

COGITO

CONSTRUCTION PHASE
DIGITAL TWIN MODEL

cogito-project.eu

D2.2 – Analysis
of digital tools
market and
prevailing
regulatory
frameworks



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D2.2 – Analysis of digital tools market and prevailing regulatory frameworks

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Executive Summary

The construction sector is of crucial importance for Europe to drive its economic growth as it reaches 9,5% of the EU GDP, provides annual revenue of approximately \$11.30 trillion and generates close to 18 million jobs. It also provides solutions for social, climate and energy challenges. In terms of digitisation in building infrastructure, the potential is not to be underestimated as it helps to save 10%-20% in the entire construction workflow, whereas project time saving is 14%. Apart from these benefits, digitalisation also improves collaboration, enhances clarity, and makes construction sites safer. In this regard, the popularity of Building Information Models (BIM) and Modelling as well as reality capture technologies in the construction phase has risen in the past decade and has led to an increased attention on efficient usage and smooth exchange of data and information across the various application areas in the construction phase. The response to this trend is the COGITO project, funded from the European Union's Horizon 2020 research and innovation programme, which introduces the COstruction-phase diGital Twin mOdel - a real-time digital representation (twin) of a construction project, using methods to ensure interoperability among the different components and technologies constituting the digital twin ecosystem, following the lean construction principles. During the 3 years of the project duration, COGITO will develop 16 interconnected digital tools/solutions for the construction sector including the Digital Twin Platform followed by the Digital Twin Visualisation with AR. These two COGITO solutions are perceived by the COGITO Partners as the results having the greatest potential for exploitation and ones that will be in high demand in the next 5 – 10 years.

An important part of the project is the development of an exploitation plan of the COGITO system and its components as well as business innovation plan that will pave the way for their commercialization. The first step in this direction is an analysis of the surrounding environment where the COGITO tools will be deployed including the market and policy aspects, which is the core of this report. The methodology applied included thorough desk research to identify and describe the existing policy strategies and regulations as well as market of construction sector, AEC and digital twin. The secondary data analysis was followed by an online survey which has been performed with COGITO Partners to investigate in detail the different aspects of COGITO tools, its potential and relevant regulations.

The report provides an overview of the pivotal role played by the public sector in pushing for the uptake of digital technologies and processes in the construction sector. In accordance with the trends towards digitalisation of the economy, policymakers are also supporting the digitalisation of the construction sector. During the last years, there were many reports presenting the EU strategies where digitalisation is mentioned as one of the priority, starting with the digital Single Market Strategy for Europe and documents supporting strictly digitalisation in the construction sector: "Supporting digitalisation of the construction sector and SMEs (Including Building Information Modelling)" from 2019 or latest European Construction Sector Observatory - Analytical Report - Digitalisation in the construction sector from 2021. Both documents mention some gaps that needs to be handled as well as suggest some activities for a quicker and more effective digitisation of the construction sector.

Further on legislative aspects, generally, the lack of regulations and specific laws in individual EU countries was mentioned, in many analysed reports as well as was pointed out by the online survey respondents, as a barrier which may hinder the implementation of the COGITO tools into the market. However, significant focus on BIM since many years [1] (In 2002, Autodesk published a white paper entitled "Building Information Modelling," and from this moment also other software developers and sellers started to be active in this field) has led to the development of a number of initiatives aiming to support the standardisation of digital technologies. Some countries also have put in place mandatory BIM requirements and others are planning to do that in the coming years. Moreover, at least 60% of the digitalisation strategies in European Union member states touch upon the construction sector and some countries even have a vertical (and tailored) strategy for construction. When it comes to national figures, digitalisation levels vary substantially across the EU-27 and different Member States. Spain and Denmark, the project pilot sites, have construction sector mentioned in either horizontal or vertical digital strategies. In both countries there are also BIM standards and guidance as well as national working group on BIM.

The market analysis on the other hand, showed that the digital twin market will only grow, by the year 2026 the CAGR of the digital twin market will reach 24.7% and even 42,7% until 2028. Global construction market is expected to reach \$16.6 trillion by 2025, growing at a CAGR of 7%; the BIM market is also predicted to grow by 13%, reaching €2.1 billion by 2023, supported by the public sector. This shows that there is a potential in the markets where the COGITO digital tools will be implemented. The report also provides a first overview of the competition landscape in Europe and globally with the main competitors listed and described. In the opinion of most online survey respondents, there are a few sellers on the market who supply a sizable portion of similar products in the market and that the competition will grow in the next years: 42% said that competition will grow at a moderate pace and 37% pointed that the competition will grow very rapidly.

COVID-19 implications have been also analysed in the report, and the presented results show that as long as the economy will recover, the Covid-19 will have long lasting and positive effects on the implementation of digital twin solutions. However, solutions need to be developed to tackle such challenges as problems with testing in real environments, evaluation and verification of digital twin solutions/tools.

The last part of the report deals with the SWOT and PESTELE analysis presenting the negative aspects that hamper/could hamper the development of digital twin solutions/COGITO tools in construction as well as the factors that favour the development of digital twin solutions including political, economic, social, technological, environmental, legal and ethical aspects. Moreover, strengths and weaknesses of the COGITO solutions have been discussed together with the first insights into the USP of the COGITO solution.

Looking at the policy documents and strategies as well as sector specific reports analysed, there are several aspects that could be important for a successful commercialisation of the COGITO tool including: ensuring better access to online services through guidelines and instructions like interactive handbooks or digital maturity scans; ensuring data security in the developed solutions; providing training especially for on-site workers in the use of digital tools, benefiting from Digital Hubs for Innovations for a better cooperation on a Member State level and for a cross sector collaboration in terms of design as well as implementing, using the project results after the project end.

The report ends with conclusions and presentation of next steps that will be continued in the work devoted to exploitation and especially task on the exploitation strategy and preliminary business innovation planning.

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List of Acronyms

Term	Description
AEC	Architecture, engineering, and construction
AI	Artificial Intelligence
AR	Augmented Reality
BIM	Building Information Modelling
CAGR	Compound Annual Growth
COGITO	Construction Phase diGItal Twin mOdel
DIH's	Digital Innovation Hubs
EC	European Commission
ECSO	European Construction Sector Observatory
EU	European Union
GDP	Global Domestic Product
HPC	High-performance Computing
MS	Member States
OECD	Organisation for Economic Co-operation and Development
Q-O-Q	Quarter Over Quarter
OHS	Occupational Safety and Health
R&D	Research and Development
SMEs	Small and medium-sized enterprises
USP	Unique Selling Proposition

1 Introduction

1.1 Scope and Objectives of the Deliverable

The overarching aim of this report is to present an overview and landscape of the EU and national regulations that are important for COGITO tools development as well as market conditions including opportunities and existing barriers that hamper digitalization of the construction sector. This is a first attempt to provide an insight into the different threats and opportunities that might impact the implementation of COGITO components in the future. The objective of this deliverable is on one hand to inform the project Partners about the relevant sectors' condition as well as perspectives in terms of digitalisation of construction and key policy aspects. The information provided in deliverable D2.2 will also provide some first insights for technical developers to understand the trends, opportunities and threats which may be essential for COGITO tools components development. On the other hand, it is worth to mention that this work will be continued in WP9 where, having more details on the exploitation plans and strategies, regulations and market aspects of relevance for commercialisation of COGITO components will be updated, as well as detailed analysis of the target markets will be performed. In this sense the goal of this deliverable is to provide first insights to the future work on exploitation in WP9.

Therefore, in this document, we would like to focus on the concept of a digital twin in relation to legal regulations and policies in the European Union. We will also describe other initiatives or recommendations related to the digitization of construction, for example the European Construction Industry Manifesto for Digitalisation. Next, we will present an analysis of the market and the macroeconomic environment related to digitization in the European Union. In addition, we will look at the existing competitors and their technological solutions similar to those offered by the COGITO project. We will try to answer the question whether the pandemic situation had an impact on this sector. Moreover, we will perform a SWOT and PESTELE analysis in relation to the digitization of construction. We will also present the results of the survey conducted in the project partner countries to present their insights on the topic of market potential of COGITO solutions.

1.2 Relation to other Tasks and Deliverables

As mentioned above, this report is the first step in defining exploitation strategy and preliminary business innovation planning which is included in WP9, Task T9.3 Exploitation Strategy and Preliminary Business Innovation Planning, starting from M19. The work done in WP2, under T2.2 will provide first insights and data for WP9 tasks related to exploitation. It also served to initiate discussion about exploitation plans at holistic solution level as well as at each Consortium Partner level. At the beginning of T9.3 (M19-M36), an update of information and data presented in D2.2, especially analysis of the construction market, overview of any new regulations which may be introduced in the near future, will be performed.

2 Methodological note

The research performed to elaborate this report includes **desk research** and **field research techniques**. The main research technique applied at this stage of the regulations & markets analysis was desk research. At the beginning of this task comprehensive desk research has been applied in order to investigate the construction sector, the market of Architectural, Engineering and Construction (AEC) and digital twin. The aim of this desk research was to gather data as a starting point for further in-depth analysis conducted within this task and that will be conducted in the following steps of exploitation route definition in WP9.

Desk research is a research technique based on the analysis of gathered data, also called secondary data analysis. It is a method of research used to collect and analyse data on a selected problem without the need to undertake work "in the field". The characteristic feature of the desk research method is that the study is based on the analysis of available materials and data. All data, before being included in the research, are checked for their reliability, credibility and timeliness.

Data sources that have been used include for example the following: Eurostat; available analysis and reports on construction, AEC and digital twin market in Europe, European Commission and Organisation for Economic Co-operation and Development (OECD) website and analysis, web sites of suppliers, competitors, legislation acts regulating the construction and digital twin market.

After some information via desk research had been collected, data that needs to be acquired from fieldwork has been identified. The primary research has been conducted with the use of **online survey** to investigate in detail the different aspects of COGITO tools and relevant markets, regulations. The survey has been performed among the COGITO project Partners with the use of online questionnaire (Annex I). The survey has been divided into several parts to obtain information about following aspects:

- general popularity and potential for tools supporting digital twin-based construction;
- the COGITO tools with the greatest potential and interest from project Consortium Partners;
- competition and competitors;
- chosen details on the current offering;
- market opportunities and threats including impact of COVID-19;
- strengths including Unique Selling Proposition and weaknesses of COGITO solutions;
- legislation important for COGITO tools development .

In total, 20 responses have been collected from the majority of COGITO Partners. The survey was conducted in the period of May – June 2021 using online questionnaire as this is a time- and cost-efficient method which allows the respondent to complete the survey at any time and any place and to obtain information on the relevant sectors and legislations as well as first insights into exploitation potential.

As the questions included in the online questionnaire touched many different aspects of COGITO tools, answers have been incorporated in relevant sections of the report, where also desk research outcomes have been presented on particular topic.

3 Exploitable results of the Cogito Project

3.1 List of COGITO results

As market research and analysis performed within WP2 is strictly connected with the exploitation tasks that will be performed within WP9 and especially with the results planned in the project, below we present a list of the COGITO components (or tools) that will be delivered within COGITO. The list has been taken from D2.1 – Stakeholder requirements for the COGITO system and has been initially derived from the DoA and subsequently reviewed and refined while developing the Use Cases within the framework of Task 2.1 Elicitation of Stakeholder Requirements.

Table 1 - The Main COGITO components making up the COGITO solution

COGITO Component Name	Description
Work Order Definition and Monitoring tool (WODM)	The WODM is the tool used for defining work order templates, generating work orders and executing/monitoring the defined workflow. The definition of work order templates and generation of work orders are conducted using the tool's UI, but a workflow can also be imported from a BPMN file. Work orders execution can be monitored through communication using the WOE tool.
Work Order Execution Assistance tool (WOEA)	The Work Order execution assistance tool (WOEA) is an app for smart glasses supporting work order execution and reporting. The worker is guided via smart glasses through the work order, which enables immediate reporting of the results of the work. WOE can work online or offline and provides hands-free operation support. The app also enables Remote Assistance through video call with remote annotations.
Digital Twin Platform (DTP)	The Digital Twin Platform (DTP) is the core of the entire toolchain. It supports both the necessary information management as well as the semantic (and pragmatic) alignment among the COGITO services and data pre-processing systems, while enabling interoperability with existing and emerging standards and data formats covering numerous domains.
Process Modelling and Simulation tool (PMS)	<p>The Process Modelling and Simulation tool allows to define and simulate both the construction business process model as well as the operative workflow model.</p> <p>This allows the user to identify process steps that are critical for the successful implementation of the project exposing optimization opportunities to minimize time and/or cost.</p> <p>The combination with real-world data is supported by data mining algorithms and statistical methods and allows the calibration of the simulation model to the actual process occurring on the construction site.</p>
Digital Twin visualisation with AR (DigiTAR)	DigiTAR is software package for commercial AR head mounted displays (HMDs) to help to visualise and interact in situ with the output of the QC tools (location, type and severity of geometric and visual defects) and Safety tools (location and type of safety hazards and expected mitigation measures).
GeometricQC Tool (gQC)	The GeometricQC tool controls automatically the geometric quality of the executed works against the specified geometric dimensions and tolerances given as-built 3D data acquired onsite. The as-built 3D data is (dense laser scanned) point clouds acquired on site. The specified dimensions are obtained from the as-design BIM model (part of the DT) and the specified tolerances are obtained from ISO/CEN standards used by industry (and

	translated digitally to enable the automated process). The QC results are modelled and semantically linked to the BIM/DT model.
VisualQC (vQC)	The Visual QC tool automatically detects in colour images (visual spectrum) common visual defects of constructed/erected concrete components and their severity. The QC results are modelled and semantically linked to the BIM/DT model.
Digital (Visual) Command Centre (DCC)	The DCC renders the 3D BIM model, IoT data and other data and annotations generated by the QC, H&S and Workflow tools (available through the DT platform). The DCC will help the Project Manager to monitor through visualisation the progress, QC defects and H&S issues; The DCC is solution to visualise/navigate the DT data, but not edit it.
BlockChain Platform Tool	The Blockchain Platform tool will allow the deployment of smart contracts, through the SLA Manager. It will interact with the Work Order Definition and Monitoring tool and based on the operative workflow model it will provide the blockchain based smart contracts in order to enhance transparency and to provide trusted means to verify completion of construction tasks, asset release, etc.
BlockChain SLA Manager	The Blockchain SLA Manager has a local DB with already designed SLAs that include predefined rules and KPIs. WODM could fetch the SLAs through the SLA Manager in order to bind relevant stakeholders with the respective KPIs. Then WODM inform the SLA Manager with the results and SLA Managers saves the SLA with the respective Stakeholders on the local DB. BC can fetch the completed SLA with the assigned stakeholders and the respective configurations to initiate & instantiate the Smart Contract operation.
SafeConAI	The SafeConAI tool identifies regions in the BIM model where (specific types of) hazards are, suggests and adds mitigation measures to the model. It uses as input a 4D BIM of as-planned construction project, consisting of n time steps, where each time step corresponds to stage of construction of the asset. Six types of hazards in four major categories are considered (slips, trips, fall from height, caught-in between, struck-by, electrocutions), and one or two specific safety code entries are considered for each of these hazards (i.e. approximately 6-12 safety codes total).
ProActiveSafety	The ProActiveSafety tool utilizes behavioural data of resources (equipment and personnel) on the construction site to avoid close-calls, accidents, and collateral damage. Location data from the Location Data Acquisition Tools is analysed to predict trajectories of resources and detect imminent close-calls and accidents by cross-checking those trajectories with potential hazards based on previous experiences/observations, rules, and the probability of hazards given the dynamic nature of the work environment.
VirtualSafety	The VirtualSafety tool provides personalized construction safety education and training, focusing on the top 6 hazards: Slips/trips/falls from height, caught-in between, struck-by, and electrocution. The highly realistic VR provides easy-to-use, reliable safe learning environment and technology that assists advanced HSE decision making and provide personalized feedback in a safe learning environment
Geometric Data Acquisition (GDA) Tools	The Geometric Data Acquisition Tool(s) are employed on-site to acquire 3D geometry of the site. Within COGITO, laser scanning will be principally used because of the accuracy required for geometric QC. However, other tools

	like photogrammetric systems (e.g. UAV mounted) may also be considered for other purposes.
Visual Data Acquisition (VDA) Tools	The Visual Data Acquisition Tool(s) are employed on-site to acquire 2D visual data of the site. Within COGITO, images in the visual spectrum are primarily considered, and these images may be acquired using any camera mounted a wearable AR system (e.g. DigiTAR), a phone, a mobile computer, etc.
Location Data Acquisition (LDA) Tools	The Location Data Acquisition tool(s) gather raw IoT data that are coming from sensorial devices installed or worn on the construction site and generate datasets that can be directly stored in the COGITO Digital Twin platform. The tools are used to capture location data about the workforce, machinery, and materials.

3.2 Outcomes of online survey relating to COGITO solutions

As mentioned above, COGITO will offer 16 interconnected digital tools/solutions for the construction sector.

We have asked respondents in our online questionnaire (the project Partners) which of them have the greatest potential for exploitation. They had to rank them from 1 to 16 where 1 means the greatest potential. Digital Twin Platform obtained the highest score of 13.74 points followed by Digital Twin Visualisation with AR, VisualQC, Geometric QC tool and Digital (Visual) Command Centre (Figure 1).

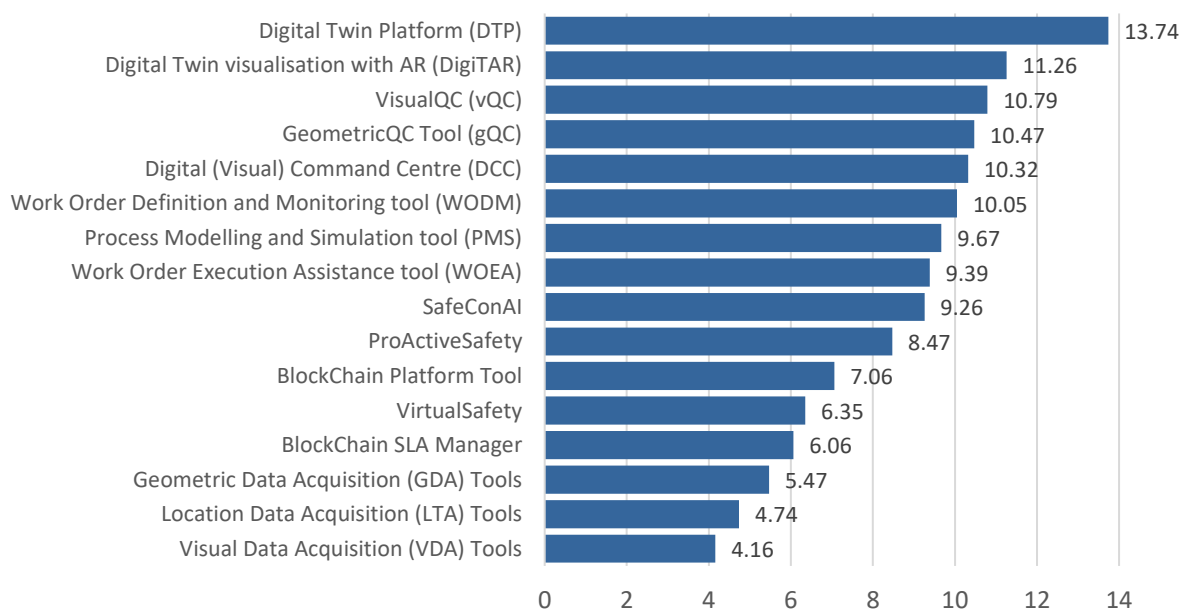


Figure 1 – COGITO tools' potential for exploitation

Source: Cogito T2.2 survey

In another question we were interested which, in the opinion of our respondents, COGITO tool will be highly demanded in the next 5 – 10 years. Similar to the previously presented question, also here (see Figure 2), Digital Twin Platform was in first place (45%) and in the second (30%) Digital Twin visualisation with AR. This shows a big potential of those mentioned tools which will be analysed in detail in WP9, in terms of their market potential, exploitation route as well as target groups and markets. Other mentioned tools included: Digital (Visual) Command Center and BlockChain Platform Tool, and two tools connected with OHS, SafeConAI and Virtual

Safety. The last two shows that there is and will be bigger focus on the safety on construction sites to avoid many risks connected with the safety of workers (Figure 2).

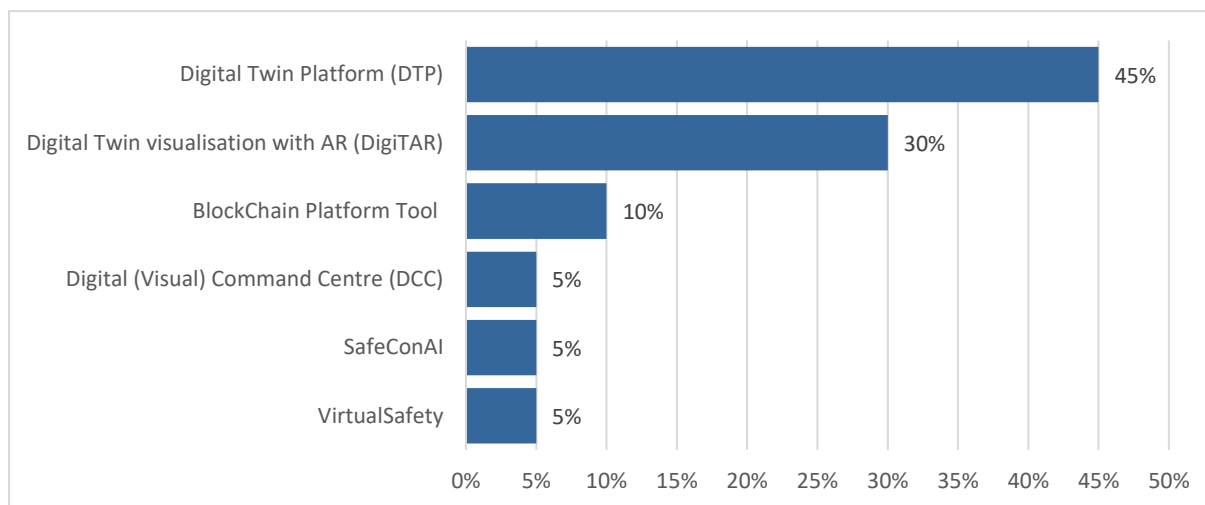


Figure 2 – COGITO tools with highest demand

Source: Cogito T2.2 survey

We have also asked a question: “In which construction sub-sectors COGITO tools and COGITO holistic solution have the biggest potential for development”? Respondents could choose **small buildings** (e.g., single-family residences, small shops) with budget lower than €1m, **medium buildings** (e.g., multi-family, schools, medium commercial, small infrastructure) with budget between €1m to €50m and large building (e.g., hospitals, industrial, large infrastructure) with budgets over €50m. As presented in the figure below 60% pointed large buildings and 35% medium buildings. None of the respondents choose small buildings, as the ones where digital twin tools could be used (Figure 3).

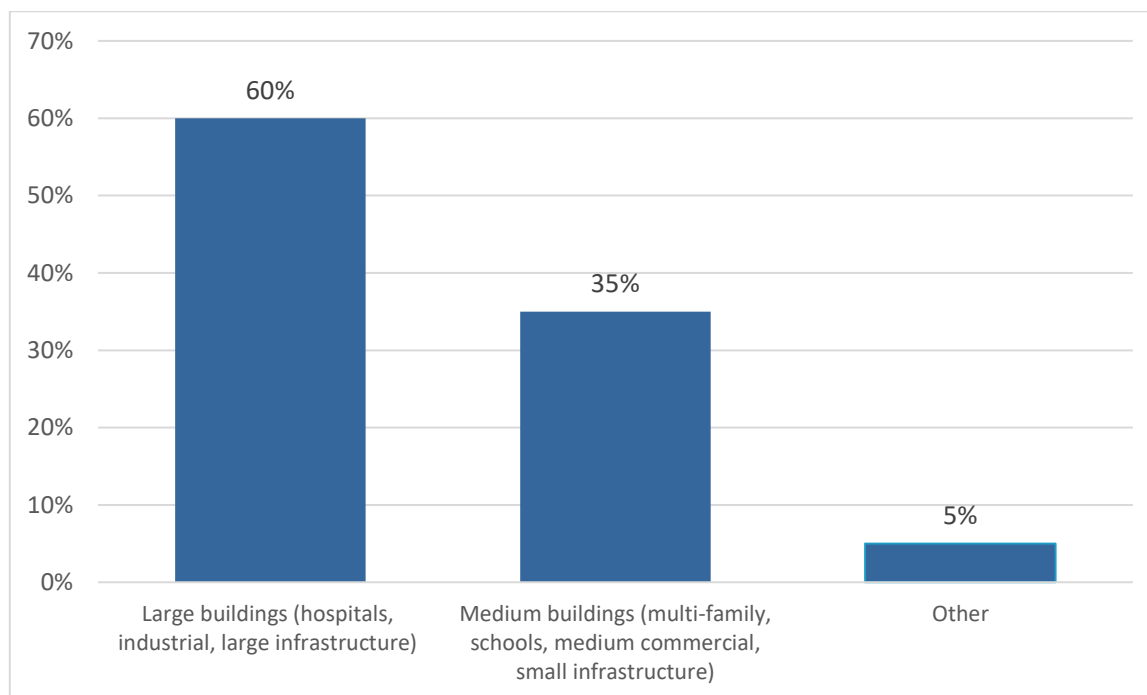


Figure 3 – Segments of biggest potential for the development of COGITO tools.

Source: Cogito T2.2 survey

Based on the answers and taking into consideration the characteristics of the digital twin-based solutions and tools we can say that they are mostly useful for the bigger and more complicated constructions with higher budgets. This will be important later when describing the particular target markets and its potential, where the COGITO tools could be implemented. On the other hand, this might be somehow related to one of the challenges that the construction and AEC sector faces – to change the perception, that BIM and similar technologies are only suitable for big projects.

4 Legal and regulatory frameworks

The goal of this chapter is to identify the European and national strategies that may have influence on the implementation of COGITO tools within the project duration, and after the project end. In this chapter we therefore concentrate on presenting the latest European Union strategies and how this may influence the adoption of the digital tools in the construction sector. Secondly, based on demo Partners' feedback, national legislation or other frameworks are presented.

Moreover, it needs to be emphasized that the governments need to implement relevant policies and financing framework to incentivise the uptake of digital technologies, practices and business models and as a consequence contribute to supporting the digitalisation of the construction sector and faster implementation of many digital tools in this sector. Regulations and standards can act as an effective tool to push construction companies to digitalise – thus adopting a “push and pull” type of approach. It is also worth noting, that in order to be truly effective, digitalisation needs to be understood and embraced by all actors involved in the construction value chain, both private and public.

4.1 The EU strategy and legislation

In order to have a good and common understanding of the European Union strategy toward construction sector we have to go back to the year 2012 when European Commission released a document named “[Strategy for the sustainable competitiveness of the construction sector and its enterprises](#)”. This document was published within the “Europe 2020” initiative. One of the priorities of this agenda is the promotion of sustainable growth in the construction sector. European Commission pointed 5 areas that need further development [2]:

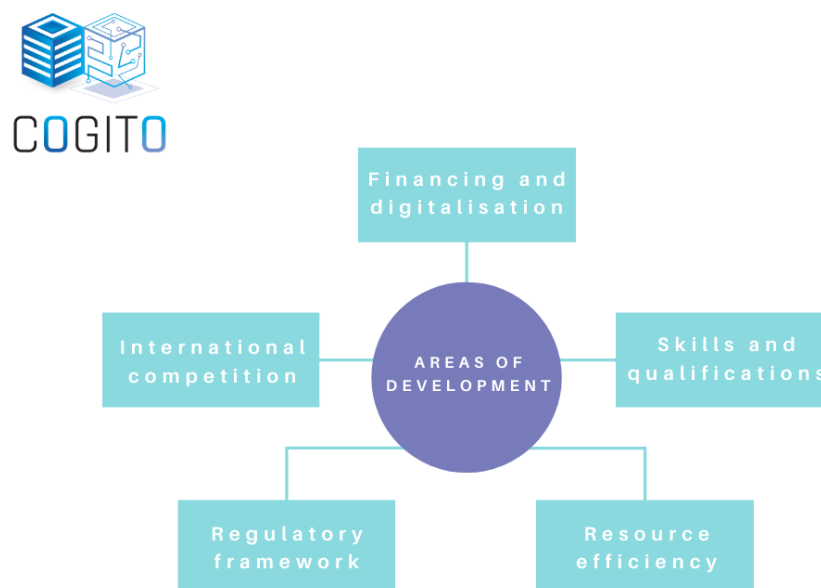


Figure 4 - Construction sector areas of development

Source: European Commission¹

¹ COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL, Strategy for the sustainable competitiveness of the construction sector and its enterprises, 31.7.2012

It is clear that since year 2012, one of the priorities in the construction sector (and others) is digitalisation, especially for research and innovation in a smart, sustainable, and inclusive environment.

During last 9 years there were many publications/documents presenting the EU strategies e.g.:

1. Energy Performance of Buildings Directive ([2018/844/EU](#)) [3] amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency where digitalisation of the building sector is mentioned:
“The agendas of the Digital Single Market and the Energy Union should be aligned and should serve common goals. The digitalisation of the energy system is quickly changing the energy landscape, from the integration of renewables to smart grids and smart-ready buildings. In order to digitalise the building sector, the Union’s connectivity targets and ambitions for the deployment of high-capacity communication networks are important for smart homes and well-connected communities. Targeted incentives should be provided to promote smart-ready systems and digital solutions in the built environment. This offers new opportunities for energy savings, by providing consumers with more accurate information about their consumption patterns, and by enabling the system operator to manage the grid more effectively” [4]
2. [European Green Deal factsheet: Building and renovating](#) [5] where it was stated that in order to achieve better energy performance of buildings, increased digitalisation is needed.
3. [A digital Single Market Strategy for Europe](#) – in that document we can find guidelines toward the digitalisation of the EU market. “A Digital Single Market is one in which the free movement of goods, persons, services and capital is ensured and where individuals and businesses can seamlessly access and exercise online activities under conditions of fair competition, and a high level of consumer and personal data protection, irrespective of their nationality or place of residence. Achieving a Digital Single Market will ensure that Europe maintains its position as a world leader in the digital economy, helping European companies to grow globally” [6]. The Digital Single Market Strategy has three pillars (Figure 5):



Figure 5 - Digital Single Market pillars

Source: European Commission²

² COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A Digital Single Market Strategy for Europe, 6.5.2015, page 3

4. [Supporting digitalisation of the construction sector and SMEs \(Including Building Information Modelling\)](#) [7]

In this document we can find results of a study and desk research that shows us 10 gaps (Table 2) regarding the digitalisation of the construction sector which should be also taken into account while introducing the COGITO tools into the market after the project end.

Table 2 – Gaps in the digitalisation of construction sector

Gaps
Digitalisation targets are lacking at EU and national levels
Limited capability of SMEs for digitalisation in the construction sector
Market failure and lack of cooperation at Member States level that hinders the digital transformation on a European level
Lack of investment in research and development for SMEs, especially for the combined use of digital technologies
Lack of investment to support the implementation of digital technologies by the construction industry
Lack of trained employees (blue-collars) on the use of digital technologies
Lack of experts for data handling and analysis
Lack of complementing Asset Lifecycle information Management (ALIM) standards
Lack of software (both open source and commercial off the-shelf) that uses the available asset life-cycle information management standards
Lack of data security and preparedness for cyberattacks, especially in the construction sector

Source: European Commission³

Moreover, after analysing all the gaps, there were 10 actions prepared as the suggested reaction. In order to prioritize them or choose the most important ones, the selection process was based on the three criteria:

- *The prioritised actions are proposed to be facilitated by the European Commission.* It means that the main role to undertake the action should be done by the EC, without other countries or industry facilitation.
- *Impact.* This criterion is about having clear influence on the digitalisation of SMEs.
- *Feasibility of the implementation of the proposed actions.* This criterion is focused on the three indicators: time, budget and synergies/overlap with already functioning initiatives or organisations like e.g.: [European Construction, built environment and energy efficient building Technology Platform](#)⁴.

Following these criteria three actions were recommended to be undertaken [8]:

- Interactive handbook and digital maturity scan for the adoption and implementation of digital technologies.

Challenge: The challenge is to increase the adoption of digital technologies by SMEs, especially the microenterprises with limited capability, by providing guidelines and instructions embedded in an existing digital platform.

- Facilitate the setup of DIHs (Digital Innovation Hubs) to support the construction sector and link them in a pan-European network.

Challenge: With this action, we want to bridge the market failure gap and the lack of cooperation on a Member State level that hinders the digital transformation.

- Provide lifelong (Digital) skill development for (blue collars) within the construction sector.

³ European Commission, Supporting digitalisation of the construction sector and SMEs, Including Building Information Modeling, 2019, page 35-41

⁴ [Home \(ectp.org\)](#)

Challenge: The challenge is to increase the number of skilled workers, especially on-site workers, in the use of digital technologies.

5. [European Construction Sector Observatory - Analytical Report - Digitalisation in the construction sector – April 2021](#) [9] – This document presents full report regarding digitalisation in construction sector. Apart from the market analysis, we can find there an overview of the most recent EU policies and frameworks. These policies are divided into five types (below):

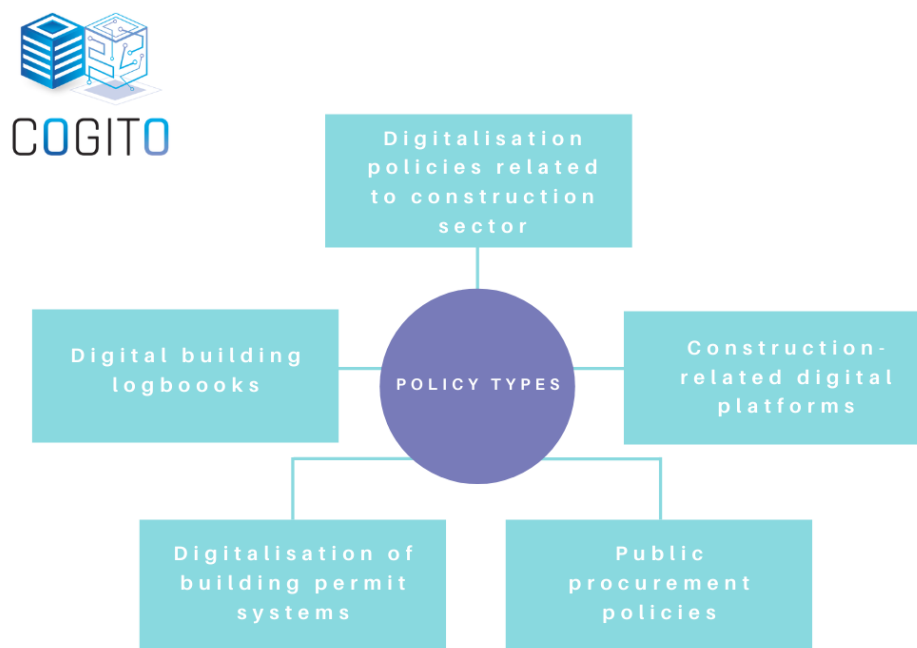


Figure 6 - Policy types

Source: European Construction Sector Observatory⁵

Below the most important strategies pointed out by ECSO (European Construction Sector Observatory) are presented briefly:

- **Construction 2020** [10] is a Strategy for the sustainable competitiveness of the construction sector and its enterprises (2012). It is completed by the Construction 2020 Action Plan, to support the construction sector in its adaptation to key upcoming challenges and to promote the sustainable competitiveness of the sector. Its first thematic objective concerns Innovation, aiming at boosting the digital uptake in the construction sector.
- **The Renovation Wave** [11] is a strategy aiming to foster building renovation to address climate change and support the recovery and the green and digital transition. More specifically, the EC aims to at least double renovation rates in the next ten years, thereby i) reducing energy poverty in the EU; ii) improving the quality of life for people living in and using the buildings; and iii) reducing Europe's greenhouse gas emissions – taking into account that the building stock in the EU accounts for 40% of energy consumed and 33% of CO2 emissions. This will, among other objectives, foster digitalisation, improve the reuse and recycling of materials, and contribute to creating employment and growth opportunities across the renovation supply chain.

⁵ European Construction Sector Observatory, Digitalisation in the construction sector, Analytic Report, April 2021, page 55

6. The EC also supports the adoption of digital technologies and particularly BIM in the construction sector, through the EU Directive on Public Procurement (Directive 2014/24/EU) to incentivise EU Member States to take account of digitalisation as a possible requirement in their public procurement process – thus encouraging construction companies to digitalise.

Generally, this is a non-mandatory requirement (“For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar.” [12]) however currently Denmark, Sweden, Finland, Italy, Lithuania and Germany have put in place mandatory BIM requirements applicable either to all projects or at least for projects of a determined minimum budget.

It should be also noted that three more countries are on their way to implement BIM requirements, namely Spain, Czech Republic and Latvia, which have announced their intention of putting such requirements in place in their public procurement policies [9].

7. The EC has also developed a number of initiatives aiming to support the standardisation of digital technologies – for instance, CEN/TC 442 'Building Information Modelling', a technical committee of European Committee for Standardisation (CEN) on the European level aims to develop and maintain standards in the BIM domain.

Moreover, in the draft work programmes of Digital Europe for 2021-2022 relevant to the construction sector following aspects were pointed out which might be of importance for the COGITO tools [13]:

- Focus on cybersecurity, where manufacturers have to include cybersecurity features in connected products at the design stage. There has been a large number of complex cyberattacks in the last years, which undermine the functioning of communication networks, critical infrastructure, services and as a consequence undermine public confidence in the integrity of digital systems and data, and the decisions made using them. In this respect the tools that are being developed should take into account the digital security issues.
- providing SMEs and public administrations access to the latest digital technologies through Digital Innovation Hubs – As the idea of network of European DIHs is to broaden the use of applications, technologies and services benefitting from AI (Artificial Intelligence), HPC (high-performance computing) and cybersecurity with the EU-wide deployment of innovative and cost-effective data-driven tools and services based on technologies like AI and data analytics.
- making ICT products and services sustainable, by prioritising their energy efficiency as well as climate neutrality, reparability, lifespan and recycling.
- deploying open, interoperable, trustworthy urban digital platforms tailored to communities' needs, offering easy standardised access to new datasets, and the large-scale roll-out of AI driven services in among others Smart Energy, industry and (re)manufacturing.

Furthermore, focal points of the Construction 2020 Strategy in the area of digitalization were also pointed out by the European Commission which are [14]:

1. BIM, which is described as the basis for our digital infrastructure and the perspectives for its development are very promising: The BIM market is predicted to grow by 13%, reaching €2.1 billion by 2023, supported by the public sector.
2. Supporting cross-sector collaboration and finding common solutions as digitalisation requires collaboration of all stakeholders.
3. Support information flow, reliability and investment towards an EU Building Digital Logbook.

All presented documents show, that there is a clear focus in the European Union on digitalisation and future ahead of digital tools, applied in the construction sector as by digitalising the construction process, Europe can achieve economic benefits and savings between 17 – 21% over a period of about 5 – 10 years [15]. On the other hand, it clearly shows how pivotal role the public sector is playing in the uptake of digital technologies and processes in the construction sector and that without these, the adoption of digital tools in construction sector will be limited. It is also a direction which COGITO Project Partners should carefully analyse in the next steps in

terms of commercialisation of COGITO tools on those markets, where there is the biggest potential for implementation, from policy point of view.

4.2 National legislation

Digitalisation levels vary substantially across the EU-27 and different Member States follow different policy approaches, which can be categorised in two dimensions:

- Horizontal digitalisation strategies covering a wide range of sectors, technologies and areas.
- Vertical digitalisation strategies for the construction sector, covering the full or part of the value chain, and specific digital technologies (such as BIM) or all digital technologies without distinction.

The table below shows the Digital Construction Policies/Strategies across the EU-27.

Table 3 - Digital Construction Policies/Strategies across the EU-27 [9]

Countries	Type of Digital Construction Policy					
	Horizontal Policy/Strategy – does not comprise construction	Horizontal Policy/Strategy – comprises construction	Vertical Policy/Strategy – targets the construction sector	Comprehensiveness		
				Strategy	Action Plan	Financial instruments
Austria		✓		✓	✓	✓
Belgium	✓			✓	✓	✓
Bulgaria		✓		✓	✓	✓
Croatia		✓		✓	✓	
Cyprus		✓		✓	✓	✓
Czech Republic		✓		✓	✓	✓
Denmark		✓		✓	✓	✓
Estonia			✓	✓	✓	
Finland			✓	✓	✓	✓
France			✓	✓	✓	✓
Germany			✓	✓	✓	
Greece			✓	✓	✓	✓
Hungary	✓			✓	✓	✓
Ireland			✓	✓	✓	✓
Italy	✓			✓	✓	✓
Latvia		*				
Lithuania			✓	✓	✓	✓
Luxembourg			✓	✓	✓	✓
Malta	✓			✓	✓	✓
Netherlands	✓					
Poland	✓					
Portugal	✓			✓	✓	✓
Romania	✓					
Slovakia	✓			✓	✓	✓
Slovenia		*				
Spain			✓	✓	✓	
Sweden			✓	✓	✓	✓

* Latvia's and Slovenia's strategy is currently under development.

Source: Slightly adopted from European Construction Sector Observatory

Close to 60% of Member States (16 out of 27) have in place policies covering or targeting the digitalisation of the construction sector, demonstrating the interest of policymakers in tackling this issue. Despite the fact that the construction sector was not included in nine Member States' digitalisation strategies or policies, some of these countries have in place several advanced side-initiatives on digital technologies in the construction sector, such as BIM.

Moreover, the implementation of BIM has accelerated quickly in recent years and both public and private sector stakeholders are increasingly recognising the benefits to be gained by adopting it, which is also a positive signal for the COGITO tools.

As mentioned before, currently, Denmark, Sweden, Finland, Italy, Lithuania and Germany have included mandatory BIM requirements in national legislation. They will be followed by Spain, Czech Republic (2022), Latvia (2025) and several other EU countries such as Poland, Ireland, Slovakia, Slovenia, France, the Netherlands, Belgium, which have put in place partial BIM requirements (Figure 7).

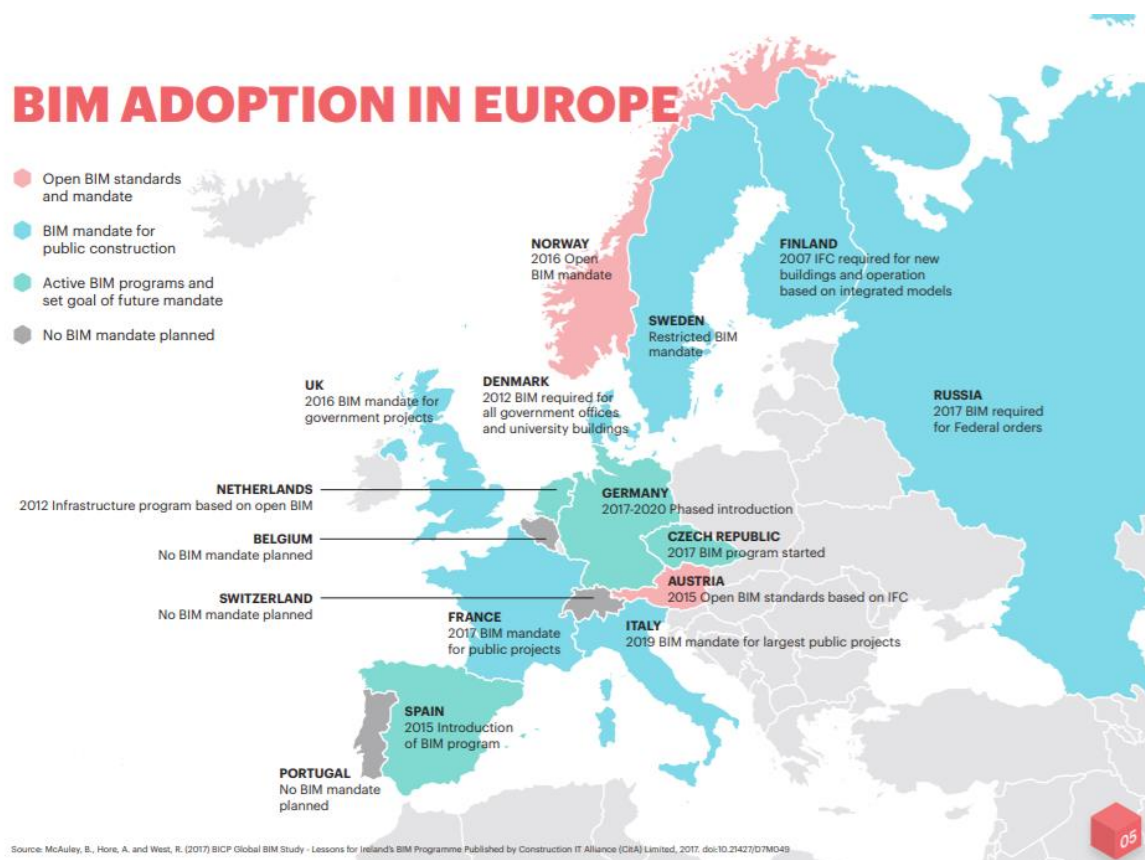


Figure 7 - BIM adoption in Europe [16]

Source: From whitepaper by MagiCAD

Moreover, the results of the survey conducted by the European Construction Sector Observatory show, that 22 EU Member States have implemented a national working group on BIM; nine MS have implemented a BIM/Digital Construction Strategy; and 21 MS have implemented BIM Standards and/or guidance respectively (Table 4).

Table 4 - Policy or measure is in place to support BIM adoption, beyond public procurement

	BIM/Digital Construction Strategy	BIM Standards and/or guidance	National working group on BIM
Austria			
Belgium			
Bulgaria			
Croatia			
Cyprus			
Czech Republic			
Denmark			
Germany			
Greece			
Estonia			
Finland			
France			
Hungary			
Ireland			
Italy			
Latvia			
Lithuania			
Luxembourg			
Malta			
Netherlands			
Poland			
Portugal			
Romania			
Slovakia			
Slovenia			
Spain			
Sweden			
	Present	Absent	

Source: European Construction Sector Observatory

It is worth mentioning that Austria, which is the COGITO Consortium country, has adopted open BIM standards to support a transparent workflow among project members, who are not obliged to adopt specific software. Moreover, a common language allows industry and government to generate projects with transparent commercial engagement, comparable service evaluation and assured data quality.

With regards the countries, where the demos will take place in the framework of COGITO project, according to the information confirmed by the Spanish partner (Rhombert Sersa Rail Group) of COGITO project, there are no specific policies or legislation regarding digitalisation of construction sector in Spain. The regulatory framework is based on the ISO standards:

1. ISO 19650 is an international standard for information management throughout the life cycle of a building object using BIM. Since December 2018, 4 standards were published and two of them are still under development:
 - a. [ISO 19650-1 \[17\]](#): Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling: Concepts and principles
 - b. [ISO 19650-2 \[18\]](#): Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling: Delivery phase of the assets

- c. [ISO 19650-3 \[19\]](#): Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling: Operational phase of the assets
 - d. [ISO/DIS 19650-4 \[20\]](#): Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling: Information Exchange (still under development)
 - e. [ISO 19650-5 \[21\]](#): Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling: Security-minded approach to information management
 - f. [ISO 19650-6 \[22\]](#): Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling: Health and Safety
2. ISO 12006 is an international standard dealing with structuring of information for construction. This standard has two parts:
- a. [ISO 12006-2 \[23\]](#): Building construction -- Organization of information about construction works
 - b. [ISO 12006-3 \[24\]](#): Building construction -- Organization of information about construction works: Framework for object-oriented information (first edition was published in 2007, now second edition is under development)

Second demo of COGITO will take place in Denmark. In 2019 Danish Ministry of Transport, Building, and Housing announced a Strategy for Digital Construction in Denmark [25], that contains several initiatives for digital construction. One of the purposes of that strategy was adoption of the ISO 19650 standards. Now, as well as Spain, Denmark is using the ISO standards mentioned above. Denmark has also several national legislations like: Danish Building Act or Danish Building regulations [26]. According to the ECSO report Denmark together with Austria are countries with the highest level of BIM adoption [9].

4.3 Other initiatives, activities and recommendations

If we want to look closer toward the digitalisation of the construction sector, apart from all the EU frameworks and policies, we have to check as well, if there are any external initiatives, activities or recommendations. One of the institutions that are dealing with the digitalisation of the construction sector is [FIEC⁶](#) (European Construction Industry Federation). FIEC has published alone or in the cooperation three crucial documents with the recommendation on digitalisation:

1. [Building Information Modelling Manifest \[27\]](#) – First manifest prepared by FIEC regarding BIM technologies. This manifest has two objectives:
 - a. *“To establish the digital construction industry as a main player in developing key concepts and policies such as smart cities, efficient infrastructure and smart homes (and as key player in their delivery), using as integrated platform that gives holistic view of the construction project in question”.*
 - b. *“To improve the sector’s productivity, competitiveness, customer satisfaction and image, by advocating both:*
 - *Top-down digital transformation, facilitated by the EU and national governments through policy and investment/EU funding*
 - *Bottom-up digital transformation driven by the construction industry itself (as opposed to other interested players such as the IT industry)”*
2. [Construction Manifesto for action EU tern 2019 – 2024 \[28\]](#) – This document (prepared by FIEC and [European International Contractors⁷](#)) was divided into 7 sections with a recommendation to EU:

⁶ Home: FIEC

⁷ EIC Federation | (eic-federation.eu)

- a. **“Investing in a competitive Europe:** *Promote public and private funding; allow greater flexibility in the Stability and Growth Pact; Infrastructure maintenance; Adapt the global financial, fiscal and regulatory environment”.*
 - b. **“Ensure a level playing field:** *Both private and state-owned companies fight against the award of contracts to ALT’s (Abnormally Low Tenders); Ensure reciprocity in opening markets”.*
 - c. **“Construction 4.0: Accelerate the digital transformation of the construction industry:** *Construction as a priority sector; Data policies, Smart Cities”.*
 - d. **“Construction Products Regulation (CPR): Ensure that it works in practice:** *Ensure that regulatory gaps will be compensated; Eliminate the backlog of uncited standards”.*
 - e. **“Committing to the social dimension of the construction industry:** *Update existing training schemes; Strengthening the mutual recognition of qualifications; Investment in initial and lifelong training and apprenticeship; Fight against fraudulent practices; Developing a culture of prevention and strengthening Occupational Safety and Health; Support Social Partners’ initiatives; Respect the principle of subsidiarity in labour-related issues”.*
 - f. **“Build a sustainable Europe:** *Innovative construction methods and implementation of research results.*
 - g. **Single point of coordination:** *Mandate a Vice-President with the task of ensuring efficient and co-ordinated collaboration”.*
3. [The European Construction Industry Manifesto for Digitalisation \[29\]](#) - In this manifesto undersigned by 23 organisations, three statements were pointed by the authors toward the EU:
- a. **“European Union must take the political lead on digital construction”** – Authors pointed out that the digitalisation of the construction sector should be one of the top priority of the EU and should be also part of the [“Digitising European Industry” \[30\]](#) initiative.
 - b. **“We need an appropriate regulatory framework on data policy”** – “An appropriate regulatory framework should ensure better data quality and data management, address challenges around intellectual property rights and cybersecurity, establish who is responsible – and liable – for data ownership, and avoid abuse by monopolies thus ensuring a level playing field, in which SMEs can thrive and reap the benefits of digitalisation”.
 - c. **“The new EU budget must focus on digital skills, R&D and deployment of IT infrastructure”.** – In this point we can find three areas that “post-2020 Multiannual Financial Framework must focus on”:
 - Digital skills
 - R&D
 - IT infrastructure

Another interesting initiatives/recommendations/publications:

1. [Digitalisation of the construction industry: The revolution is underway \[31\]](#) by Oliver Wyman where it is emphasized that the construction industry is changing, still slowly in comparison to other industries however certainly faster than previously.
2. [Policy options to support digitalisation of business models during COVID-19: Annex \[32\]](#). In this document prepared by OECD in 2020 we can find policy examples of initiatives many from G20 countries that contributed to better availability and use of digital tools to strengthen business continuity and resilience in the time of COVID-19 pandemic.
3. [Digitalisation as a Strategic Means of Achieving Sustainable Efficiencies in Construction Management: A Critical Review \[33\]](#) i.e. in this publication we can find five key activities (with full description) needed to reach a good level of digitalisation (Figure 8). [34]

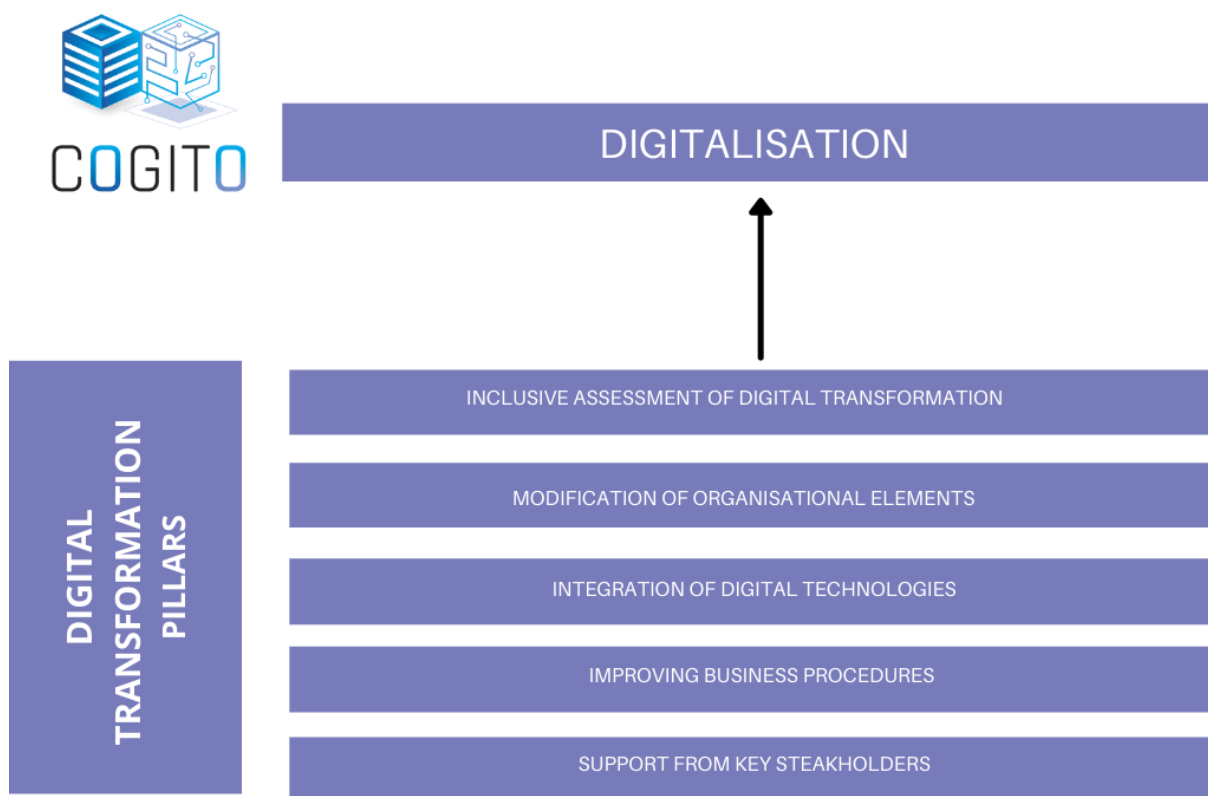


Figure 8 - Digital transformation pillars⁸

Source: *Digitalization as a Strategic Means of Achieving Sustainable Efficiencies in Construction Management: A Critical Review*, Sustainability 2021, 13(9), 5040

4. [The European Cloud Initiative \[35\]](#) - Building a competitive data and knowledge economy in Europe which aims to strengthen Europe's position in data-driven innovation, improve competitiveness and cohesion, and help create a Digital Single Market in Europe.
5. [Construction 2050: Building tomorrow's Europe today \[36\]](#) – document prepared by over 20 construction sector stakeholders as a result of Construction 2020 framework.

⁸ Bahareh Nikmehr, M. Reza Hosseini, Igor Martek, Edmundas Kazimieras Zavadskas and Jurgita Antucheviciene, „Digitalization as a Strategic Means of Achieving Sustainable Efficiencies in Construction Management: A Critical Review,” 2021

5 Market analysis

5.1 Digitalisation of economy

Digitalisation of the economy is nowadays one of the most important principles among the global policy makers and it covers all strategic sectors. “The ongoing digitalisation of our economies and societies will only expand and deepen. Digitalisation does not only contribute to productivity and efficiency, but also to broader socio-economic development” [37]. It is an accelerator of development and the G20 must be ready to make the most of it”. In 2017 OECD listed 11 recommendations (below) of action to be taken in order to provide high quality digital transformation of economy. Full report is available on the [OECD website](https://www.oecd.org/G20/key-issues-for-digital-transformation-in-the-G20.pdf)⁹.

Table 4 – Recommendation for digitalisation of economy

Recommendation
Call for international digital strategies to close the access and usage gaps and ensure that the Internet is for all.
Boost investments in digital infrastructures and their key enablers.
Improve framework policies to foster the financing of digital infrastructures (including data) and innovative business models.
Development of standards and standard based interoperability to support the IoT and Industry 4.0.
Ensure competition in the ICT sector and across the economy.
Call for national privacy and security risk management strategies and improve interoperability among frameworks
Craft more effective strategies that enable all people to adapt to and excel in the digital economy.
Support SME's in reaping the benefits of digitalisation and addressing challenges.
Promote consumer protection in the digital era.
Adapt legal frameworks to the realities of an increasingly digital and data-driven global economy and improve measurement.
Co-ordinate and co-operate to better measure digitalisation across G20 economies.

Source: OECD

Taking into consideration the statements mentioned above, we can say that the solution proposed by COGITO project meets the expectations of the OECD. The development of the 4.0 industry and digitalisation of economy is a trend that it is not foreseen to stop. What is more, it is shown in the recent publication that the digitalisation of the economy will grow more faster due to outbreak of COVID-19 pandemic. In a survey conducted at European level about 70% of directors from Austria, Germany and Switzerland confirmed that the pandemic could only accelerate the pace of their digital transformation. [38]

5.2 Construction sector analysis

General Data

In terms of condition of the general European economy in the second quarter of 2021, it is expected to recover faster than previously expected due to the improving health situation and limiting the pandemic control restrictions caused by falling numbers of new infections and hospitalisations. According to the recently conducted survey results among consumers and businesses and data tracking mobility, a rebound in consumption can be observed and this should only strengthen in the coming months. Tourism sector also starts to revive, and all these positive symptoms of economy recovery are expected to outweigh the temporary production input shortages and rising costs which several manufacturing sectors has been affected with. [39]

⁹ <https://www.oecd.org/G20/key-issues-for-digital-transformation-in-the-G20.pdf>

According to the FIEC report, [Construction Activity in Europe \(edition 2020\) \[40\]](#), the construction sector has reached 9,5% of the EU GDP and generates close to 18 million jobs. Apart from creating new jobs, it drives the economic growth, and provides solutions for social, climate and energy challenges. Being among the top contributors to the world economy it provides annual revenue of approximately \$11.30 trillion [41]. Moreover, according to the ResearchAndMarkets.com, the global construction market is expected to reach \$16.6 trillion by 2025, growing at a CAGR of 7% [42].

In the FIEC report mentioned above, we can find a lot of useful economic data showing the importance of the construction sector for the European Union as well as for the whole economy. In the table below we present the most important ones.

Table 5 – Construction sector main indicators

Indicator	Indicator data
Investment in construction in 2019 (BLN €)	<p>TOP 4:</p> <ol style="list-style-type: none"> 1) Germany – 373 2) France - 194 3) Italy – 130 4) Spain – 125 <p>Other COGITO project countries:</p> <ol style="list-style-type: none"> 5) Austria - 45 6) Denmark – 33 7) Slovakia – 9 8) Greece - 8 <p>General indicators:</p> <ol style="list-style-type: none"> 9) UE 27 – 1,324 10) USA – 1,157
Jobs in construction 2019	<ol style="list-style-type: none"> 1) EU 27 – 12,7 million workers 2) USA – 7,5 million workers <p>Employment in the construction sector in EU 27:</p> <ol style="list-style-type: none"> 1) 6,1% of total employment 2) 27,4 % of employment in industrial sector
Main activities in construction sector 2019	<ol style="list-style-type: none"> 1) 18,8% Civil engineering 2) 21,6% New housebuilding 3) 28% Rehabilitation & Maintenance (in housing) 4) 31,6 % Non-residential (e.g. hospitals, schools)

Source: FIEC

In terms of condition of the construction sector, the latest Eurostat data show that EU GDP has decreased by 0.1% in the first quarter of this year, however this was a much milder decrease compared to the estimate presented in the Spring Forecast (-0.4%). There was also a decrease in private consumption, by 1.9% q-o-q which was caused by the fact that people purchased fewer durable goods and services and spent a bit less on non-durable goods. On the contrary, investment proved resilient (+0.8%) for the third quarter in a row which was a consequence of a **positive impulse from construction** (see Figure 9).

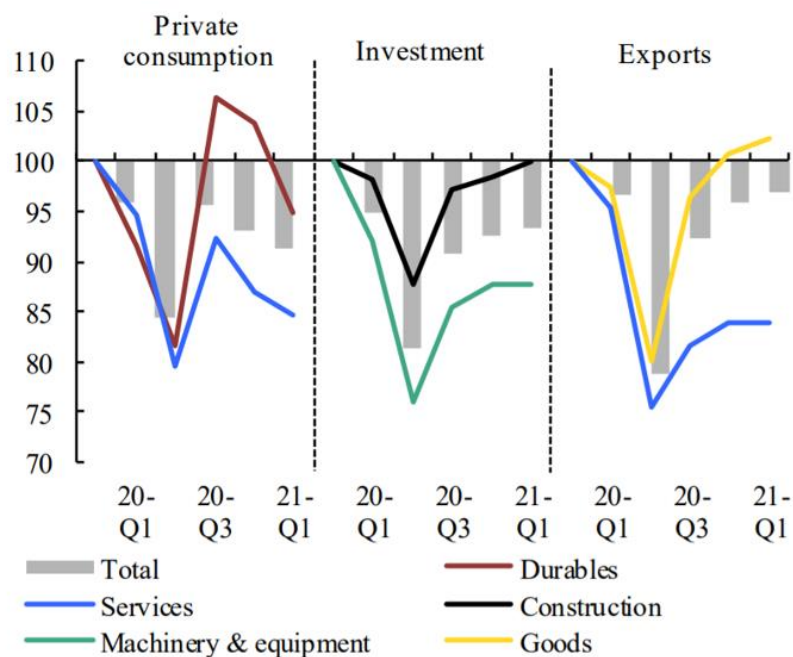


Figure 9 - GDP demand-side components, EU, change

Source: European Commission

Several sources also confirm that the recovery of the European construction industry is more rapid than initially anticipated with much of the losses from the pandemic expected to be recovered in 2021. According to data provided by [Euroconstruct](#)¹⁰ (which is represented by research and consulting companies, covering nineteen European countries), construction volume in the Euroconstruct area is to grow by 3.8% in 2021, following a slump of 5.1% in 2020. Similarly, to the above situation with the EU GDP, the decline was less than expected, and the pre-crisis level will thus be reached again by 2022, at the latest [43].

Challenges

There are many challenges that construction sector is facing. Some of them, especially toward digitalisation, were mentioned in chapter 4. In general, European Commission pointed four main challenges [44] (see table below).

Table 6 - Construction sector challenges

Challenge	Description
Stimulating demand	Efficiency improvements in existing buildings and renovations have the highest potential to stimulate demand.
Trainings	Improving specialised training and making the sector more attractive, in particular for blue-collar workers, technical colleges and universities
Innovation	More active uptake of new technologies
Energy efficiency and climate change	Buildings account for the largest share of total EU final energy consumption (40%) and produce about 35% of all greenhouse emissions.

Source: European Commission

¹⁰ [EUROCONSTRUCT - Home - WIFO](#)

Construction industry trends

Trends are also a pivotal factor to analyse, taking into account introducing new product on the market. The latest trends in global construction are presented below.

Table 7 – Global construction industry trends

Trend	Description
Innovation	Advances in the sector are not only driven by traditional and well-established construction companies, but by new disruptors as well. Materials represent an important innovation opportunity since they can have a big impact on construction costs, quality, and sustainability.
Competitive dynamics and margin improvement	The traditional low margins in the industry—combined with increasing project complexity, competition from Asian companies, and supply chain constraints—put extra pressure on the sector’s profitability.
Internationalism	Although construction companies tend to obtain higher margins in their domestic markets, the international expansion of the industry continues to be a dominant trend.
Compliance, regulations and transparency	Past and recent corruption incidents, together with company failings, have clearly affected the construction industry’s reputation. There is an urgent need to enhance compliance practices at construction companies, reshape regulation, and increase transparency across the board.
Sustainability	Sustainable construction is becoming a requirement rather than just an extra, and firms must be able to introduce improvements in a cost-efficient way.

Source: Deloitte

As we can see, challenges pointed by the European Commission have many similarities with the trends mentioned by Deloitte. Generally, if we look closer toward any example presented in this document regarding construction sector development or construction sector digitalisation, it can be observed that both EC or EU framework/policy and non-governmental initiatives are having same conclusions.

In terms of digitization, nowadays it is amid significant transformations; however, the adoption rate of new digital technologies and automation in construction is still very slow. While other sectors have seen persistent productivity improvements driven by the adoption of new digital technologies, global construction labour productivity continuous to remain capped at just 1% annual gains. And the potential is not to be underestimated. The 2019 Geospatial Market in the AEC Industry report finds that “digitalization in building infrastructure helps to save 10%-20% in the entire construction workflow, whereas project time saving is 14%. In transport infrastructure, there is a cost saving of 15%-23% in the design and engineering phase and 8% in the entire construction workflow, whereas time-saving is around 17%. In industrial infrastructure, the total cost saving is 8%-10% in the construction workflow and project time saving is about 8%. Apart from these benefits, digitalization also improves collaboration, enhances clarity and makes construction sites safer.” [41]

5.3 Architecture, Engineering and Construction (AEC) market

As already mentioned at the end of the chapter above, another important market for the COGITO tools is the AEC market so the Architecture, engineering, and construction market.

Architecture, engineering, and construction software is used by many groups like real estate companies, construction firms, surveyors, interior designers, and others, for effective project life cycle management. The idea to apply architecture, engineering, and construction software is to enhance project performance and produce better outcomes and, in this sense, AEC supports construction managers to gather data and information from different relevant fields and communicate them more effectively. Enhanced data communication and coordination among various stakeholders, architectures, and construction supervisors is coupled with improved construction productivity to provide a leading edge to AEC users. [45]

In a report prepared by Allied Market Research we can read that “The global AEC market size was valued at \$7,188.00 million in 2020, and is projected to reach \$15,842.00 million by 2028, growing at a CAGR of 10.7% from 2021 to 2028.” [45]

The software segment dominated the overall AEC market in 2020 accounting for nearly two-thirds of the total market share in 2020 [45] and it is expected that this trend will continue due to an increase in construction projects and adoption of software such as BIM software in the AEC. Most construction and infrastructure companies are already benefiting from these solutions to integrate all construction processes together. However, there should be an increase in applying those in the services segment in the upcoming years due to, again, an increase in adoption of services among end users as it ensures effective functioning of AEC software and platforms. Moreover, high implementation of AEC creates need for services in the market, which is expected to drive the market in the coming years, and it is estimated that the services segment will witness the highest CAGR of 12.1% from 2021 to 2028 [45]. Moreover, looking from the deployment mode side, the on-premises segment dominated the AEC market share in 2020 contributing to around three-fifths of the global AEC market [45], and this trend is also expected to continue due to higher concerns relating to security of data associated with construction projects. Larger firms in the AEC industry such as Autodesk Inc. and Nemetschek AG provide on-premises software for their customers in industrial, infrastructure, and residential sectors. However, an increase in the cloud segment is also expected to occur (to witness the largest CAGR of 12.4% from 2021 to 2028 [45]) due to the fact, that it does not involve capital cost as well as has low maintenance requirements, hence is most preferred by mid-sized financial institutions. Moreover, the COVID-19 pandemic was also the reason for this increase among both large and mid-sized enterprises. In terms of company size, the market was dominated by large enterprises globally in 2020 and in the coming years this trend is likely to be attained. The reason for this was the rise in use of cutting-edge technology such as augmented reality and virtual reality in large scale enterprises, which needs AEC. On the other hand, SMEs are also very active in this field as they are facing lots of competitive pressure in emerging countries, which forces them to adopt AEC software for better co-ordination in the AEC industry.

When it comes to market development, growth in infrastructure projects, due to rapid urbanization and increase in productivity, growth in adoption of AR and VR in the construction industry and rise in implementation of IoT in numerous construction projects and regulations applied by government authorities for the use of AEC software drive the market globally. On the other hand, again, high initial cost of implementation of AEC software, lack of standards and unclear policy frameworks and lack of skilled workers in the industry restrain the market globally. [45]

Emerging trends in AEC industry are presented in table below.

Table 8 - Emerging trends in AEC industry [41]

Trend	Description
Integrated approach to infrastructure development	Bringing together various components and sub-systems into one functional system is a trend that started to appear in the last years. The sector is not that fragmented as it was used to be, and companies are focusing today on synchronization and cooperation across the value chain. They are defining mutual standards and setting new goals. For example, Australia is pioneering the standardization of project alliance agreements and is adopting a model of cooperative partnership to reduce initial costs.
Public-Private partnerships	Governments play a key role in supporting the sector as solid transport infrastructure projects require huge public sector investments. However, as such high investments may not be possible at all times for governments, the AEC industry is turning to public-private partnerships (PPP). This is a feasible, reliable and viable mode of creating infrastructure in both developed and developing countries. Globally, the share of PPP projects in the overall infrastructure investment ranges from 5% to 10%. Many G20 countries have published concrete national infrastructure plans and project pipelines to help investors get a better understanding of return on investment, payback period,

	project lifecycle and asset management efficiency. However, regulation and insufficiency of funds with governments are some of the problems encountered in the PPP model.
Digitalization of AEC industry	The AEC is the least digitalized sector — traditional methods are still prevalent and technology adoption is low. However, things are changing and digital technologies like BIM, Cloud, Digital Twin, Artificial Intelligence, drones, Augmented Reality, Virtual Reality and Mixed Reality are now being used.
Geospatial technology in AEC	Geospatial technology is revolutionizing the construction industry from planning and designing to building and operating. There are many data and information in construction projects at every stage, from drawings, layouts, blueprints, schedules to cost estimates and specifications and often overlaps and lack of consistency in information leads to construction errors. This can be remedied if spatial and non-spatial data is maintained in a single environment and changes are made to these documents at one place. Geospatial technology can help in achieving that by assisting construction managers at each and every level and establishing a clear line of communication between all stakeholders.
BIM and GIS	BIM integrated with GIS system ensures that all the data is stored in a central repository. It is necessary so that they communicate with each other to build and operate within the desired infrastructure and communities. Today, many BIM and geospatial solution providers are creating integrated solutions to optimize construction workflows that enable users to access, update and use built-in data in spatial context throughout the construction lifecycle.

Taking into account the challenges as well as positive signs and emerging trends it needs to be also noted, that the industry needs collaborations among different actors. Construction companies and geospatial market stakeholders need to enhance education and training capacity, the policymakers have to implement regulations promoting collaboration between all parties to bring digitalization. A good way forward would be also to focus on smaller projects instead of flagship ones, changing the perception that BIM and geospatial technology is only for big projects. The AEC industry also needs to embrace new age disruptive technologies such as IoT, cloud computing and Virtual Reality to develop innovative solutions [41].

5.4 Digital twin market data – general

“A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person, or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes” [46].

There are several reports and analysis of the digital twin market. Each of them shows that the Digital Twin Market will grow in next few years. In the “[Digital Twin Market – Forecast \(2021 – 2026\)](#) [47]” it is estimated that by the year 2026 the CAGR of the digital twin market will reach 24.7%, while in the report prepared by [Grand View Research](#) [48] it is predicted that the CAGR will rise 42.7% between 2021 and 2028 and reach USD 86.06 billion. What is more, in those reports it is pointed out that the growth of the digital twin market will be also boosted by the COVID-19 impact on global economy (digitalisation of economy). In the 2018 report prepared by [Gartner](#)¹¹ it is said that 13% of enterprises already use digital twin technology and 62% began the process of implementation or was to start the process. The growth of interest in the digital twin technologies can also be observed within the “digital twin” phrase searching i.e. in google (see figure below). Since the beginning of 2016 till 2021 we can see that this interest is growing year by year.

¹¹ [Global Research and Advisory Company | Gartner](#)



Figure 10 – Popularity of the digital twin search

Source: Google Analytics

We have asked respondents in our questionnaire to rate (on the scale from 1 to 10, where 1 means no progress and 10 means intensive development) what will be the progress of the construction sector digitalisation in the next 5 – 10 years. As presented in the figure below the average rate was 6.2 (see figure below) which shows a positive progress however not intensive one, as also confirmed in the desk research presented above.

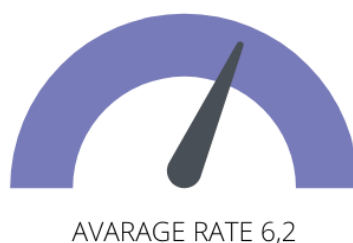


Figure 11 – Opinion on the construction sector digitalisation progress

Source: Cogito T2.2 survey

In the report prepared by [Global Market Insights¹²](#) they have pointed three big challenges that using digital twin technologies can overcome, two of the can be related with the construction sector [49]:

1. “Accurate inventory to avoid overstocking: The global inventory management software market space has lately been brainstorming the possibilities of digital twin to reduce cost and revenue leakages, for gargantuan warehouses and supermarkets, where managing optimum inventory level is the biggest challenge. Digital twin market analysis suggests that the availability of real-time consumption data can lead to a quicker replenishment of supplies and avert over-inventorying, which can cause product

¹² [Digital Twin Market Size, Growth Forecast Report 2027 \(gminsights.com\)](#)

spoilage. Hence, the fast-paced adoption of digital twin in the inventory market offers lucrative growth opportunities for the digital twin industry”.

2. **Amplifying testing & product development capabilities:** Digital twins can potentially help industries in reducing product development and testing expenses. Companies depending heavily on destructive testing for developing products can use the virtual replica of the real-world scenario for significant portion of the product testing. Say for example, automotive industry can employ digital twin for crash testing prototype vehicles. Likewise, enterprises creating giant models and prototypes for feasibility analysis can save money with digital twins during product development. Digital twin market is slated to advance at a rapid pace in the coming years, given the above backdrop.

As the digital twin market is growing and the general digital technologies are still developing, we have asked in our survey, how (in the opinions of our respondents) will tools that supports digital twin-based construction develop (on the scale from 1 to 10, where 1 means no progress and 10 means intensive development) in the next 5 – 10 years. The majority of the respondents rated that the development will be intensive and as presented in the figure below the average rate was calculated at 7.0 which shows a firm development.



Figure 12 – Opinion on the digital twin-based tools development

Source: Cogito T2.2 survey

Taking into consideration all data mentioned above: CAGR predictions, number of enterprises willing to use digital twin technologies, challenges and respondents’ opinions, the COGITO project solution exactly matches the development of the market and meets its expectations.

5.5 Competition analysis for digital twin-based construction supporting tools

To have a wider view on the digital twin market situation we have carried out a desk research in first place. Taking into consideration the construction industry we have chosen most important players on market that provides digital twin solutions (see Table 6) [50]. Most of the companies mentioned in the table below were also listed in the recent report prepared by Market Research Future: [Global Digital Twin Market Research Report \[51\]](#).

Table 9 –Companies providing digital twin solutions

Company	Description
General Electric	GE is a pioneer in the Industrial Internet of Things, offering a wide range of disruptive services and solutions. GE can offer a company everything from digital twin assets and elements to systems and processes. They want to reduce risk within business environments in collaboration with increased reliability and improved production processes. That’s why they’ve created Predix Operations Performance Management (Predix OPM) — a complete on-premises, control-to-cloud analytics solution. The goal is management of process variability, prediction, and improvement of product quality. GE Predix OPM presents real-time visibility and insights into operations execution metrics to identify and solve performance problems faster.
Azure Digital Twins	Azure Digital Twins is a platform that presents organizations with the foundation to build the next generation of IoT solutions. They create data-driven workspaces that

	combine all necessary sources and create new production technologies. Azure Digital Twins can be connected to Azure Stream Analytics, Azure AI, Azure Maps, Azure Storage, Microsoft Mixed Reality, Office 365, or Dynamics 365. The aforementioned IoT and AI platforms significantly reduce the complexity of creating digital twin solutions by enabling functions that trigger automatic endpoint actions based on incoming information. Azure Digital Twins utilizes all types of environments, such as warehouses, offices, schools, hospitals, and banks. It can even be applied to factories, parking, stadiums, parks, smart grids, and cities.
Siemens	Digital twin technology from Siemens has become one of the Industry 4.0 foundational basics. This technological approach has opened the way to the creation of a seamless connection between system objects. They've created the Siemens Digital Enterprise Suite that can coordinate integrated software and automation solutions for industrial companies. The digitalization of communication networks helps contribute all the data on an ongoing basis to the MindSphere, which is one of the best IoT operating systems designed by Siemens.
IBM	IBM is another leader who has had a priceless impact on the digital twin revolution. IBM's Watson Internet of Things system unites capabilities for system design, Engineering Lifecycle Optimization, and Rational Lifecycle Integration. Digital twin technology is used by IBM for virtual creation, testing, monitoring of products, and processes. The extended IBM Engineering Lifecycle Management (ELM) solution, with integrations to a number of third-party tools, helps reduce latency in the feedback loop between design and operation. The IBM Engineering Systems Design Rhapsody (Rational Rhapsody) products offer a comprehensive solution for design, development, and test environment for system engineers. Simplifying the operations of software engineers is achieved through the support of UML, SysML, and AUTOSAR.
Cisco Systems	Cisco invests in the Digital Twin method to keep today's businesses running safely and smoothly towards a faster, go-to-market strategy. Cisco's industrial infrastructure creates a highly reliable, intelligent, and secure connectivity solution within the plant, manufacturing facility, or production space. The Cisco DNA Center helps configure all your network devices in minutes. The implementation of Wi-Fi-connected, non-disruptive PLCs and sensors on each machine helps collect production data with the use of Cisco Kinetic IoT platform and Field Network Director — corporate products that enable the enhanced production control.
Oracle	Oracle's digital twin helps businesses create virtual twins that assist them in building representations of physical assets and devices in the cloud, speeding up the performance of a specific process. They are concentrating on the product lifecycle management and improving production scalability. The data from the physical assets transmit to the complex event processing (CEP) engine in the Oracle IoT Cloud Service, and through the Oracle Stream Explorer, an event-processing engine. Data analysts subsequently create models using Oracle R, an Advanced Analytics for Hadoop (ORA AH). They've also created an additional tool, Oracle Big Data Discovery, for non-technical specialists, that enables them to create simple models using a user-friendly interface
SenSat	SenSat is a London-based startup concentrating on the digital twins of real-world locations. Their solution Mapp is an intuitive and easy-to-use, cloud-based digital twin platform that enables its users to visualize and interact with multiple types of datasets. Visual representation allows for the control of physical projects digitally, in real-time, and provides the ability to discuss plans in a visual and intuitive sense. SenSat can install IoT sensors on a company's territory and feed automated operational updates directly to the team responsible for flagging potential concerns.
Ansys	Ansys is a global leader in building simulation. ANSYS's physics-based simulation consolidated with analytics allows companies to make accurate predictions about future product performance with close assessments of their digital twin developments. Ansys's portfolio consists of collaborations between automotive, aerospace & defense,

	construction, energy, and healthcare industries. The variety of applications grants the possibility to provide markets with solutions specific to the needs of a given business or industry. They've created the ANSYS Store with paid and free applications.
NavVis	NavVis creates digital indoor solutions based on either the technology using the API for the NavVis IndoorViewer or NavVis Positioning SDK for the Navigation App. These products can be shared with a broader ecosystem or customized for individual indoor spaces. Their system works on scanning mechanisms, which allows for the creation of 360-degree immersive images and photorealistic point clouds. NavVis creates digital maps of a building and provides users with a digital companion in order to get around.
Synavision	Synavision is a Germany-based company that broke into the market with its Digital Test Bench software. It verifies building performance and accelerates commissioning. Their main competitive advantage is that they check the operation of the building quickly, efficient, and transparently. The approach doesn't require any additional installations or long-term contracting. On the other side, Synavision has created Software-as-a-Service (SaaS) — a cloud-computing solution for engineers that helps with planning, commissioning, and technical monitoring.

Source: Dashdev - Product Owner Talks: 20 Digital Twin solution providers.

To deepen our knowledge on the key players on the market, we have asked respondents in our survey three questions regarding COGITO competition. One of the questions was about naming the main players (direct competitors of COGITO tools/holistic solution) in the market. In the survey companies were divided into three groups: Global players, European Players and National Players. The answers were based on the respondent's current knowledge regarding companies that provides digital twin solutions, some of them named more than one, on the other hand some of respondents answered that they do not know any competitors. As we can see below, respondents pointed many companies at international level (global players) that offers they products all over the world and also has their offices in different countries. If we talk about the European level there were only two companies mentioned that offers products only in the Europe. In terms of the national level there was much less answers and most of the indications concerned universities or local initiatives and associations.

Some of the companies were also already included in the table above: General Electric, IBM, Azure Digital Twins and Ansys. The Table 10 presents the profile of the competitors which were not yet described in the table above.

Table 10 –COGITO other direct and indirect competitors

Level of players	Players name
Global players	<ul style="list-style-type: none"> - WillowTwin operates in real estate: commercial office, corporate real estate, smart campuses; infrastructure: Railways and Roads (Served by WillowRail). Willow is a technology company, born from the property space that specialises in Digital Twin creation. WillowTwin is an enterprise technology solution that can be adopted at scale. The platform has been designed to capture and maximise the opportunities that are arising from Cloud Computing, Intelligent Edge and the Intelligent Cloud (Industry 4.0), and is delivering benefits today that create significant value for a variety of stakeholders; whether that be on a new construction project, existing building, an entire portfolio or entire infrastructure network. [52] - Autodesk Autodesk Inc. operates its business through segments such as Architecture, Engineering, and Construction (AEC), Manufacturing, AutoCAD and AutoCAD LT, and Media & Entertainment. The company offers a wide range of products for various applications including Asset lifecycle information management, Asset Reliability, Bridge Analysis,

Building Design, Civil Design, Construction, Electrical and Instrumentation, Enterprise Interoperability, Hydraulics and Hydrology, Mine Design, Modelling and Visualization, Offshore Structural Analysis, and others. [53]

- Bentley Systems
Bentley Systems Inc. operates its business through segments such as Products and Services. some of the key offerings of the company include Construction management and workface planning software, ConstructSim planner, ConstructSim systems completion, ConstructSim work package server, and ProjectWise construction management. [53]
- Bexel
Bexel Manager is developed by Bexel Consulting and based on advanced technologies intended to make your project proceed to completion smoothly and fast. Experts in BIM software based on more than a decade of research and exploration of BIM practices and principles. Following the latest trends in AEC and BIM software industries and implementing newest breakthroughs. Bexel Manager provides single solution that enables construction professionals to digitalize key workflows through advanced integrated and flexible system. The solution is based on integrated SD/4D/5D/6D BIM technologies. [54]
- AVEVA
AVEVA, a global leader in industrial software, drives digital transformation for industrial organizations managing complex operational processes. Through Performance Intelligence, AVEVA connects the power of information and artificial intelligence (AI) with human insight, to enable faster and more precise decision making, helping industries to boost operational delivery and sustainability. Our cloud-enabled operational data management, combined with software that spans design, engineering and operations, asset performance, monitoring and control solutions. By leveraging data that is created at every stage of the lifecycle, from design and build to operate and maintain, AVEVA provides a practical and efficient way to creating, integrating and maintaining Digital Twins to enable new ways of working. [55]
- SAP
SAP is the market leader in enterprise application software, helping companies of all sizes and in all industries run at their best: 77% of the world's transaction revenue touches an SAP system. Machine learning, Internet of Things (IoT), and advanced analytics technologies help turn customers' businesses into intelligent enterprises. Digital Twins solutions help to monitor a constant stream of usage and performance data in real time, combine end-to-end asset or product lifecycle data into digital threads, support new product-as-a-service business models, drive innovation in manufacturing, R&D, supply chain, asset management, service, and logistics. [56]
- Simio
The company Simio LLC was established to deliver leading edge solutions for the design, emulation, and scheduling of complex systems. The name Simio comes from Simulation Modeling framework based on Intelligent Objects. A private company headquartered in Sewickley, Pittsburgh, PA, Simio is dedicated to delivering the best possible suite of simulation and

production scheduling tools. A Digital Twin, or Device Shadow, provides an actual virtual representation of all the elements involved in an operation. This allows its performance to be studied and optimized, avoiding potential problem areas to achieve optimal outcomes. Working as a Digital Twin, Simio Software: models production processes, including Industry 4.0; interacts with MES/MRP/ERP systems in Real Time; optimizes schedules and reschedules when required. [57]

- Lendlease
Lendlease is a globally integrated real estate and investment group with core expertise in shaping cities and creating strong and connected communities. Lendlease Podium includes a portfolio of software products bringing together the property lifecycle. Lendlease Digital is a business unit of Lendlease. Lendlease recently built a digital twin to test and determine the viability of building a multistory complex on Collins Wharf, located on the Yarra River in Melbourne from sustainable timber (exhibit). PODIUM SUPPLY AUTOMATION - connecting the entire supply chain in the construction and property industry, enabling live data sharing and coordination of supply, parts and process. PODIUM PROPERTY INSIGHTS - property insights and decision making through consolidated industry, enterprise and asset data in a real time environment. [58]
- PTC inc.
PTC is an American computer software and services company founded in 1985 and headquartered in Boston. They specialise in digital solutions in real-world applications. They are using: Augmented Reality to deliver critical information to frontline workers—exactly when and where they need it; Industrial Internet of Things (IIoT) to connect machines, employees, and processes—unlocking new data-driven capabilities; CAD Software Solutions - pioneer with its computer-aided design solutions and is the industry standard for product design and development software for parametric modeling, simulation/analysis, and product documentation; PLM (Product Lifecycle Management) to provide the context, security, traceability, and processes needed across enterprise teams and systems to ensure product data is accessible and trustworthy. They also do consulting, implementation and training business, also in the area of digital twins. [59]
- Nemetschek
Nemetschek SE operates the business through segments such as Design, Build, Manage, and Media & Entertainment. The company offers a wide range of construction solutions. Some of the key offerings include Allplan Architecture, Allplan Engineering, Allplan Bimplus, and others. [59]
- Newforma Inc.
Newforma Inc. operates its business through segments such as Products and Support & Services. The company offers cloud-based construction management solutions to streamline RFI, submittal, and document management for architects, contractors, engineers, and owners. ConstructEx is one of its key offerings. [53]
- 3D Repo
3D Repo is a digital platform for BIM data. 3D Repo is a Software-as-a-Service (SaaS) platform for Building Information Modelling (BIM) coordination in the cloud. The platform allows users to manage 3D

model revisions and highlight potential issues using live collaboration tools, which enable the whole project team to work from a single source of truth anywhere and at any time. 3D Repo's open API gives users access to a wealth of data stored on its servers, it permits a growing list of integrations including Asite, Procore, Luminova, Dynamo, and most recently Microsoft Power BI.

The Power BI integration exploits 3D Repo's free-to-download embeddable viewer, where users can pull models from software like Revit, Navis, IFC, Civil 3D, or Bentley DGN into interactive dashboards to share with colleagues. By harnessing the power of existing software to create meaningful 4D digital twins, they can all reap the benefits of reduced construction costs, faster project completion, improved on-site health and safety, better-coordinated facilities management and a safer environment for building occupants in the longer term. [60]

- Trimble
From purpose built products to enterprise lifecycle solutions, Trimble software, hardware and services are transforming industries such as agriculture, construction, geospatial and transportation and logistics. Core technologies in positioning, modeling, connectivity and data analytics connect the digital and physical worlds to improve productivity, quality, safety, transparency and sustainability. They offer Trimble Connected Construction which provides all customers along the project lifecycle with confidence by improving productivity, quality, transparency, safety and sustainability. [61]
- RIB software
RIB IT solutions represent the conjunction of virtual and real construction. The digitalization of the entire project life cycle as a BIM 5D simulation supports our customers in safely avoiding cost and time overruns and making construction more productive, less costly and more sustainable. RIB assists in continuous digital planning, construction and operation. [62]
- Carlson Software
Carlson Software Inc. delivers one-source technology solutions for the entire project cycle for civil engineering, land surveying, GIS, construction, and mining. Available worldwide and specializing in CAD design software, field data collection, laser measurement, GNSS, and machine control products. [63]
- MagiCAD
MagiCAD is the number one BIM solution for Mechanical, Electrical and Plumbing (MEP) design used by thousands of companies in over 80 countries worldwide. MagiCAD makes the design of BIM models easier, faster and more accurate. Fully integrated within Autodesk's Revit and AutoCAD platforms, MagiCAD offers a set of powerful modelling functions for each MEP discipline and enables integrated system calculations. With MagiCAD, you design with over 1,000,000 intelligent manufacturer-verified BIM objects from leading MEP manufacturers. Additionally, MagiCAD supports many local standards and symbols making it a unique and truly international solution. MagiCAD Cloud includes a free browsing library for MEP designers with a wide selection of high-quality BIM objects. By bringing the whole BIM content online, collaboration for selecting the right products for a project can happen effectively between teams from across the entire

	<p>build – key to achieving the benefits of BIM for any large-scale building project. [64]</p> <ul style="list-style-type: none"> - Construsoft Construsoft develops and provides worldwide leading model-based software. They are the local partner of Tekla and offer complementary services like training and support. [65] - GEOTEC Software GEOTEC Software is providing universities and consulting companies with the right tools for the last 25+ years. They also assist their clients in various geostructural projects. From basic to advanced problems, GEOTEC Software can provide with the right technical assistant. [66] - Hexagon AB Hexagon is a global leader in sensor, software and autonomous solutions. Offerings for the complete lifecycle of vertical structures, with solutions that ensure projects are optimised to reduce rework and build to plan — on time and on budget — while protecting human and material resources throughout the life of the asset. [67] - ABB ABB is a leading global technology company that energizes the transformation of society and industry to achieve a more productive, sustainable future. By connecting software to its electrification, robotics, automation and motion portfolio, ABB pushes the boundaries of technology to drive performance to new levels. [68] - Dassault Systems Dassault Systèmes SE operates in a unified business segment. The segment operates the sale of company's complete software solutions. Optimized Construction is the key offering of the company. The solution leverages the collaborative, cloud-based, integrated BIM environment, project delivery teams to simulate, optimize, and manage prefabrication, on-site assembly, equipment, labor, and costs. [53] <p>Already described in table above but mentioned by the respondents:</p> <ul style="list-style-type: none"> - Azure Digital Twin - General Electric - Ansys - IBM
European players	<ul style="list-style-type: none"> - ASHVIN ASHVIN is a consortium that combines strong R&I players from 9 EU member states and received funding from the Horizon 2020 programme. It aims at enabling the European construction industry to significantly improve its productivity, while reducing cost and ensuring absolutely safe work conditions, by providing a proposal for a European wide digital twin standard, an open source digital twin platform integrating IoT and image technologies, and a set of tools and demonstrated procedures to apply the platform and the standard proven to guarantee specified productivity, cost, and safety improvements. ASHVIN DIGITAL TWIN TOOLKIT - Along with the concept of the IoT-driven digital twin platform, ASHVIN introduces a digital twin toolbox that extends existing ICT

	<p>methods and innovations from low technology readiness levels to proven technical solutions at the system or the sub-system level. All developed innovations are built upon the ASHVIN digital twin platform and are linked to digital twin data. [69]</p> <ul style="list-style-type: none"> - LiNear Founded in 1989 in Aachen, liNear became a worldwide innovator in digitizing the design of building systems by providing software solutions and services for the MEP design. The brand stands for competence in technical calculation and CAD design applications within BIM processes. Initially conceived as a pure schematic drawing tool, liNear today offers the largest product portfolio of design software for building services engineering from a single source: drawing, calculation, simulation and 3D design programs – seamlessly integrated, easy to use and therefore easy to learn. [70]
National level/Other initiatives	<ul style="list-style-type: none"> - Allplan (DE) A subsidiary of the Nemetschek Group. BIM expertise and software know-how. [71] - National Digital Twin programme (UK) The National Digital Twin programme (NDTp) is run by the Centre for Digital Built Britain, a partnership between the University of Cambridge and the Department for Business, Energy and Industrial Strategy. High-quality, secure data can improve how infrastructure is built, managed, operated and eventually decommissioned. It is therefore crucial that this data is captured and used effectively to bring forward savings for stakeholders and ensure societal benefits for all. This focus is reflected in the NDTp's objectives: enable a National Digital Twin – an ecosystem of connected digital twins to foster better outcomes from our built environment; deliver an Information Management Framework – to ensure secure resilient data sharing and effective information management; align a Digital Framework Task Group – to provide coordination and alignment among key players. [72] - Tallin University of Technology (EE) They have developed the universal production logistics robotic vehicle Boxbot and its digital twin developed at the Department of Mechanical and Industrial Engineering of Tallinn University of Technology. [73] - Newcastle University “Researchers at Newcastle University are using a digital twin of a new Urban Sciences Building (USB) to monitor and tweak performance and test future operational scenarios”. [74]

Source: Own elaboration based on entities named in Cogito T2.2 survey

We have also asked the Partners the question: “What is the competition among providers of digital twin-based construction supporting tools?”. Most of the respondents (48%) pointed that a few sellers supply a sizable portion of products in the market. Few respondents (16%) answered that many sellers offer differentiated product that differ slightly but serve similar purposes. Some of the respondents (26%) choose “other” option where they said that they do not have knowledge on, or that the current market landscape is unclear (Figure 13).

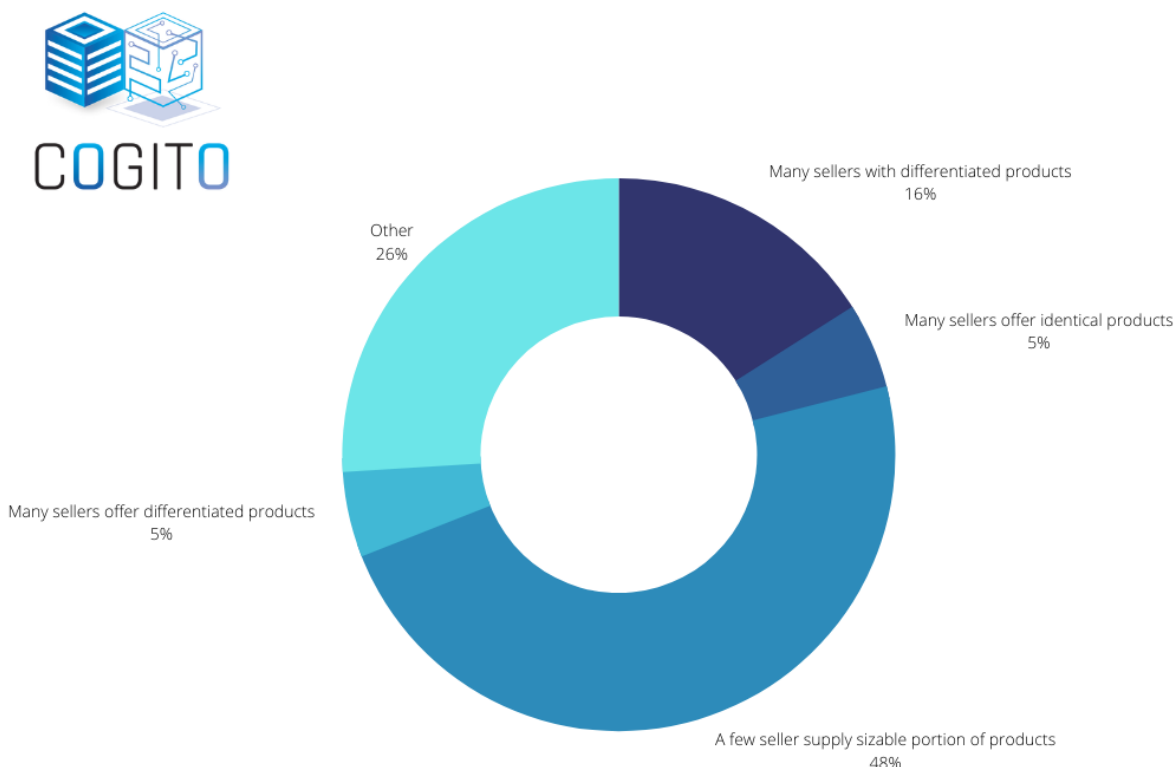


Figure 13 - Opinion on the types of competition

Source: Cogito T2.2 survey

Last question in the competition section of our survey was: “How fast do you think the competition will grow in the next 5-10 years?” (see figure below). Most of the respondents said that the competition will grow: 11% said that the competition will grow but very slowly, **42% said that competition will grow at a moderate pace** and 37% pointed that the competition will grow very rapidly. What is the most interesting fact nobody said that the competition among companies providing digital twin solutions will decrease and only one person cannot predict that. This is of course a clear indication that the commercialisation activities should take place quickly at the project end with a solid exploitation strategy and planning and that ongoing monitoring of the markets and competition should be performed to be able to react to the quickly changing environment.

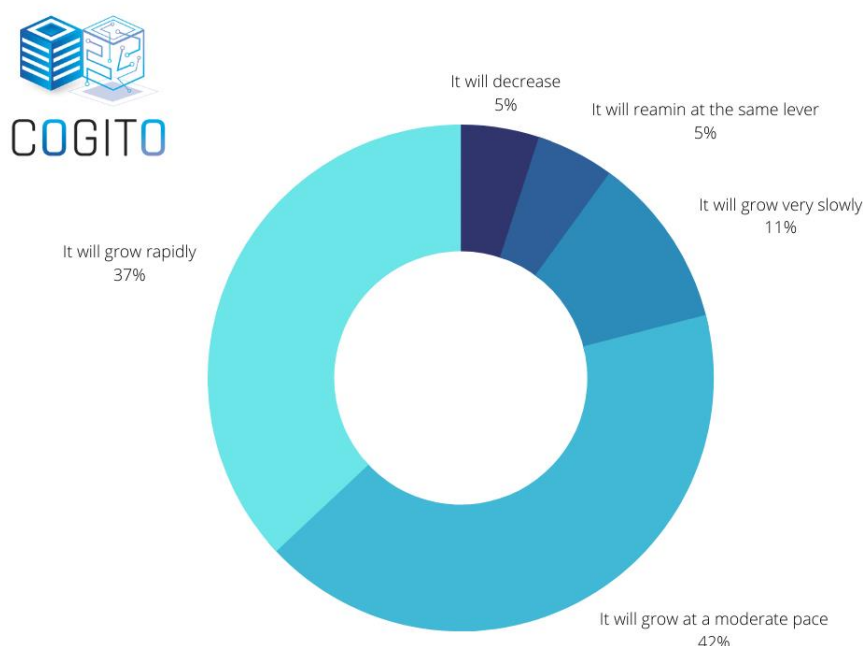


Figure 14 - Opinion on the digital twin competition growth

Source: Cogito T2.2 survey

Furthermore, we have also asked about the type of support the vendors offer for tools supporting digital twin-based construction or engineering. The results (see figure below) show that the most popular support is advisory & consulting (47%), followed by data and analysis (42%), training (26%) and verification and assurance (21%). In other type of support SAAS and Implementation has been mentioned. This is a first indication of the additional services offered by the companies selling tools supporting digital twin-based construction or engineering that should be carefully analysed in WP9 when elaborating the COGITO exploitation strategy and business model.

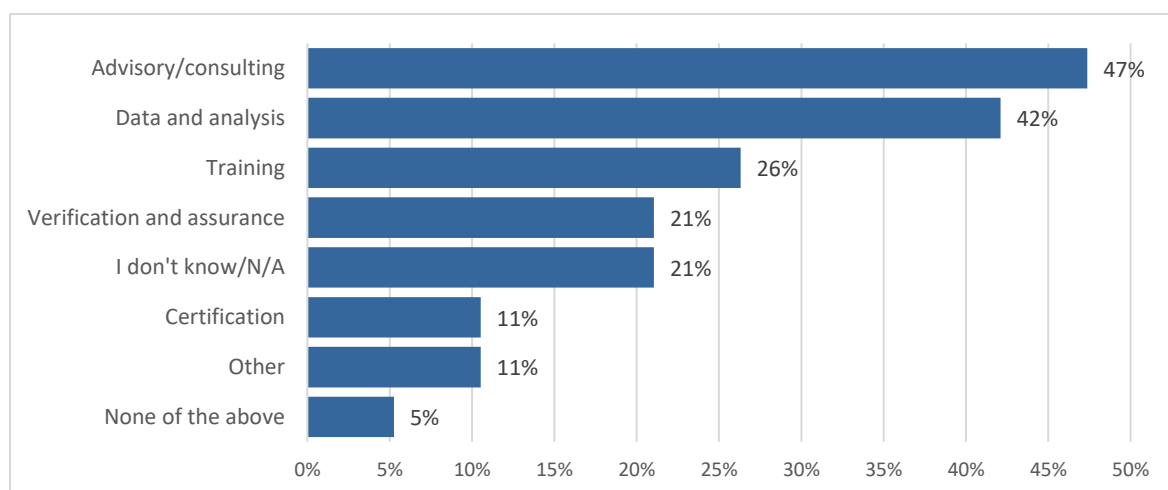


Figure 15 - Type of support the vendors offer for tools supporting digital twin-based construction

Source: Cogito T2.2 survey

Another question regarding the COGITO competition was about the availability of the tools supporting digital twin-based construction or engineering. Most of the respondents said that that kind of tools are not commonly available, and they are not easily affordable or that they require advanced technical readiness. What is more,

they have pointed out that the digital twin concept is very wide and sometimes it is even hard to search for demanded tools or information in the internet. In another question we have asked our respondents to rate/estimate the cost of that tools, whether they are high, average or low. Most of the respondents pointed that the prices are high because the digital-twin solutions are very complex, they are dealing with digitalisation and hi-tech software. What is more, some of the respondents said that is hard to estimate because that kind of tools are still in the R&D phase. However, one of the respondents said, with regards digital twin-based tools as well our COGITO solution that, if we compare the savings that can be achieved by using these tools (i.e. process optimization), these costs seem to be low.

5.6 COVID-19 implications

Due to the outbreak of the COVID-19 pandemic, we have observed a huge impact on our lives. The question we would like to answer in this section is what the impact of COVID-19 on the global economy and digitalisation is. “The Covid-19 pandemic is a global shock ‘like no other’, involving simultaneous disruptions to both supply and demand in an interconnected world economy. On the supply side, infections reduce labour supply and productivity, while lockdowns, business closures, and social distancing also cause supply disruptions. On the demand side, layoffs, the loss of income (from morbidity, quarantines, and unemployment) and worsened economic prospects reduce household consumption and firms’ investment. The extreme uncertainty about the path, duration, magnitude, and impact of the pandemic could pose a vicious cycle of dampening business and consumer confidence and tightening financial conditions, which could lead to job losses and investment [...]” [75]. The pandemic has disrupted lives across all countries and communities and negatively affected global economic growth in 2020 beyond anything experienced in nearly a century. Estimates indicate the virus reduced global economic growth in 2020 to an annualized rate of -3.4% to -7.6%, with a recovery of 4.2% to 5.6% projected for 2021. Global trade is estimated to have fallen by 5.3% in 2020 but is projected to grow by 8.0% in 2021. According to a consensus of forecasts, the economic downturn in 2020 was not as negative as initially estimated, as already discussed above, due in part to the fiscal and monetary policies governments adopted in 2020. Generally, economic growth forecasts captured the decline and subsequent rebound in economic growth over the second and third quarters of 2020 but have been challenged since by the prolonged nature of the health crisis and its continuing impact on the global economy [76]. In the publication [Global Economic Effect of COVID-19 \[76\]](#) it is also written that according to the recent [World Economic Outlook \(April 2021\)](#)¹³ prepared by [International Monetary Fund](#)¹⁴ the global economy growth will reach 6% in the 2021 and 4,4% in the 2022. If we look at the European Market, we can see that the data regarding the growth forecast are very similar to the global ones, as reported by EC in the publication [Summer 2021 Economic Forecast](#)¹⁵, which was presented already above. As predicted by the EC, the overall growth of the GDP will reach 4,8% in 2021 and 4,5% in 2022. Below we can find detailed data for each country in the EU (see Table 11).

Table 11 – GDP forecast in the EU

Country	GDP% - 2020	GDP% - 2021	GDP% - 2022
Belgium	-6.3	5.4	3.7
Germany	-4.8	3.6	4.6
Estonia	-2.9	4.9	3.8
Ireland	3.4	7.2	5.1
Greece	-8.2	4.3	6.0
Spain	-10.8	6.2	6.3
France	-7.9	6.0	4.2
Italy	-8.9	5.0	4.2

¹³ [World Economic Outlook \(imf.org\)](#)

¹⁴ [International Monetary Fund - Homepage \(imf.org\)](#)

¹⁵ [Summer 2021 Economic Forecast: Reopening fuels recovery | European Commission \(europa.eu\)](#)

Cyprus	-5.1	4.3	3.8
Latvia	-3.6	3.8	6.0
Lithuania	-0.9	3.8	3.9
Luxembourg	-1.3	4.8	3.3
Malta	-7.8	5.6	5.8
Netherlands	-3.7	3.3	3.3
Austria	-6.3	3.8	4.5
Portugal	-7.6	3.9	5.1
Slovenia	-5.5	5.7	5.0
Slovakia	-4.8	4.9	5.3
Finland	-2.8	2.7	2.9
Euro area	-6.5	4.8	4.5
Bulgaria	-4.2	4.6	4.1
Czechia	-5.6	3.9	4.5
Denmark	-2.7	3.0	3.4
Croatia	-8.0	5.4	5.9
Hungary	-5.0	6.3	5.0
Poland	-2.7	4.8	5.2
Romania	-3.9	7.4	4.9
Sweden	-2.8	4.6	3.6
EU	-6.0	4.8	4.5

Source: Adapted from EC

Taking into consideration data presented above, the overview of the global and European GDP predictions looks optimistic. As highlighted in the Summer 2021 Economic Forecast the real growth will depend a lot on the level of response to the rapidly changing situation with the pandemic.

Moreover, as mentioned already above, the COVID-19 crisis has accelerated the change in the way companies in all sectors do business. According to a global survey conducted in July 2020 by McKinsey [77] with 899 C-level executives, they have stated that their companies have accelerated the digitization of their customer and supply-chain interactions and of their internal operations by three to four years. What's more shocking, they have also mentioned that the share of digital or digitally enabled products in their portfolios have accelerated by seven years. Majority have also stated that the change in the direction of digitalisation will be long lasting, and they are already making investments to sustain this. The respondents also said when asking about the impact of the crisis on a range of measures, that funding for digital initiatives has increased more than anything else. [77]

Furthermore, COVID-19 outbreak has a moderate impact on growth of the architecture, engineering, and construction market as worldwide lockdown during the COVID-19 has increased wide adoption of AEC software to allow projects to continue in a virtual and digital environment even when participants were unable to meet in person. The pandemic has forced to find safer and smarter ways for construction of highways, offices, and homes which is expected to increase the adoption of AEC software among end users. [45]

When it comes to the information gathered from our online survey, the opinions were divided. Out of 17 answers, 7 times negative aspects have been mentioned that might further affect development of tools like delays, construction stopped, cut in investments, disruption in the semiconductor industry, problems with testing in real environments, evaluation, verification of digital twin solutions/tools which could calibrate the tools as well as standard implications and challenges in collaboration, travelling, getting to know the partners, areas of focus, pilot sites etc. in person and through physical interactions. On the other hand, 6 times positive influence of Covid-19 on the development of COGITO tools has been mentioned, mainly around boosting the development of the

tools and giving a positive push in the digital twin construction industry. The reasons included recovery measures implemented that can support the sector's transformation towards sustainability and digitalization; social distancing norms, remote working and traveling restrictions which means that robotic/remote sensing method and data processing for project monitoring is increasingly important.

The presented results show that the as long as the economy will recover as estimated by different sources, the Covid-19 will have long lasting effects on the implementation of digital twin solutions. However, solutions need to be developed to tackle such challenges as problems with testing in real environments, evaluation and verification of digital twin solutions/tools.

6 PESTELE and SWOT analysis

In order to provide necessary description of the COGITO external environment, we have decided to use two frameworks: PESTELE and SWOT. Below we present the results and analysis divided into two subsections.

6.1 PESTELE analysis

PESTLE analysis, which is sometimes referred to as PEST analysis, is a concept in marketing principles. Moreover, this concept is used as a tool by companies to track the environment they're operating in or are planning to launch a new project/product/service, etc. **PESTLE** is a mnemonic which in its expanded form denotes P for Political, E for Economic, S for Social, T for Technological, L for Legal, and E for Environmental. It gives a bird's eye view of the whole environment from many different angles that one wants to check and keep a track of while contemplating a certain idea/plan [78]. In our analysis we have to add another factor that might impact on the development of digital twin solutions which is another E for Ethics (see Figure below).

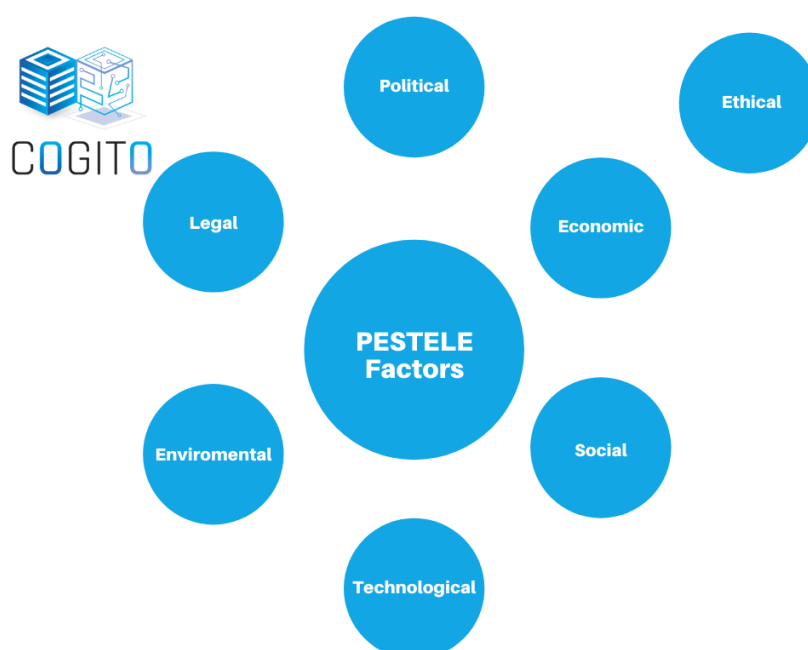


Figure 16 – PESTELE Factors

Source: Cogito T2.2 survey

For the purpose of the COGITO project, we asked partners two questions regarding PESTELE framework and the impact of each factor types:

1. In your opinion, are there any factors that favour the development of digital twin solutions/COGITO tools in construction in the below mentioned areas?
2. In your opinion, are there any factors that hamper/could hamper the development of digital twin solutions/COGITO tools in construction in the below mentioned areas?

The answers for these two questions are shown below in the Table 12 (question 1) and Table 13 (question 2):

Table 12 – PESTELE analysis (positive factors)

PESTELE	Respondents answers
P – Political	<ul style="list-style-type: none"> - Public/private partnership in medium and large construction projects - Proposals for future standardisation for Digital Twins at European level - Relatively stable political situation in EU

	<ul style="list-style-type: none"> - Willingness to promote new technologies among people involved in politics - Digitalisation and environmental legislation - Digital Economy development - Decrease of construction workers impacts on digital development
E – Economic	<ul style="list-style-type: none"> - Significant cost reduction - Better scheduling forecast and reduction of costs on consortium projects - Worldwide investments in digitalisation - Decrease of costs - Economic growth - More jobs to people - Less money wasted on construction because of bad planning and errors/accidents - Optimisation: reduced construction time means cheaper construction products - The need for time saving
S – Social	<ul style="list-style-type: none"> - Faster project completion - Reduced numbers of accidents on construction sites - Importance of safety on construction sites - Grow interest in the public for related technologies - Smart City concept - Remote working
T – Technological	<ul style="list-style-type: none"> - 5G network - Development of Artificial Intelligence - Industry 4.0 - Technological development - New technologies in the AEC domain - Quality development in the constructions - Development of robotic sensing platforms - Augmented Reality and data gathering - Digitalisation
E – Environmental	<ul style="list-style-type: none"> - Sustainability - Green building development - Energy management, less garbage politics - Carbon print regulations - Agenda Net Zero - Climate change impact
L – Legal	<ul style="list-style-type: none"> - Smart contracts - Adaptation of regional legislation to EU directives
E – Ethical	<ul style="list-style-type: none"> - Transparent procedures - Personal Data Privacy and Security

Source: Cogito T2.2 survey

To summarize the main factors that could positively impact on the digital twin solutions are primarily factors connected with the development of technologies and digitalisation itself. Another important factor is that companies are looking for solution that can result in savings e.g. in construction management. Another factors that could positively affect COGITO solution is paying attention to the safety of the employees, popularisation of the Smart City concept, global policy for the environment e.g., Agenda Net Zero [79]. As could be seen, there are many factors currently in the external environment that favour the development of the COGITO solutions.

On the other hand, some negative aspects were presented which may hinder the implementation of the COGITO tools into the market. The political aspects and lack of government regulations should be highlighted as this was also mentioned in the chapter above saying, that policies are crucial to incentivise the uptake of digital technologies, practices and business models and as a consequence contribute to supporting the digitalisation of the construction sector and faster implementation of many digital tools in this sector. In this regard, COGITO

should also, apart from the activities planned within the Description of Action, think of additional information package directed towards policy makers and standardisation bodies to push the implementation of regulations in this regard. For the other factors presented in the table below, a discussion should take place whether there is a possibility to include in the development phase, marketing offer or other any aspect of the solution elements which could reduce the impacts of these negative factors.

Table 13 – PESTELE analysis (negative factors)

PESTELE	Respondents answers
P – Political	<ul style="list-style-type: none"> - Bureaucracy - Lack of government regulations
E – Economic	<ul style="list-style-type: none"> - Financial difficulties due to COVID-19 that could discourage corporations from investing in the digital twin market - Expensive software to support digital twin - High cost of tools and hardware could not be easy to afford - Competitive methods of construction management - Cost of implementation
S – Social	<ul style="list-style-type: none"> - Disruptive nosiness models - Lack of skilled personnel and difficulties in hiring staff with relevant experience - Being afraid of new technologies - It will be difficult to get used to work with digital twin
T – Technological	<ul style="list-style-type: none"> - Slowdown of development - Security and hardware - lack of interoperability among existing standards - Problems with Reliability - Indoor localisation
E – Environmental	<ul style="list-style-type: none"> - Respondents did not indicate any factor, the answer in all cases was “none”
L – Legal	<ul style="list-style-type: none"> - GDPR like legislation which could prevent location monitoring - GDPR - Might not be easy to collect data from people or might be hard to get permission of many people - Privacy legislation - Enforcement of smart contracts
E – Ethical	<ul style="list-style-type: none"> - Use of data for purpose other than the intended - Tracking resources or people (if needed) - Data privacy and security

Source: Cogito T2.2 survey

6.2 SWOT analysis

SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. By definition, Strengths (S) and Weaknesses (W) are considered to be internal factors over which you have some measure of control. Also, by definition, Opportunities (O) and Threats (T) are considered to be external factors over which you have essentially no control. **SWOT Analysis** is a method of analysing the overall strategic position of the business and its environment. Its key purpose is to identify the strategies that will create a firm specific business model that will best align an organization’s resources and capabilities to the requirements of the environment in which the firm operates. In other words, it is the foundation for evaluating the internal potential and limitations and the probable/likely opportunities and threats from the external environment. It views all positive and negative factors inside and outside the firm that affect the success. A consistent study of the environment in which the firm operates helps in forecasting/predicting the changing trends and also helps in including them in the decision-making process of the organization [80]. If we compare SWOT analysis with the PESTELE, we can find many similarities (Table 14).

Table 14 – SWOT analysis

PESTELE	Respondents answers
S – Strengths	<ul style="list-style-type: none"> - All necessary parties (research, technology providers, construction industry, etc.) are represented in COGITO consortium. - COGITO solution scope encompassing several market segments in need of innovation - Leveraging innovative digital technologies (drones, IoT, bog data) to deliver value-adding services - Exploitation of multisource data
W – Weaknesses	<ul style="list-style-type: none"> - Health & Safety compliance requirements do not necessitate new technology solutions - Innovative digital technologies incur additional learning cycles & costs on construction - Long-term development and market penetration cycle
O – Opportunities	<ul style="list-style-type: none"> - Emerging market (construction digital twins) without incumbents - Strong EU policy push for construction industry digitalisation - Digital twin technologies high on the hype cycle generating buzz - Rapid technology advances and equipment costs decline; growth in adoption of AR and VR in the construction industry and rise in implementation of IoT in numerous construction projects
T – Threats	<ul style="list-style-type: none"> - High inertia of industry in adapting new practices - Construction digitization penetration slow, despite benefits and buzz - Digital twins not yet part of policy push

Source: Cogito T2.2 survey

In terms of USP of the COGITO solutions following elements have been mentioned in the COGITO survey:

- provisioning of the elements of the solution by a larger group of participants from different fields of expertise,
- development of new services based on a holistic approach,
- it covers planning, quality control and safety at once,
- the interoperability among its different components,
- COGITO combines many potentials, existing approaches and services; thus, it can be implemented in many subsectors of AEC.

These are the first ideas to identify the competitive advantage that will be elaborated in WP9 while developing business model for the COGITO solution.

If we analyse together both, PESTELE and SWOT, we can see that there are more opportunities toward the digitalisation and generally use of digital twin-based tools than the negative factors. It seems that the COGITO project will benefit from all the positive factors of socio-economical external environment and should carefully examine the negative aspects.

7 Conclusions

If we would like to summarise the outcomes of this report it is worth to start by saying that **digitalisation is a key to the future of construction sector industry**.

In this report we have tried to focus on few important things that may influence the COGITO project and the implementation of the COGITO tools. As presented in the chapter 3, COGITO offers a big variety of software tools and solutions that may be of interest to potential buyers. Products offered by COGITO project are also in line with market requirements and respond to stakeholders needs. Desk research carried out on existing documents, EU or EC regulations and other initiatives or publications shows the common idea about the next steps toward construction sector industry. As stated at the beginning of this chapter, the most relevant issue is digitalisation, and most guidelines and policies focus mainly on this element. It is not only important with regard of construction sites itself or with the architectural design but also it is important for the whole construction process e.g., project management, risk management or Occupational Health and Safety issues management. The thing that was often mentioned, which is still not fully resolved when we talk about the construction market, is the lack of guidelines and specific laws in individual EU countries. It needs to be improved and developed. Moreover, COVID-19 outbreak did not stop the progress in the digitalisation, and what is more, it even caused its acceleration. Taking into consideration what was presented in the deliverable D2.1 [81] and in this report, we can say that the COGITO project and its tools and solutions create great opportunities toward the digitalisation in the construction sector industry.

Some recommendations, for the design and implementation of the tools, could be formulated, based on the research performed, like ensuring better access to online services through guidelines and instructions (e.g. interactive handbooks or digital maturity scans); including data security aspects in the design of the solutions; ensuring interoperability of different tools, providing training for on-site workers in the use of digital tools, making digital tools and services sustainable (ensuring its energy efficiency, climate neutrality, reparability, lifespan and recycling), benefiting from Digital Hubs for Innovations for a better cooperation on a Member State level and cross sector collaboration in terms of design as well as implementing, using the project results after the project end.

On the other hand, there are also many challenges and threats in the construction and AEC sector, also ones that appeared due to Covid-19 pandemic, and all these need to be taken into account when developing exploitation strategy and business model for the project solution. This is also the next step in the project development in terms of designing an appropriate exploitation strategy. In the following months, the consortium will conduct a series of activities towards the definition of a plan for the exploitation of the project's tangible and intangible results including update of the construction market analysis and direct competitors. The early definition of the project's exploitation strategy and the identification of project partners responsible for exploitation of each result in the next phase will also allow to define the target markets and the suitable actors for the marketization of project outputs. This will also lead to an in-depth analysis of legislative frameworks, availability, cost, construction financing options, information gaps, lack of appropriate tools and vendor support of solutions/components due to the particularities of national/regional circumstances in the selected target markets/countries.

Finally, in the process of creating a preliminary business innovation plan for the project outcomes, the consortium will identify the value proposition of the project results for the various (existing and emerging) market actors and evaluate those parts of the COGITO system that have the biggest potential to commercialize and monetize.

"I believe that we must make much better use of the great opportunities offered by digital technologies, which know no borders. To do so, we will need to have the courage to break down national silos in telecoms regulation, in copyright and data protection legislation, in the management of radio waves and in the application of competition law".

Jean-Claude Juncker

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Annex I – Online questionnaire

COGITO T2.2 Survey among Consortium Partners on market and regulatory insights into COGITO solutions

For the purpose of this survey, we understand Digital twin as a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity. It is fed with right-time data from the Real Twin (i.e. the physical product or process) and in this sense DT is not the same as BIM however most likely BIM will be needed to develop a DT.

Sources:

1. The definition of a digital twin - <https://www.digitaltwinconsortium.org/hot-topics/the-definition-of-a-digital-twin.htm>



2. Can a Building Information Model (BIM) be called a Digital Twin?, Frédéric Bosché, <https://www.linkedin.com/pulse/can-building-information-model-bim-called-digital-twin-bosch%C3%A9/?trackingId=4hrr%2Bf7xbWl%2FgXEO1O5W2g%3D%3D>

Important: Whenever there is a question about tools supporting digital twin-based construction please think of tools/solutions similar to the ones that we are developing in COGITO project.

1. Do you know of countries / regions in Europe/worldwide where tools supporting digital twin-based construction are particularly popular/used?

2. Which European countries have the greatest potential for COGITO solution / tools development? Please justify your answer.

3. Which COGITO solutions have the greatest potential for exploitation? Please rank the solutions starting with 1 which means a solution with the greatest exploitation potential.

		Work Order Definition and Monitoring tool (WODM)
		Work Order Execution Assistance tool (WOEA)
		Digital Twin Platform (DTP)
		Process Modelling and Simulation tool (PMS)
		Digital Twin visualisation with AR (DigiTAR)
		GeometricQC Tool (gQC)
		VisualQC (vQC)
		Digital (Visual) Command Centre (DCC)
		BlockChain Platform Tool
		BlockChain SLA Manager
		SafeConAI
		ProActiveSafety
		VirtualSafety
		Geometric Data Acquisition (GDA) Tools
		Visual Data Acquisition (VDA) Tools
		Location Data Acquisition (LTA) Tools

4. Which is the one COGITO tool that you think will be in the highest demand in the next 5-10 years?

5. In which construction sub-sectors, COGITO tools as well as the COGITO holistic solution have the biggest potential for development?

- ☐ Small buildings (single-family residences, small shops) (typically < €1m)
- ☐ Medium buildings (multi-family, schools, medium commercial, small infrastructure) (typically €1 to €50m)
- ☐ Large buildings (hospitals, industrial, large infrastructure) (typically > €50m)
- ☐ Other (please specify)

6. To the best of your knowledge, what is currently the % of contractors who use tools supporting digital twin-based construction similar to the ones developed in COGITO?

7. What is the competition among providers of digital twin-based construction supporting tools?

- ☐ Many sellers offer differentiated products—products that differ slightly but serve similar purposes
- ☐ Many sellers offer identical products
- ☐ A few sellers supply a sizable portion of products in the market
- ☐ Only one seller in the market
- ☐ No sellers in the market yet
- ☐ Other (please specify)

8. Please name the main players (direct competitors of COGITO tools/holistic solution) in the market?

Global players

European players

National players

9. How fast do you think the competition will grow in the next 5-10 years? Please justify your answer.

10. Are the tools supporting digital twin-based construction or engineering, commonly available? Please elaborate.

11. How would you rate the cost of tools supporting digital twin-based construction or engineering? Is it high, average, low? Please justify your answer.

12. What kind of support, to the best of your knowledge, do the vendors offer for tools supporting digital twin-based construction or engineering?

- ☐ Advisory/consulting
- ☐ Data and analysis
- ☐ Training
- ☐ Certification
- ☐ Verification and assurance
- ☐ Other (please specify)

- ☐ None of the above

13. In your opinion, are there any factors that favor the development of digital twin solutions/COGITO tools in construction in the below mentioned areas?

Political

Economic

Social

Technological

Environmental

Legal

Ethical

14. In your opinion, are there any factors that hamper/could hamper the development of digital twin solutions/COGITO tools in the below mentioned areas?

Political

Economic

Social

Technological

Environmental

Legal

Ethical

15. How would you assess the construction industry digitization rate in the next 5-10 years on a scale of 1 to 10 (where 1 star means no progress and 10 stars means intensive development).

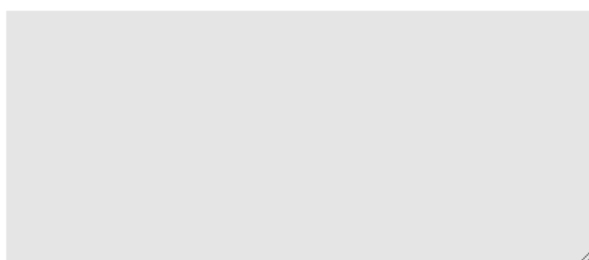
16. How will tools supporting digital twin-based construction develop in the next 5-10 years in your opinion? Please mark on a scale of 1 to 10 (where 1 star means no development and 10 stars means intensive development).

17. Are you aware of any specific EU and national regulations the COGITO tools must be compliant with for a lawful/successful commercialization?

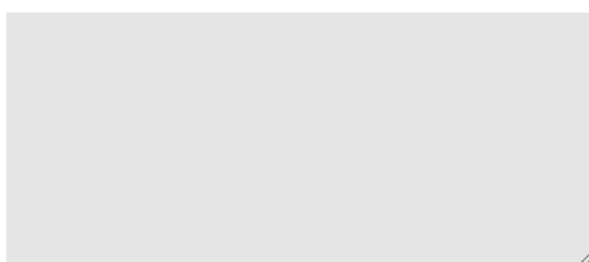
18. What impact is COVID-19 having on the development of tools supporting digital twin-based construction?

19. Please mention the strengths of the COGITO holistic solution?

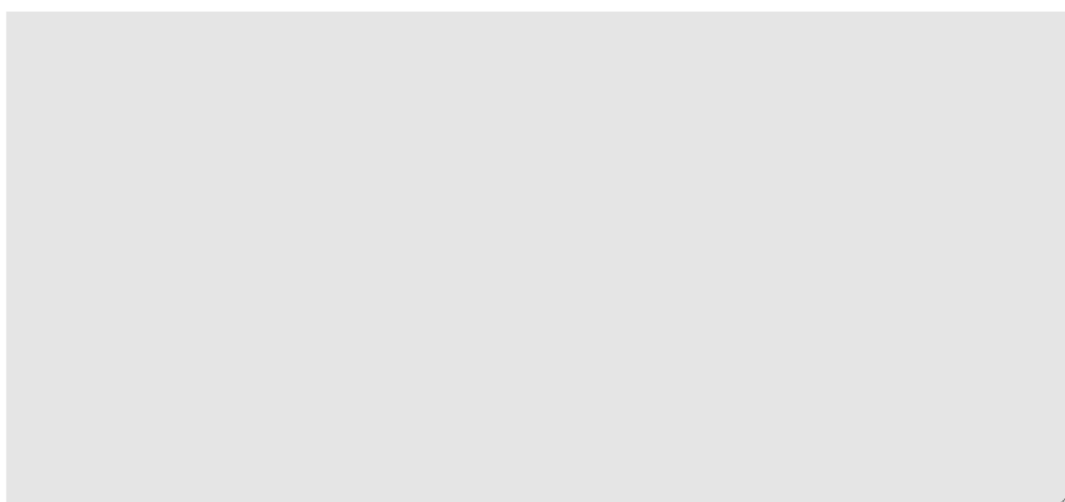
20. What is in your opinion the Unique Selling Proposition of the COGITO holistic solution?



21. What are the weaknesses in the COGITO holistic solution?



22. Are you aware of any initiatives, recommendations that are important for the development and commercialization of COGITO tools e.g. the European Construction Industry Manifesto for Digitalisation?

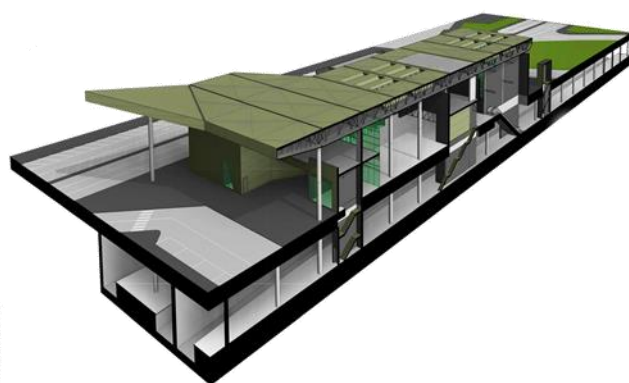


23. Are you aware of any report on the digital twin market, solutions or else relevant to the development of COGITO tools?

24. If you have any other remarks with regards to the market and regulatory conditions that you believe are important for the development and exploitation of the COGITO tools please elaborate below.

* 25. Which Consortium Partner do you represent?

Done



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CONSTRUCTION PHASE
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