Flat Owners	Signalling needs, Investing	YES	Medium	Medium	More efficient energy use	Easier to implement renovation works. Easier to replicate. Cost reduction	Low
Neighbourhood Association / community of neighbours	Preparing Brief	NO	Low	Low	More efficient solutions in renovation works. Reduced costs due to renovation in a group of flats/buildings	Easier to implement renovation works. Easier to replicate. Cost reduction	Low
Architect	Preparing brief, Implementation	NO	Medium	Low/Medium	Reviewing "As Constructed" documents, success of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	High
Engineer	Signalling needs, Preparing brief, Implementation	NO	Medium	Medium	success of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	High

Energy Experts	Preparing brief, Implementation	YES	Medium	Medium	Energy efficient building, success of design in meeting standards and regulations	Easy access to rich inventory of the materials and dynamic design tools, facilitated data flow	High

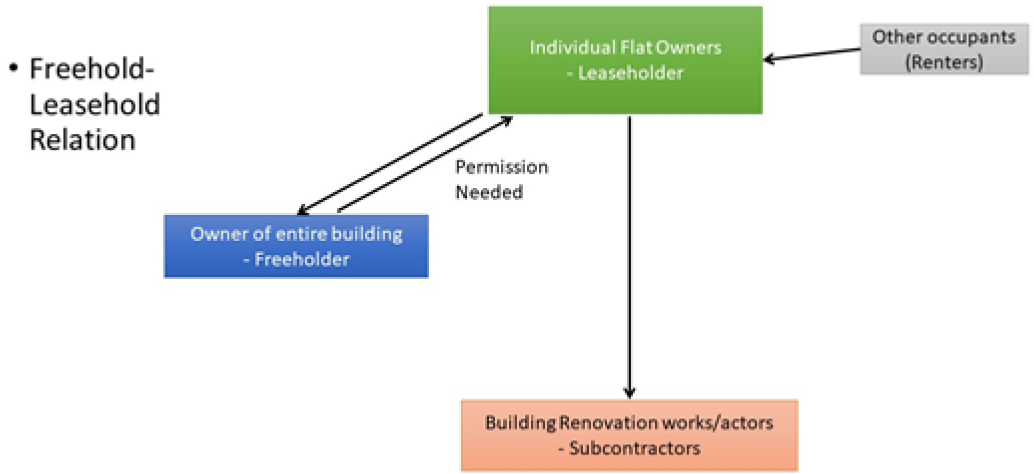
18.4 Freehold-Leasehold Relation

Contracts gives responsibility:

- Legal agreement with the landlord (sometimes known as the 'freeholder') called a "lease". This tells you how many years you'll own the property.
- This is difference from renting as you still own the property.

Renovations:

- If you only hold the leasehold to a property you need to ask permission from the freeholder before carrying out renovation works
- Some leases state you only need freeholder permission for deep renovation whilst others permission is needed to carry out any work.



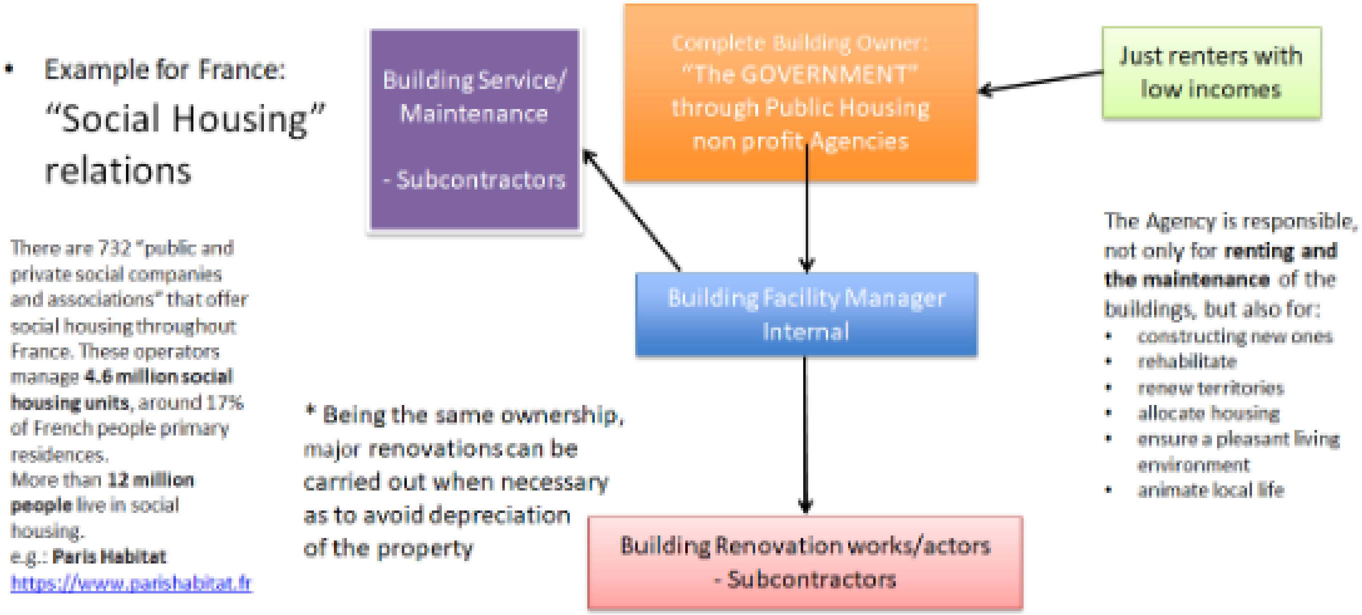
	Spain	Italy	UK	Finland	Turkey	France	Netherlands	Belgium	Germany	Austria
Applicable in Country	No	No	Yes	No	Yes	No	No	No	No	No
Share of occupancy	0%	0%	18% of English	0%	Uncommon	0%	0%	0%	0%	0%

			housing stock							

Below is a summary the analysis of each key actor in the relation, the summary has been created by taking the most common response for the relationship from the 10 countries. A breakdown of the response for each country can be found in the final section in this chapter.

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
Freeholder of entire building	Investing and Implementation	Yes	High	Medium	Efficient building, low energy costs	Easier and more reliable renovation implementation. Continuous monitoring to decide future change	Medium
Leaseholders of individual flats/dwellings	Investing and Implementation	Yes	High	Medium	Efficient building, low energy costs, reduced operation costs and time	Easier and more reliable renovation implementation. Continuous monitoring to decide future change, reduced construction time and costs. Scheduling the next renovation	Medium
Subcontractors for Building Service & Maintenance	Signalling needs, Preparing brief, and Implementation	No	Low	Medium	Low operation costs and time	Reduced project completion time, reduced costs due to the efficient use of labour and resources. Easy and transparent cost assessment and establishing a mutual trust with the client	High
Subcontractors for Building Renovation Works	Signalling needs, Preparing brief, Implementation	No	Medium	No	Low operation costs and time	Easy and transparent cost assessment and establishing a mutual trust with the client	High

18.5 Social Housing Relation



	Spain	Italy	UK	Finland	Turkey	France	Netherlands	Belgium	Germany	Austria
Applicable in Country	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Share of occupancy	Yes, but just a 2%	Unknown	Up to 8%	Unknown	Unknown	Unknown	Up to 30%	Unknown	Unknown	Unknown

Below is a summary the analysis of each key actor in the relation, the summary has been created by taking the most common response for the relationship from the 10 countries. A breakdown of the response for each country can be found in the final section in this chapter.

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
Government Comission acting as Building Owner	Investing	YES	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
Internal Building Facility Manager	Signalling needs, preparing brief, and implementation.	NO	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
Subcontractors for Building Service & Maintenance	Signalling needs and implementation.	NO	Medium	Medium	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	Low
Subcontractors for Building Renovation Works	Implementation.	NO	Medium	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to be done	High

18.6 Country Analysis Breakdown

SPAIN

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Administrador de Fincas, Building Facility Manager	Signalling needs, preparing brief, investing and implementation	YES	Medium	High	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High
Individual Flat Owners		NO	Low	Low	They will have more efficient solutions in renovation works in shorter time and lowest prices.	If the system is implemented they will take advantage of shorter terms of decision making and development of renovation works.	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their routine maintenance tasks.	Low
Subcontractors for Building Renovation Works	Preparing brief, investing and implementation.	YES	Medium	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to do the renovation works	Medium
Renters		NO	Low	Low	They will have more efficient solutions in renovation works in shorter time.	If the system is implemented, they will take advantage of shorter terms of decision making and development of renovation works.	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Building Owner	Signalling needs, preparing brief, investing and implementation.	YES	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
Internal Building Facility Manager	Signalling needs, preparing brief, and implementation.	NO	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
External Building Facility Manager	Signalling needs, preparing brief, investing and implementation.	YES	High	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	Medium
3. Neigbourhood association (if model not applicable to country leave blank)							

Neighbourhood Association / community of neighbours	XXX	NO	Low	Low	More efficient solutions in renovation works. Reduced costs due to renovation in a group of flats/buildings	Easier to implement renovation works. Easier to replicate. Cost reduction	Low
Architect	Preparing brief, Implementation	NO?	Medium	Low/Medium	Reviewing "As Constructed" documents, success of design in meeting standards and regulations	Dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	High
Engineer	Signalling needs, preparing brief, Implementation	NO	Medium	Medium	Success of design in meeting standards and regulations	Dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	High
Energy Experts	Preparing brief, Implementation	YES	Medium	Medium	Energy efficient building, success of design in meeting standards and regulations	Easy access to rich inventory of the materials and dynamic design tools, facilitated data flow	High

ITALY

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. “Administrador de Fincas” Relations (if model not applicable to country leave blank)							
Building Facility Manager	Signalling needs, preparing brief, investing and implementation	YES	Medium	High	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High
Individual Flat Owners		NO	Low	Low	They will have more efficient solutions in renovation works in shorter time and lowest prices. Information about the state of the building	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	Low
Subcontractors for Building Renovation Works	Preparing brief, investing and implementation.	YES	Medium	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to do the renovation works	Medium

Renters		NO	Low	Low	They will have more efficient solutions in renovation works in shorter time.	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Building Owner	Signalling needs, preparing brief, investing and implementation.	YES	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
3. Neigbourhood association (if model not applicable to country leave blank)							
Neighbourhood Association / community of neighbours		NO	Low	Low	More efficient solutions in renovation works. Reduced costs due to renovation in a group of flats/buildings	Easier to implement renovation works. Easier to replicate. Cost reduction	Low
Architect	preparing brief,implementation	NO?	medium	Low-medium	Reviewing "As Constructed" documents, sucess of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	high
Engineer	signalling needs, preparing brief, implementation	NO	medium	medium	sucess of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	high
Energy Experts	preparing brief, implementation	YES	medium	medium	energy efficient building, sucess of design in meeting standards and regulations	Easy access to rich inventory of the materials and dynamic design tools, facilitated data flow	high

UNITED KINGDOM

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Building Facility Manager	Signalling needs, preparing brief, investing and implementation	YES	Medium	High	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High

Individual Flat Owners		NO	Low	Low	They will have more efficient solutions in renovation works in shorter time and lowest prices. Information about the state of the building	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	Low
Subcontractors for Building Renovation Works	Preparing brief, investing and implementation.	YES	Medium	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to do the renovation works	Medium
Renters		NO	Low	Low	They will have more efficient solutions in renovation works in shorter time.	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Inmobiliaria Patrimonialista, Building Owner	Signalling needs, preparing brief, investing and implementation.	YES	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
Internal Building Facility Manager	signalling needs	no?	medium	high	efficent building, low energy costs, reduced operation costs and time	easier and more reliable renovation implementation. Continous monitoring of processes, reduced construction time. Scheduling the next renovation?	high
External Building Facility Manager	preparing brief,implementation	no	medium	low(medium_YD)	Reviewing "As Constructed" documents, sucess of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	high
Subcontractors for Building Service & Maintenance	signalling needs, preparing brief, implementation		medium	medium	sucess of design in meeting standards and regulations	dynamic design throughout construction process to ensure build meets design and correcting early errors, constant monitoring and easy access to documents	high
Subcontractors for Building Renovation Works	preparing brief, implementation		medium	medium	energy efficient building, sucess of design in meeting standards and regulations	Easy access to rich inventory of the materials and dynamic design tools, facilitated data flow	high
4. Freeholder-Leaseholder Relationship (if model not applicable to country leave blank)							
Freeholder of entire building	investing, implementation	yes	high	medium	efficent building, low energy costs	easier and more reliable renovation implementation. Continous monitoring to decide future change	high
Leaseholders of individual flats/dwellings	investing, implementation	yes	high	medium	efficent building, low energy costs, reduced operation costs and time	easier and more reliable renovation implementation. Continous monitoring to decide future change, reduced construction	high

						time and costs.Scheduling the next rennovation	
Subcontractors for Building Service & Maintenance	Signalling needs, preparing brief, and implementation	no	low	medium	low operation costs and time	Reduced project completion time, reduced costs due to the efficient use of labour and resources. Easy and transparent cost assessment and establishing a mutual trust with the client	
Subcontractors for Building Renovation Works	signalling needs, preparing brief, implementation	no	medium	no	low operation costs and time	Easy and transparent cost assessment and establishing a mutual trust with the client	

FINLAND

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Administrador de Fincas, Building Facility Manager	Signalling needs, preparing brief, Implementation	Yes	High	High	Information in one place. As-built models, energy, water and electricity consumptions.	Up-to-date information. Different accessfor different stakeholders.	High
Individual Flat Owners	Investing, implementation	Yes	Medium	High	As-built model up to date, energy consumption.	Portal to flat information, models, energy information	Medium
Subcontractors for Building Service & Maintenance	Preparing brief, Implementation	No	Medium	Medium	Up-to-date maintenance plan, Energy, water and electricity consumptions.	Maintenance status in model, current values and history data for energy consumption, temperature and other sensors.	Low
Subcontractors for Building Renovation Works	Preparing brief, Implementation	No	Medium	Medium	As-built model, documentation.	One place to share materials for different stakeholders.	Low
Renters	Signalling needs	No	Low	Low	Quick renovation, no disturbance.	Plans visible.	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							

Inmobiliaria Patrimonialista, Building Owner	Preparing brief, Investing	Yes	High	High	Key figures available, up-to-date information and models from building.	One place for materials, share with different stakeholders.	High
Internal Building Facility Manager	Signalling needs, Preparing brief, Implementation.	Yes	High	High	Information in one place. As-built models, energy, water and electricity consumptions.	Up-to-date information. Different accessfor different stakeholders.	High
External Building Facility Manager	Signalling needs, Preparing brief, Implementation.	No	High	Medium	Information in one place. As-built models, energy, water and electricity consumptions.	Up-to-date information. Different accessfor different stakeholders.	Medium
Subcontractors for Building Service & Maintenance	Preparing brief, Implementation	No	Medium	Low	Up-to-date maintenance plan, Energy, water and electricity consumptions.	Maintenance status in model, current values and history data for energy consumption, temperature and other sensors.	Low
Subcontractors for Building Renovation Works	Preparing brief, Implementation	No	Medium	Low	As-built model, documentation.	One place to share materials for different stakeholders.	Low
5. "Social Housing" Relations (if model not applicable to country leave blank)							
Government Comission acting as Building Owner	Signallind needs, Investing	Yes	High	High	Key figures available, up-to-date information and models from building.	One place for materials, share with different stakeholders.	High
Internal Building Facility Manager	Signalling needs, Preparing brief, Implementation	Yes	High	High	Information in one place. As-built models, energy, water and electricity consumptions.	Up-to-date information. Different accessfor different stakeholders.	Medium
Subcontractors for Building Service & Maintenance	Preparing brief, Implementation	No	Medium	Low	Up-to-date maintenance plan, Energy, water and electricity consumptions.	Maintenance status in model, current values and history data for energy consumption, temperature and other sensors.	Low
Subcontractors for Building Renovation Works	Preparing brief, Implementation	No	Medium	Low	As-built model, documentation.	One place to share materials for different stakeholders.	Low

TURKEY

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Building Facility Manager	Signalling needs, preparing brief, investing and implementation	YES	High	High	Process needs and carry operations paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High
Individual Flat Owners	Signalling needs	NO	Low	Medium	Desire more efficient solutions in renovation works in shorter time and lowest prices. Information about the state of the building	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	if the digital twin is developed they will take advantage of it for the implementation of their repetitive maintenance tasks.	Low
Subcontractors for Building Renovation Works	Preparing brief, investing and implementation.	YES	Medium	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to be done in scope of the renovation works	Medium
Renters	Signalling needs	NO	Low	Low	Renters desire less hassle, consensus with their landlords, more efficient solutions in renovation works in shorter time.	shorter terms of decision making and development of renovation works. Support for monitoring of sensors	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Building Owner	Signalling needs, preparing brief, investing and implementation	YES	High	High	More efficient building, increased capital value of property after implementation, low cost and efficient operation	Easier to commission renovation works (use of digital twin BIM data)	Medium
Internal Building Facility Manager	Preparing brief, investing and implementation.	NO	Medium	High	User satisfaction through more efficient building and low-cost high-quality operation	If the digital twin is developed, they will take advantage of it for the implementation of their repetitive maintenance tasks.	High
External Building Facility Manager	Preparing brief and implementation.	NO	Medium	High	User satisfaction through more efficient building and low-cost high-quality operation	If the digital twin is developed, they will take advantage of it for the implementation of their repetitive maintenance tasks.	High

Subcontractors for Building Service & Maintenance	Implementation.	NO	Low	Low	User satisfaction through more efficient building and low-cost high-quality operation	Have a clear plan of what is needed to be done in scope of the renovation works	Medium
Subcontractors for Building Renovation Works	Implementation.	NO	Low	Low	User satisfaction through more efficient building and low-cost high-quality operation	Have a clear plan of what is needed to be done in scope of the renovation works	Medium
4. Freeholder-Leaseholder Relationship (if model not applicable to country leave blank)							
Freeholder of entire building	Investing, Implementation	YES	High	Medium	Efficient building, low energy costs	Easier and more reliable renovation implementation. Continous monitoring to decide future change	High
Leaseholders of individual flats/dwellings	Signalling needs, Investing, Implementation	YES	Medium	Medium	Efficient/comfortable building, low energy costs, reduced operation costs and time	Easier and more reliable renovation implementation. Continous monitoring to decide future change, reduced construction time and costs.Scheduling the next rennovation	High
Subcontractors for Building Service & Maintenance	Signalling needs, Preparing brief, and Implementation	NO	Low	Medium	Low operation costs and time	Reduced project completion time, reduced costs due to the efficient use of labour and resources. Easy and transparent cost assessment and establishing a mutual trust with the client	Medium
Subcontractors for Building Renovation Works	Signalling needs, Preparing brief, Implementation	NO	Medium	No	Low operation costs and time	Easy and transparent cost assessment and establishing a mutual trust with the client	Medium

FRANCE

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Administrador de Fincas, Building Facility Manager	Signalling needs, preparing brief and implementation	YES	Medium	High	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High

Individual Flat Owners	Investing	YES	Low	Low	They will have more efficient solutions in renovation works in shorter time and lowest prices.	If the system is implemented they will take advantage of shorter terms of desition making and development of renovation works.	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	Low
Subcontractors for Building Renovation Works	Preparing brief, investing and implementation.	YES	Medium	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to be done	Medium
Renters	-	NO	Low	Low	They will have more efficient solutions in renovation works in shorter time.	If the system is implemented they will take advantage of shorter terms of desition making and development of renovation works.	Low
5. "Social Housing" Relations (if model not applicable to country leave blank)							
Government Comission acting as Building Owner	Investing	YES	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
Internal Building Facility Manager	Signalling needs, preparing brief, and implementation.	NO	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High

Subcontractors for Building Service & Maintenance	Signalling needs and implementation.	NO	Medium	Medium	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	Low
Subcontractors for Building Renovation Works	Implementation.	NO	Medium	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Have a clear plan of what is needed to be done	High

NETHERLANDS

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Building Facility Manager	Signalling needs, Implementation, Preparing brief	YES		Medium	Satisfied customer	Assessment of improvement measures, traceable improvement activities	High
Individual Flat Owners	Signalling needs, Investing	YES		Medium	Comfortable dwelling, low opex, low investment costs	Assessment of improvement measures, Assessment of renovation actions	Low
Subcontractors for Building Service & Maintenance	Implementation	NO	High			SPHERE recognized organization could have large client base	Medium
Subcontractors for Building Renovation Works	Implementation	NO	High			SPHERE recognized organization could have large client base	Medium
Renters	Signalling needs, Investing	YES		High	Comfortable dwelling	Assessment of improvement measures	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Building Owner	Signalling needs, Preparing brief, Investing	YES	High	High	Easy to rent buildings, low opex, low capex	Early assement of improvement measures	High
Internal Building Facility Manager	Signalling needs, Preparing brief	YES	Medium	Medium	Low opex, low capex	Traceable improvement activities	High
External Building Facility Manager	Signalling needs, Preparing brief	YES	Medium	Medium	Low opex, low capex	Traceable improvement activities	High
Subcontractors for Building Service & Maintenance	Implementation	NO				SPHERE recognized organization could have large client base	Medium

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Subcontractors for Building Renovation Works	Implementation	NO	XXX	XXX	XXX	SPHERE recognized organization could have large client base	Medium

BELGIUM

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Administrador de Fincas, Building Facility Manager	Signalling needs, preparing brief, investing and implementation	YES	High	medium	Time savings > more efficient work process (their income = typically a fixed fee per flat)	Easier Commissioning less ad hoc repairs (pro-active) Easier selection & decision process	Medium
Individual Flat Owners	Signalling needs	YES	High	High	Money savings > better & transparant maintenance & operations	Money saving in energy consumption Increased property value Lower maintenance costs	high
Subcontractors for Building Service & Maintenance	Implementation	NO	Low	Low	Better control over the building to provide their maintenance services.	More efficient repetitive maintenance execution.	Low
Subcontractors for Building Renovation Works	Implementation.	NO	Medium	medium	When working for a fixed price > less bad surprises	Better scope of the renovation works	Medium
Renters	Signalling needs	NO	Low	Low	A good place to live	shorter terms of decision making and development of renovation works. Lower energy consumption	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Inmobiliaria Patrimonialista, Building Owner	Signalling needs, preparing brief, investing and implementation	YES	high	high	- more efficient building - increased capital value of property - low cost and efficient operation	Easier Commissioning less ad hoc repairs (pro-active) Easier selection & decision process	medium
Internal Building Facility Manager	Signalling needs, preparing brief, implementation	YES	medium	high	Time savings > more efficient work process (their income = typically a fixed fee)	More efficient repetitive maintenance execution.	high

External Building Facility Manager	Signalling needs, preparing brief, implementation	YES	medium	high	Time savings > more efficient work process (their income = typically a fixed fee)	More efficient repetitive maintenance execution.	high
Subcontractors for Building Service & Maintenance	implementation.	no	low	low	Better control over the building to provide their maintenance services.	More efficient repetitive maintenance execution.	medium
Subcontractors for Building Renovation Works	implementation.	no	low	low	When working for a fixed price > less bad surprises	Better scope of the renovation works	medium
5. "Social Housing" Relations (if model not applicable to country leave blank)							
Government Comission acting as Building Owner	Preparing Brief, Investing	Yes	High	High	budget investments and control quality. Savings in time, money,...	deliver insights in real estate portfolio	High
Internal Building Facility Manager	Signalling needs, Preparing brief, Implementation	Yes	High	High	Time savings > more efficient work process (their income = typically a fixed fee)	More efficient repetitive maintenance execution.	High
Subcontractors for Building Service & Maintenance	Implementation	No	Medium	Low	Better control over the building to provide their maintenance services.	More efficient repetitive maintenance execution.	Low
Subcontractors for Building Renovation Works	Implementation	No	Medium	Low	When working for a fixed price > less bad surprises	Better scope of the renovation works	Low
Government Comission acting as Building Owner	Preparing Brief, Investing	Yes	High	High	budget investments and control quality. Savings in time, money,...	deliver insights in real estate portfolio	High

GERMANY

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Building Facility Manager		YES	Medium	High		Overall knowledge of the state of the building for daily management tasks	High
Individual Flat Owners		YES	Medium	High		Overall knowledge of the state of the building and real energy performance	Low
Subcontractors for Building Service & Maintenance		NO	Low	Medium		Predefined proposals (materials, technologies, solutions, ...) for renovation activities.	Low
Subcontractors for Building Renovation Works		NO	Low	High		Predefined proposals (materials, technologies, solutions, ...) for renovation activities.	Medium
Renters		NO	Low	Low		Overall knowledge of the state of the building	Low

AUSTRIA

Actor	Process stage	Ability to invest	Ability to implement change	Incentive to act	Intended Outcome	Potential benefit from SPHERE	Likely User
Options to choose from:	(signalling needs, preparing brief, investing and implementation).	(yes/no)	(low, medium, high)	(low, medium, high)	Open fill in field	Open fill in field	(low, medium, high)
1. "Administrador de Fincas" Relations (if model not applicable to country leave blank)							
Building Facility Manager	signalling needs, preparing brief, investing and implementation	Yes	Medium	High	Develop a system of control of the building paid by the owners, but managed by them. They ensure future renovations will be controlled by them.	Easier to commission renovation works (use of digital twin BIM data)	High
Individual Flat Owners	signalling needs, preparing brief, investing and implementation	Yes	High	High	They would like to have more efficient solutions in renovation works in shorter time and lowest prices.	If the system is implemented they will take advantage of shorter terms of desicion making and development of renovation works and lower cost risk	Medium
Subcontractors for Building Service & Maintenance	preparing brief and implementation	No	Low	Medium	Better control over the building to provide their maintenance services.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	High
Subcontractors for Building Renovation Works	preparing brief and implementation	No	Low	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary renovation tasks.	High
Renters	signalling needs	No	Low	Low	They will have more efficient solutions in renovation works in shorter time.	If the system is implemented they will take advantage of shorter terms of desicion making and development of renovation works.	Low
2. "Inmobiliaria Patrimonialista" Relations (if model not applicable to country leave blank)							
Building Owner	Signalling needs, preparing brief, investing and implementation.	Yes	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data) and more efficient solutions in renovation works in shorter time and lower cost risk.	High
Internal Building Facility Manager	Signalling needs, preparing brief, and implementation.	No	High	High	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	High
External Building Facility Manager	Signalling needs, preparing brief and implementation.	No	High	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	Easier to commission renovation works (use of digital twin BIM data)	Medium

Subcontractors for Building Service & Maintenance	Implementation	No	Medium	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary maintenance tasks.	High
Subcontractors for Building Renovation Works	Implementation	No	Medium	Medium	Have a precise and reliable control of the state of the building, which will be available when reforms and updates are necessary.	In the case the digital twin is developed they will take advantage of it for the implementation of their rutinary renovation tasks.	High

19 Appendix G - Ontology of Barriers developed in the SPHERE project

SPHERE Barriers Listing			
Code	**Group**	**Barrier Category**	**Barrier**
10		**Financial barriers**	
10	10	**Financial barriers**	Renovation costs
10	20	**Financial barriers**	Access to finance
10	30	**Financial barriers**	Low energy prices
10	40	**Financial barriers**	Too high risk of investment
20		**Technical barriers**	
20	10	**Technical barriers**	Lack of general technical solutions
20	20	**Technical barriers**	Cost of technical solutions
20	30	**Technical barriers**	Lack of knowledge about solutions of construction professionals
20	40	**Technical barriers**	Lack of experience with solutions of construction professionals
20	50	**Technical barriers**	Absence of tailormade specific solution for unique building type
30		**Process & behavioural barriers**	
30	10	**Process and behavioural barriers**	Absence of collective decision making abilities
30	20	**Process and behavioural barriers**	Absence of enough capable firms for renovation/refurbishment works
30	30	**Process and behavioural barriers**	Burdening of home owners
30	40	**Process and behavioural barriers**	Need for temporary resettlement of residents
30	50	**Process and behavioural barriers**	Availability of time by key decision makers
30	60	**Process and behavioural barriers**	Difficulty in identifying skilled professionals for activity/tasks
40		**Political and Regulatory barriers**	
40	10	**Political and Regulatory barriers**	Vague ambition of performance requirements
40	20	**Political and Regulatory barriers**	Multiple definitions for renovation
40	30	**Political and Regulatory barriers**	Lack of enforcement of regulations
40	40	**Political and Regulatory barriers**	Absence of hard drivers of change in regulation
40	50	**Political and Regulatory barriers**	Limited ability to renovate due to historic building regulations
40	60	**Political and Regulatory barriers**	Lack of knowledge of local planning authorities
40	70	**Political and Regulatory barriers**	Lack of incentives to invest from housing companies
50		**Awareness barriers**	
50	10	**Awareness barriers**	Lack of awareness of energy savings potential
50	20	**Awareness barriers**	Lack of awareness of technologies
50	30	**Awareness barriers**	Lack of awareness of softwares
50	40	**Awareness barriers**	Lack of awareness of renovation / energy efficiency subsidies

20 Appendix H - Literature Search Results

Key Literature Covering Integrated Design and Delivery Solutions

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21 Appendix I – External Review Report – Alessandro Defranco (IDP)

Issue	Yes	No	Score (1=low to 5=high	Comments
Task and content comments				
Does the document cover the tasks and issues that need to be reported for the deliverable as described in the Description of Activities (DoA)?	✓		4	Yes
Is the executive summary clear and understandable?	✓		5	The purpose of the executive summary is clear. I think it is missing a line in the fifth paragraph: "Both by covering the."
Is the content of the document clear and well described?	✓		4	In general, the document is clear and effective, there are just a few writing mistakes.
Does the content of each section describe the advances carried out during the task?	✓		4	Yes, I think also that referring to DoA at the beginning of the chapter helps to focus on a particular solution.
Does the content have sufficient technical descriptions to make the research and development that was carried out clear?	✓		3	In general, ok. I think that DT Manager and BIM Manager relations needs to be detailed further. The good communication between these 2 agents is crucial, to obtain good BIM model and a good database for SPHERE Platform
Layout, textual and technical comments				
Is the format of the document correct?	✓		5	Yes
Are all the figures and tables numerated and described?	✓		5	Yes
Is the written English of sufficient quality to be understandable and communicate the results well?	✓		4	Just a few writing mistakes
Are the main technical terms correctly referenced?	✓		5	Yes
Is the referencing of the material from external sources clear and correctly done?	✓		5	Yes

22 Appendix J – Nearly Zero Energy Buildings, country regulations

United Kingdom

In the Second Cost Optimal Assessment of the EPBD for the United Kingdom, the cost optimal levels for insulation and building efficiency parameters with renewables included are compared with the current effective building regulation parameters. The report shows that current standards are mostly cost optimal and setting these cost optimal values as a minimum requirement can facilitate further transition to nZEBs.[26] Furthermore, the Welsh Government introduced a set of changes in the energy efficiency requirements to set nZEB standards as minimum standards.[7]

The UK also has introduced zero carbon standards and targeted all new residential buildings to meet these standards from 2016. This step comes in advance of the EPBD target for nZEB and is considered as an early step for nZEB. Different to nZEBs which involves the calculation of the primary energy consumption ($kWh/m^2/year$), zero carbon homes involve the calculations of the energy required for a house to maintain internal comfort conditions (FEES), and carbon compliance ($kg/m^2/year$). [27] Despite the difference in unit the metrics are comparable. For this reason, UK's zero carbon standard can be considered as the UK's definition for domestic nZEB.[8]

To an extent, Part L of the Building Regulation directly addresses the EPBD and aspects of energy efficiency. In order to comply with the energy performance standards and carbon compliance target, Target Fabric Energy Efficiency (TFEE) and Target Emissions Rate (TER) for domestic buildings were defined in 2014 within part L. Furthermore, the Regulation 25B in the amended Building Regulation introduces the integration of EPBD requirements for new buildings to be nZEBs, stating that the newly erected buildings must be a nZEB. The regulation came into force on 1 January 2019 for new buildings used by public authorities and will be in force for all other buildings on 31 December 2020.[28] In January 2019 an open letter clarifying the implementation of the requirements for nZEBs for new public buildings was circulated.[29]

A final mechanism nZEBs is the Renewable Heat Incentive (RHI). The RHI was put into effect in 2014 in order to promote use of renewable heat technologies amongst householders, business and communities with financial incentives.[30]

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26 Ministry of Housing, Communities & Local Government(2019) Energy Performance of Buildings Directive: Second Cost Optimal Assessment for the United Kingdom , [Available at]: https://www.gov.uk/government/publications/energy-performance-of-buildings-directive-second-cost-optimal-assessment

27 Regulations, UK Building, and E. U. Directives. "Zero carbon homes and nearly zero energy buildings." *Zero Carbon Hub: London, UK* (2014).

28 Building reg

29 Ministry of Housing, Communities & Local Government(2019), Nearly zero energy buildings requirements for new public buildings, [Available at]: https://www.gov.uk/government/publications/nearly-zero-energy-buildings-requirements-for-new-public-buildings

30 UK National Plan: Increasing the number of nearly zero energy buildings (2012), https://ec.europa.eu/energy/sites/ener/files/documents/united_kingdom_en_version.pdf

Denmark

Denmark is one of the first EU countries to set-up a national nZEB definition and a roadmap to 2020 in line with the EPBD. The main strategy of the Danish policies is to improve the energy performance through increasing the requirements for building insulations and improving the portion of the renewable energy supply and district heating in the energy mix. BR10 sets the minimum energy performance requirements for all types of buildings. In addition to these requirements, BR10 defines two voluntary classes; Low energy class 2015 and nZEB 2020 (Building class 2020) which aims to monitor the building envelope, total calculated energy consumption, indoor air quality and climate amongst others.[31] Denmark is also considered as one of the frontrunners among the member states as the BR10 is implemented strictly and will gradually become stricter starting from the actual standard. In 2016, voluntary low energy class 2015 renamed as Danish Building Regulation 2015 (BR 2015) and introduced as the minimum requirements for all types of new buildings together with the nZEB requirements. It is expected that Building Class 2020, which is equivalent to nZEB levels, will become the minimum requirement in 2020.[32]

		BR10	2015	2020
Minimum Requirements	Residential Buildings (housing sector & hotels)	52.5 + 1650/A*kWh/m²/yr	30 + 1000/1650/A*kWh/m²/yr	20 kWh/m²/yr
	Non-residential buildings (offices, schools etc.)	71.3 + 1650/A*kWh/m²/yr	41 + 1000/1650/A*kWh/m²/yr	25 kWh/m²/yr

Table 1: Evolution of the energy performance requirements towards nZEB levels in Denmark[33]

The net primary energy demand is named as an energy frame in BR15 and it means the end use energy demand extracted by renewable energy supply. The aim of the Danish government is to have an energy frame of 0 for new residential and non-residential buildings from 2026 and onwards[34]. In addition, in 2012 Denmark announced its commitment to have 100% renewable energy supply by 2050.[35]

[31] https://vbn.aau.dk/ws/portalfiles/portal/207672923/FI_Nov_2014_SBi.pdf

[32] ECOFYS (2013), National plan for increasing the number of nearly zero- energy buildings in Denmark [Available at]: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/nearly-zero-energy-buildings/content/eu-countries-nearly-zero-energy-buildings-national-plans-0

[33] Atanasiu, B., et al. "Overview of the EU-27 Build-ing Policies and Programs Factsheets on the Nine Entranze Target Countries: Cross-Analysis on Member-States' Plans to Develop their Building Regulations Towards the nZEB Standard." *ENTRANZE Project, EACI, Brussels, Belgium* (2012).

[34] Thomsen, Kirsten Engelund. "Danish plans towards nearly zero energy buildings." *Rehva Journal* 51.3 (2014): 6-8.
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Germany

EnEV, released in 2013, outlines the new requirements of the EPBD and considered as a facilitating step towards nZEB since it forms minimum requirements. EnEV includes a maxiumum non-renewable primary energy demand, which is building specific (depends on the geometry, function etc) and complies with the Renewable Energies Act. Apart from these, EnEV describes minimum requirements for the energy performance of the building's thermal envelope. Additionally, EnEV describes component specific minimum efficiency requirements for renovations.

The definition of the nZEB in line with the EPBD, was given in The Energy Saving Act[36] which was amended in 2013. In the same year, the specific definition of the nZEB in line with the KfW efficiency houses was given in the nZEB national plan.[37] The relation of the KfW efficiency house scheme and nZEB definition is built on the primary energy consumption, as it is a requirement for the nZEBs. For instance, the KfW 40 scheme for new residential buildinges states that the asset does not use more than 40% of the annual primary energy consumption of the reference building.[2]

As a part of zero energy targets, the German Government is targeting to reduce the primary energy demand of the building stock by 80% by 2050 and achieve a milestone of a 20% decrease in heat demands by 2020. These improvements are intended to be obtained through efficiency improvements. Supporting EnEv to achieve these targets, the Renewable Energies Act and the Act on the Promotion of Renewable Thermal Energy (EEWärmeG) aim to promote the use of renewable energy supply in the households such as EEWärmeG imposes the use of renewable heat energy technologies, including solar heating systems and heat pumps, in the construction of new buildings. Furthermore, a minimum share of renewables is also designated taking into account the considerations of the EEWärmeG for new and existing non-residential buildings undergoing deep renovations, respectively.

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[36] Energy Saving Act (*Energieeinsparungsgesetz*) (EnEG): current version with English introduction: www.bbsr-energieeinsparung.de/EnEVPortal/EN/Regulation/EnEG/eneg_node.html; current version with German introduction: www.bbsr-energieeinsparung.de/EnEVPortal/DE/Regelungen/EnEG/eneg_node.html; former versions: www.bbsr-energieeinsparung.de/EnEVPortal/EN/Archive/EnEG/eneg_node.html

[37] Government ıf the Federal Republic of Germany (2013), Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

- National plan for increasing the number of nearly zero-energy buildings pursuant to Article 9, [Available at]: https://ec.europa.eu/energy/sites/ener/files/documents/germany_en_version.pdf