

COGITO

CONSTRUCTION PHASE
DIGITAL TWIN MODEL

cogito-project.eu

D2.1 – Stakeholder requirements for the COGITO system



*This project has received funding
from the European Union's Horizon
2020 research and innovation programme
under grant agreement No 958310*

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Dissemination Level:	Public
Deliverable Type:	Report
Lead Partner:	UEDIN
Contributing Partners:	All partners
Due date:	30-04-2021
Actual submission date:	14-05-2021

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Version History

Version	Editors	Date	Comment
0.1	UEDIN	14.01.2021	First Draft
0.2	UEDIN	08.02.2021	Added initial content
0.3	UEDIN	16.03.2021	Section 4 (most content)
0.4	UEDIN, OLOD, FER	06.04.2021	Section 2 (except Safety) Section 3 Section 4 (updates) Sent for first review
0.5	UEDIN, CERTH, ASM, RSRG	28.04.2021	Section 5 (Quality)
0.6	UEDIN, NT, BOC, QUE, UPM, UCL, HYP	02.05.2021	Section 2 (Safety) Section 5 (Safety) Section 6

			Executive Summary Various updates
0.7	UEDIN, RSRG, AU	05.05.2021	Section 5 (Safety) Completion of minor remaining matters Sent for final internal review.
1.0	UEDIN	14.05.2021	Final corrections following internal review

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Executive Summary

This deliverable presents the work conducted to elicit **Stakeholder Requirements (SRs)**, also commonly called **User Requirements**, that are used to define and refine the different components of the COGITO platform and their expected interactions; thereby setting the skeleton for the COGITO framework. The produced requirements are derived through engagement with COGITO main stakeholders, principally drawn from the COGITO partners as well as from participants in the COGITO Living Lab. COGITO thus engages stakeholders from the early stages to ensure the COGITO solutions are relevant and can be successfully exploited.

The first phase of this work entailed the definition of **Business Scenarios (BSs) and Use Cases (UCs)** that drove the whole requirement definition process. The COGITO system **Main Stakeholders** were then identified, as the **users** of the tools to be developed by COGITO and the providers and consumers of the data used and produced by those tools, ranging from project manager to foremen and site workers. Next, **SR Questionnaires and Workshops** were prepared to capture the views and requirements of those stakeholders.

It is noteworthy that the process of defining the UCs was iterative. The primary motivation for this approach was to ensure that feedback occurred continuously during the process and especially that the UCs were developed using input from different stakeholders and agreed broadly to ensure that the questions in the SR Questionnaires and activities in the SR Workshops were relevant. A second reason was that D2.1 is not to be followed by another deliverable that would be the second version of that report. Therefore, it was felt critical to conduct our work with frequent feedback from the outset.

Overall, the COGITO consortium identified 3 BSs supported by 9 UCs of the COGITO solution. Ten Main Stakeholders were identified. A questionnaire was issued and two workshops conducted with professionals from the industry partners representing those stakeholder groups. The analysis of the questionnaire and workshop results led to the establishment of 75 SRs subsequently split into 33 “MUST” requirements, 24 “SHOULD” requirements, 12 “COULD” requirements, and 6 “WOULD” requirements, following the MUST-SHOULD-COULD-WOULD (MoSCOW) prioritisation approach.

The activities and their results summarised in this report form the basis for the design and development of the COGITO system architecture (which will be reported in deliverable D2.4 “COGITO system architecture v1”) and subsequently the work conducted in the technical work packages. Later, the UCs and SRs will also guide the evaluation phase of the project at the pilot premises.

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List of Acronyms

Term	Description
ACWP	Actual Cost of Work Performed
AEC	Architecture, Engineering and Construction
AI	Artificial Intelligence
AR	Augmented Reality
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
BIM	Building Information Model
BPMN	Business Process Model and Notation
BS	Business Scenario
CA	Cost Account
CAC	Cost Account Code
CAVAR	Cost Account Variance
CBS	Cost Breakdown Structure
CDBB	Centre for Digital Built Britain
COGITO	Construction Phase diGital Twin mOdel
CMCS	Cost Management and Control System
CPE	Collective Protective Equipment
CPM	Critical Path Method
CPI	Cost Performance Index
CV	Cost Variance
DCC	Digital Command Centre
DigiTAR	Digital Twin visualisation with AR
DoA	Description of Action
DT	Digital Twin
DTP	Digital Twin Platform
EVA	Earned Value Analysis
F	Foreman
FM	Facility Management
GDA	Geometric Data Acquisition
gQC	GeometricQC tool
H&S	Health and Safety
HSE	Health, Safety and Environment
HSEM	Health, Safety and Environment Manager
HSES	Health, Safety and Environment Supervisor
HSET	Health, Safety and Environment Trainer
IoT	Internet of Things
ITS	Inspection Test Schedule
KPI	Key Performance Indicator
LDA	Location Data Acquisition

LSM	Linear Scheduling Method
MAR	Material Approval Request
MCCS	Management of Cost and Control System
MoSCoW	Must, Should, Could, Would
MS	Milestone
PDCA	Plan-Do-Check-Act
PERT	Program Evaluation and Review Technique
PM	Project Manager
PMS	Process Modelling and Simulation
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
QCE	Quality Control Engineer
QM	Quality Manager
QRP	Quality Records Package
QS	Quantity Surveyor
RAMS	Risk Assessment (and) Method Statement
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013
S	Surveyor
SHE	Safety & Health and Environment
SLAs	Service Level Agreements
SM	Site Manager
SPI	Schedule Performance Index
SR	Stakeholder Requirement
SV	Schedule Variance
T	Task
UAV	Unmanned Aerial Vehicle
UC	Use Case
UDI	User-Driven Innovation
UI	User Interface
UR	User Requirement
VDA	Visual Data Acquisition
vQC	VisualQC
VR	Virtual Reality
W	Worker
WBS	Work Breakdown Structure
WIR	Works Inspection Record
WMS	Works Method Statement
WODM	Work Order Definition and Monitoring tool
WOEA	Work Order Execution Assistance tool
WP	Work package

1 Introduction

Building Information Modelling (BIM) is increasingly used in the Architecture, Engineering and Construction (AEC) industry to enable more integrated workflows and information exchanges for the design and construction of built environment assets. However, BIM has been principally thought out and developed with design as the main use case and the information modelling technology employed to represent building information models (BIM models) was developed with a view of the asset model being a product that emerges “slowly” from design and that is essentially *static*, in particular once design is completed.

Lean Construction theory – based on the lean production theory – aims to maximise the construction project value chain by enhancing the performance of the processes on that chain and reduce waste [1]. While BIM has been identified as an enabler of Lean Construction, the above-described “static” state of BIM models has been recognised to be inadequate to meet the lean production’s need for continuous monitoring of the state of the product and its generation process. This is particularly true for the construction and facility management (FM) phases of the product life cycle.

Digital Twinning (DT) is a concept that has first been explored in various industries like aerospace and manufacturing. While various definitions of DT exist, one definition of a DT model by the DT Hub (part of the Centre for Digital Built Britain (CDBB)¹) is: “A digital representation of a physical asset or the service delivered by it, used to make decisions that will affect the physical asset. Any change to the physical assets will be reflected in the digital twin” [2]. In contrast to a BIM model, this definition highlights the need for a DT model to be dynamic, evolving with and reflecting the state of the physical asset. It must, however, be highlighted that while this definition focus on DT models of an asset as a product, the DT concept equivalently applies to processes.

This project hypothesises that the DT concept can be effectively applied to the construction phase of capital facility projects and a DT model of the construction site and its process can help improve construction performance in terms of time and cost (and their predictability) as well as quality and safety.

As such, the COGITO project aims to develop such a DT model as well as services that both contribute and consume data/information from the DT model and deliver the stated benefits.

As presented in greater detail in the DoA, this COGITO Construction 4.0 Toolbox shall enable:

- i. Efficient and detailed scheduling of construction works with optimal resource allocation (human, material, equipment, etc.), and dynamic rescheduling to take account of variance between planned and actual progress (see next point) as well as unplanned issues.
- ii. Update of the BIM/DT model as the process evolves to mirror the as-built status through input from a multitude of reality capture tools.
- iii. On-the-field guidance to construction workers – through wearable device applications – and real-time asset monitoring for real-time safety management.
- iv. Systematic and (semi-)automated geometric tolerance compliance checking and visual defect detection with structured recording of quality control (QC) results in the DT model.
- v. Systematic planning and active monitoring of safety measures (e.g. collective protective equipment) on site.
- vi. Construction stakeholders to have live access, either offsite or onsite, to information about the state of the construction site with regard to work progress, quality and safety.

The COGITO project considers the construction phase embedded and a part of the construction project design and lifecycle thread, rather than in isolation. In that way, upstream information like the as designed model is employed as input. The as-built model evolves getting updated regularly (e.g. daily) as part of the construction progress to become the as-is model in post-construction and after handover and closeout. In that sense, in addition to the value brought to stakeholders from the various applications, it also conceptually and practically contributes to bridging the lifecycle interoperability gap. This is particularly important from an outcomes-based

¹ <https://www.cdbb.cam.ac.uk/>

perspective, as it does not only contribute to construction-level efficiencies and impact, but ultimately ensures high quality of the built asset, which is linked to increased value and lower risks for all stakeholders involved.

To deliver the envisioned Construction 4.0 Toolbox, COGITO employs a design, implementation and validation methodology that follows a User-Driven Innovation (UDI) approach [3] – also called user-centric innovation – comprising several steps. In this approach, the (main) stakeholders are collectively placed at the centre of all research, innovation, demonstration and communication activities. The UDI approach is realised through the *COGITO Living Lab* (WP9 “Dissemination, Exploitation & Standardization Activities”).

1.1 Scope and Objectives of the Deliverable

This deliverable has two main objectives:

- Elicit the COGITO Business Scenarios (BSs) and Use Cases (UCs) for the COGITO solutions, along with its Main Stakeholders²; and then
- Collect and rationalise the Stakeholder Requirements (SRs) from the identified main stakeholders for the COGITO overall solution and individual components that ensure that the UCs and BSs deliver best value.

The BSs, UCs, list of main stakeholders and the SRs altogether constitute key input to the development of the COGITO system architecture (T2.4, with deliverable D2.4), the implementation of the whole COGITO solution, and its validation.

A top-down methodological framework is principally adopted for the requirements elicitation process, although some bottom-up input is also employed in order for the technical and research partners to inform the industry partners about their visions regarding the COGITO components and ecosystem. This dual approach aims at ensuring that the high-level effort is conducted within the correct scope of work envisioned in the DoA by the individual technical and research partners.

This report presents both the methodology followed to obtain the BSs, UCs, list of main stakeholders and ultimately SRs and the results of the application of that methodology. In light of this, Section 2 summarises the construction life cycle activities focused on in the COGITO project and the innovations introduced by the COGITO project to enhance those, Section 3 then presents the methodology followed by the COGITO partners. Section 4 describes the identified BSs, UCs and Stakeholders. The section also contains a summary of all COGITO components to ease the understanding of the UCs. Section 5 presents the SRs (and other valuable input) obtained from the questionnaires and workshops. Finally, Section 6 concludes the document.

1.2 Relation to other Tasks and Deliverables

The documentation of the SRs is a key to the subsequent fulfilment of several project objectives, including the development of the COGITO system architecture, the implementation of the whole COGITO solution, and its validation. As a result, it can be argued that this deliverable underpins much of the work conducted across WP2 to WP8 (“Integration, Validation & Evaluation Activities”). Nonetheless, the work most directly impacted by this deliverable is the development of the COGITO system architecture in T2.4 (with deliverable D2.4), and the validation work conducted in Tasks T8.2 and T8.4 (with Deliverables D8.2 and D8.4).

² The UCs will be validated in the pilot sites.

2 Construction Life Cycle

Following the design phase (and often overlapping it), the construction phase of capital projects is the stage that involves the largest capital expenditure as well as exhibits the most significant risks. As a result of the many challenges faced during construction (continuously evolving weather conditions, delivery delays, human errors etc.), including those resulting from inadequate planning and monitoring, construction projects often fail. For example, it has been reported that in the 2012-2015 period only 25% of projects internationally came within 10% of their original deadlines, and only 31% of projects came within 10% of budget [4]. In addition, there is an on-going movement towards ever larger and more complex projects (culminating in “mega-projects”, particularly in infrastructure). But these projects present levels of performance even poorer than smaller ones, with reports of 98% of megaprojects facing cost overruns or delays, and with average cost increase of 80% [5]. The recently exposed delays and cost escalations of two of the largest projects in Europe, Crossrail³ and HS2⁴ in the UK, are symptomatic of this situation. Besides, despite some improvement in the last few decades, construction remains one of the most dangerous sectors. Indeed, in 2018 20% of all fatal accidents at work in the EU-27 were in the construction sector, while the sector only represents about 6% of the EU-27 GDP [6]. All this clearly illustrates that there is significant scope for improvement in the way projects are executed and monitored.

The construction industry often refers to its main areas of performance as: *time, cost, quality and safety*, now extended to include sustainability. To reflect the focus on these four main areas of performance, the industry has developed techniques for planning and monitoring each one specifically, such as the widely known Critical Path Method (CPM) and Gantt Charts for scheduling (i.e. *time*). In this section, these existing techniques and approaches are reviewed in the sub-sections 2.2 (time/cost), 2.4 (quality) and 2.5 (safety). Each of these sub-sections is finished with a presentation on what will be the contributions of COGITO to change, even transform those practices.

But before that, we first summarise the Plan-Do-Check-Act (PDCA) cycle that is at the heart of systems used by organisations for control and continuous improvement of their products or processes. In the construction sector, the PDCA cycle is explicitly or implicitly used to plan and control time/cost, quality and safety performance.

2.1 The Plan-Check-Do-Act Cycle

The Plan-Do-Check-Act (PDCA) cycle is an intuitive, but formal process to set, control and ultimately continuously improve products or processes. It is widely known because it is promoted in ISO 9001 [7], the well-established international standard on quality management. The four steps of the PDCA cycle are (see also):

- *Plan*: the objectives and activities or processes required to achieve those objectives are set.
- *Do*: the activities or processes are carried out.
- *Check*: the output of the activities and processes are analysed. This enables the identification of discrepancies between the expected/planned performance and the actual one.
- *Act (or Adjust)*: if the outcome of the *Check* step suggests sub-optimal performance (or lack of achievement of the objectives), root causes are searched, and the activities or processes are revised to eliminate those.

It is important to highlight that the PDCA cycle may be used as one single cycle to monitor performance and strive for organisational continuous improvement (i.e. learn lessons from one project to the next), but also as a repetitive cycle from continuous improvement while the activities or processes are carried out. In the construction context, and in particular the contexts of schedule/cost, quality and safety performance, both apply. For example, during a project, the schedule (including resource allocation) is set (*Plan*) and executed (*Do*).

³ <https://www.crossrail.co.uk/>

⁴ <https://www.hs2.org.uk/>

Progress is then monitored (*Check*) and deviations between planned and actual progress analysed to review the schedule – including review resource allocation and/or building method (*Act*).

The methods and techniques that constitute current practice with regard to schedule/cost, quality and safety are reviewed in sub-sections 2.2, 2.4 and 2.5, respectively. These methods and techniques have been developed to support one or more of the PDCA steps within their respective area.

2.2 Schedule

Scheduling

Effective scheduling and project execution according to that schedule is key to the success of a construction project. Scheduling entails: (1) the identification and definition of all activities that need to be conducted to deliver a project; (2) for each activity, estimating the expected duration of the activity from the selected construction method to be employed, and the type and level of resources to allocate to the execution of that method; (3) the definition of the sequencing of and dependencies between all those activities. Effective scheduling guarantees the completion of the construction project on time and within budget. Below, some aspects that motivate the scheduling effort are listed:

- Having a construction schedule allows companies to see if the schedules set by the client are achievable or not;
- Scheduling assigns dates to project tasks and activities, which is important to:
 - Set preliminary costs and prepare tenders;
 - understand the demand profile for materials, labour, and all other resources over time, enabling analysis and optimization (including avoiding over-allocations and bottlenecks);
 - coordinate contracting with sub-contractors, and with the supply chain more generally.
- It provides a baseline against which actual delivery can be compared. This helps the project management to realise and react to delays, but also apportion project delay liability caused by work strikes, owner change requests, and other unplanned events.

A good project schedule is one that is accurate and updated wherein communication on the project is prioritized and collaboration is ensured to support the successful completion of a project. In order to establish a correct schedule, it is important to bear in mind following key-aspects:

- Tasks that need to be carried out;
- Order in which these tasks need to be done;
- Dependencies between tasks;
- Duration of each task;
- Resources (material and manpower) required for each task;
- Project's milestones: during construction, these can include: concrete pouring, building is watertight, plumbing installation.

It is important to bear in mind that the method used depends on the construction project. Usually, bigger projects have a more defined and strict methodology that every stakeholder involved has to follow.

Construction project schedules can take various forms, including:

- **Table:** simply listing the activities, their start and end dates. This is the most basic representation and has the benefit that it can be created and exchanged in a spreadsheet.
- **(Linked) Gantt chart:** presenting the schedule in the form of a bar chart. A linked Gantt chart represents and enforces precedence relationships between activities, while a standard Gantt chart does not present the relationships. The (linked) Gantt chart is by far the most common form of presentation of construction schedules. There are numerous tools available to create Gantt charts, such as MS Project, Oracle Aconex, Procore and Oracle Primavera.

- **Linear Schedule diagram:** also known as the *Line-of-Balance* diagram, it is principally suited to model linear projects, such as many infrastructure projects (road, rail, pipeline, etc.), but it can in fact be used for all types of projects. While increasingly used and with benefits over the Gantt chart representation, its use remains marginal.

Regarding the methodology, the **Critical Path Method (CPM)** is commonly used to establish schedules that are represented in the form of (linked) Gantt charts (or tables). This widely used scheduling technique calculates the minimum completion time for a project along with the earliest and latest possible start and finish times for all project activities. It focuses on identifying the critical path, which represents the set or sequence of activities that must be completed on time to ensure the project is delivered on time. It is worth noting, though, that schedules obtained with the CPM take no consideration of resource demand over time, and so may often need to be altered to ensure smooth resource demand profiles.

The **Program Evaluation and Review Technique (PERT)** can be seen as a generalization of the CPM. While the CPM employs deterministic durations for the activities, PERT enables the user to work with probabilistic ranges of durations. This can be useful for scheduling projects with activities with significant duration uncertainty. As a result, it is more commonly used for (very) large projects scheduled at high level, e.g. channel tunnel duration estimations during planning.

The **Linear Scheduling Method (LSM)** is the method employed to produce Linear Scheduling diagrams. In contrast to the CPM, the LSM has a resource-focus with the goal to ensure smooth and continuous resource demand profile over time. While this means that this will not produce the fastest schedule, in practice LSM may produce more realistic ones.

Whatever the technique used, the challenge of developing good schedules lies in the complete identification of all activities -- which are typically organized in a *Work Breakdown Structure (WBS)* -- and estimation of the time required to deliver them given the selected method and anticipated conditions. For example, excavation works can take much more time during raining episodes compared to dry ones. For this reason, construction companies will typically maintain databases of past performances for different activities in order to support the work of planners/schedulers.

Schedule Monitoring

During project execution, the project management team (project manager, quantity surveyor, construction manager) will actively **monitor the actual progress** against the planned progress defined in the original schedule. This is done in various ways, such as by asking foremen and sub-contractors to frequently report progress of their activities (e.g. in the form of %) or by having quantity surveyors actively navigate sites to assess progress themselves. These assessments can at times be difficult to make visually and so should be considered approximate. In some cases, due to the difficulty faced, some specific sensing systems are used, such as total stations or even drone-mounted cameras and photogrammetry to measure excavation volumes. Besides, sub-contractors may often be tempted to over-estimate progress as this metric will be used to value work and define corresponding payments.

Another method that can be used to monitor progress is the Earned Value Analysis (EVA) which integrates time and cost monitoring and is thus presented in Section 2.3.

2.2.1 COGITO contributions

The COGITO project aims to improve scheduling before the project starts as well as schedule execution and monitoring.

Regarding scheduling, improvements will be made by developing efficient means to deliver detailed workflows from construction schedules (which are typically defined at high level), linking activities to building components (or temporary structures) and resources. A statistical data-driven workflow scheduling approach will be used, driven by past performance modulated by anticipated work conditions (e.g. weather) to enable the production of realistic durations and also the modelling of uncertainties (construction schedules are commonly produced deterministically and do not convey any knowledge of uncertainty).

Regarding schedule execution and monitoring, the above-generated detailed workflow model will be formally executed (and this execution secured and made transparent through the use of blockchain technology), ensuring all required activities are executed in the right order (including safety checks and quality control). For progress monitoring, COGITO will integrate app-based progress monitoring tool with fully-automated resource tracking – based monitoring technology. The latter will employ IoT sensors to principally monitor the location of resources to infer progress. The inferred progress will then be used to automatically revise the detailed workflow and inform all parties of any deviations.

The benefits of the above contributions are that projects will be planned and executed with much more detail. The continuous and automated monitoring shall ensure better information sharing between stakeholders and real-time reactivity to changes (e.g. work going faster or slower than planned). Besides, in the first place the data-driven scheduling approach shall enable the production of more realistic schedules (with statistical information) which shall reduce occurrences of slipping schedules. The benefits are thus principally in terms of time, and more specifically time predictability, with consequent benefits in terms of costs.

2.3 Cost

Project cost forecasting to establish a reliable budget (and bid value) is an essential project management function. And once the construction project is in its production phase, the management and control of costs and the identification of any variances from its originally planned levels is equally important, as cost performance is often the primary criteria by which project success or failure is evaluated.

Project management approaches to cost estimating, pricing and cost control are based on the theory of the Cost Management and Control System (CMCS) - aka Management of Cost and Control System (MCCS). Cost Management and Control is presented as a two-phase process, with a Planning/Budgeting phase and an Operating/Control phase.

Cost Planning / Budgeting:

The **Cost Planning / Budgeting** phase requires to first completely identify all activities required to be performed to complete the project, i.e. the establishment of the WBS as discussed in Section 2.2 about scheduling. Then, the analysis of each work package (activity) in the WBS enables the identification of the types of costs (e.g. labour, equipment, material, tools, etc.) to be incurred when delivering it given the selected construction method. Defining the level of costs is a challenging task because two seemingly similar activities may not be conducted in the same conditions, which can impact productivity, and therefore costs. Therefore, as discussed in Section 2.2 about scheduling, construction companies will typically maintain databases of past performances for different activities in order to support budgeting work. The estimated costs are then collected in cost packages organised in a Cost Breakdown Structure (CBS). The structure of the CBS is often defined by internal cost management policies. Figure 2.1 shows a simple example of CBS.

The project budget is simply the aggregation of the budgets defined for all cost packages. Within the budget, the total of any aggregating section must equal the sum of the totals of all the individual packages contained in that section.

One particular problem in forming a project budget in terms of cost accounts is the treatment of contingency amounts. Contingency amounts are allowances included in project cost estimates to accommodate risks resulting from unforeseen events for which the source of contingency expenses is not known. To account for contingencies, a dedicated budget cost package can be established to collect all of them. Different cost packages may also be created to distinguish different sources of contingency.

Once the CBS is established, each individual cost package is associated a corresponding Cost Account (CA) with a unique Cost Account Code (CAC) that is allocated the budget defined for the corresponding work package(s). CAs are essential to compare budget and actual cost during cost control (see sub-section below). In fact, to better support cost control, cost packages also include information on quantities and unit costs of relevant resources (labour, materials and equipment). With this information, actual resource usage, which is recorded during project

execution, can be compared to the planned usage, supporting the analysis of cost overruns or savings on particular cost accounts.

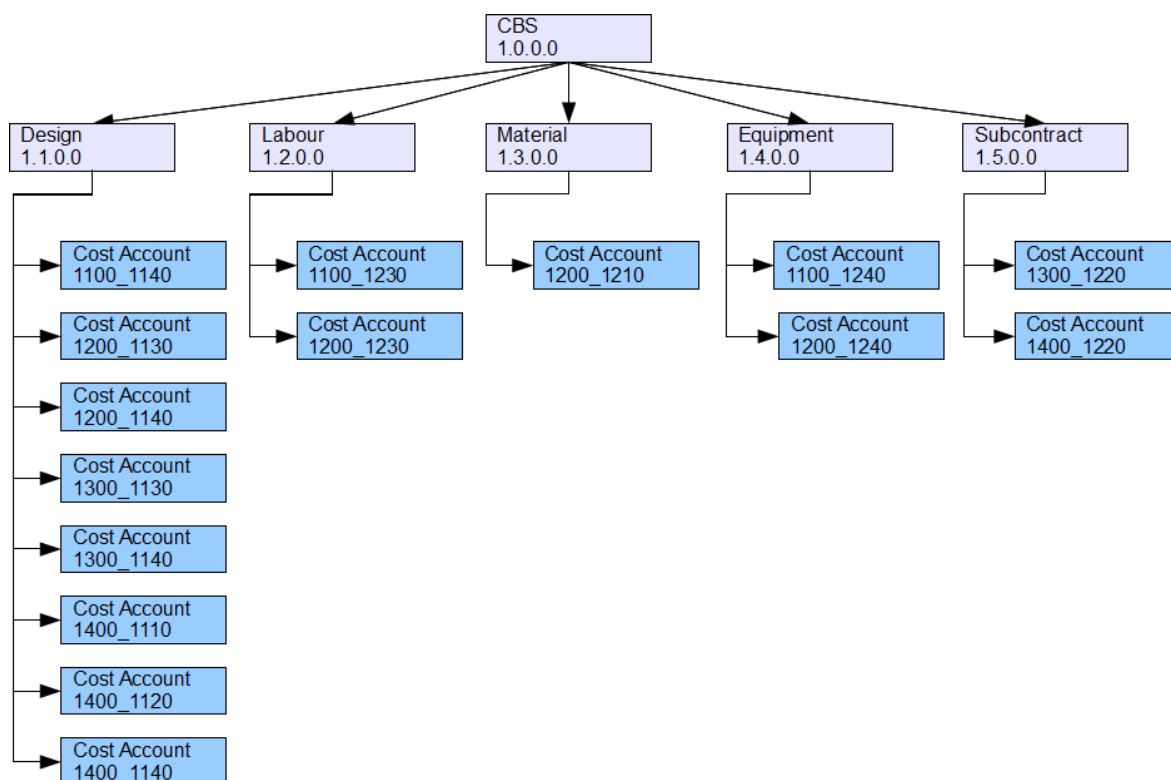


Figure 2.1: An Example CBS

The above discussion shows how budgeting is tightly linked to scheduling. Indeed, both rely on the identification of all necessary work packages, the methods and resource intensity selected to deliver them. Different methods or resource intensity will lead to different budgets and schedules. Even if resource intensity does not impact budget, it will impact the rate of expenditure and therefore cash (out)flow (cashflow is important subject because the sector is plagued by high levels of bankruptcy that are primarily the result of cash flow issues).

Operating / Control Phase:

The budget and cash flow profiles defined during the planning phase are used as baseline for the operational stage of the project.

During the execution of a project, procedures for project control and record keeping are indispensable tools to managers and other participants in the construction process. These tools serve the dual purpose of recording the financial transactions that occur as well as giving managers an indication of the progress and problems associated with a project.

As the project progresses, the project manager issues *Work Authorisations and Releases*, aka *Project Work Orders*. These set out specific details such as a work order number, work description, start and expected finish dates, individuals involved, specifications, requirements for contractual compliance, and the CAs to be charged for different types of costs.

During the execution of the work, costs incurred are collected for comparison against the planned costs and identification of any variance. *Cost accounting* is the formal/procedural stage that consists in recording all cost information in a standardized way so that costs can be tracked back as well as audited. The information has to

be complete and encompass all the cost centres relative to the site works and management, if they are to reflect the total cost to date on the construction project.

This information can then be used to produce Cost Account Variance (CAVAR) reports that aggregate all the collected data in a way that enables the project manager to assess the overall health of the project and identify where problems are occurring. CAVAR reports would normally show the variance performance of the project as a whole and then down to finer levels of detail according to the CBS. The CAVAR report would specifically identify CBS elements with negative variances. Negative variances would then be traced back until an origin point can be identified and tracked in subsequent CAVAR reports.

While cost is collected continuously and can thus be assessed as it is produced, the usual period for the formal accumulation of this data (along with other financial and accountancy data) is on a monthly basis, when specific reports are prepared for management (e.g. cost-value reconciliations) and the client (interim work valuations). Note that guidelines (and sometimes regulations) exist that define standard accounting approaches some of these accounting reports must conform to (e.g. SSAP⁵ in the UK).

Focusing on the control of incurred costs, it must be highlighted that the direct comparison of actual and planned costs is typically not meaningful because any variance can reflect differences between the planned and actual progress of the corresponding activity, and/or difference between the planned and actual resource costs. As mentioned earlier, collecting data on actual resource usage and its comparison to planned resource usage can help identify differences in this area, but this remains in fact insufficient because this does not account for schedule performance.

To support effective cost control, the **Earned Value Analysis (EVA)** method has been developed. The EVA is recommended by the APM⁶ and PMI⁷, as well as in ISO10006⁸ and BS6079⁹. EVA is a way of comparing actual with planned figures for cost by combining, within a single integrated framework, measurements of: technical performance (i.e. accomplishment of planned work), schedule performance (i.e. behind/ahead of schedule), and cost performance (i.e. under/over budget).

In practice, EVA evaluates project progress in an objective manner using three measures (see Figure 2.2):

- **Budgeted Cost of Work Scheduled (BCWS):** measures the work that is planned to be completed over time in terms of the budgeted cost. The BCWS curve can be plotted by accumulating the budget cost over the schedule showing planned percentages of completion.
- **Actual Cost of Work Performed (ACWP):** measures the work that has been accomplished to date in terms of the actual cost. The ACWP curve can be plotted by accumulating the actual expenditures over the schedule showing actual percentages of completion.
- **Budgeted Cost of Work Performed (BCWP), or Earned Value:** measures the work that has actually been accomplished to date in terms of the budgeted cost. The BCWP curve can be plotted by accumulating the budget cost over the schedule showing actual percentages of completion. This curve is key to the added value of EVA for project control.

The analysis of the BCWS, ACWP and BCWP then enables the calculation of performance indicators in terms of cost - Cost variance (CV) and corresponding Cost Performance Index (CPI) - and schedule - Schedule variance (SV) and corresponding Schedule Performance Index (SPI). Very importantly, the cost indicators are independent of schedule performance, and vice versa the schedule indicators are independent of cost performance. The above indicators not only provide information about performance to date, but can also be used to forecast ACWP and BCWP in order to show the potential impact of various management decisions.

⁵ <http://www.frc.org.uk/images/uploaded/documents/SSAP%2091.pdf>

⁶ <http://www.apm.org.uk/group/apm-earned-value-specific-interest-group>

⁷ <http://www.pmi.org/>

⁸ http://www.iso.org/iso/catalogue_detail?csnumber=36643

⁹ <http://www.itgovernance.co.uk/products/546>

CAVAR reports can naturally be produced when using the EVA, with cost and schedule performance analysed at a project level and down the CBS.

It is important to note that, for effective analysis of CAVAR reports, especially when employing the EVA, it is necessary that each Work package in the WBS be associated with its own Cost Packages/Accounts from the CBS. In other words, a CA must not be used to record costs from two different work packages, or it becomes impossible to distinguish their individual performance.

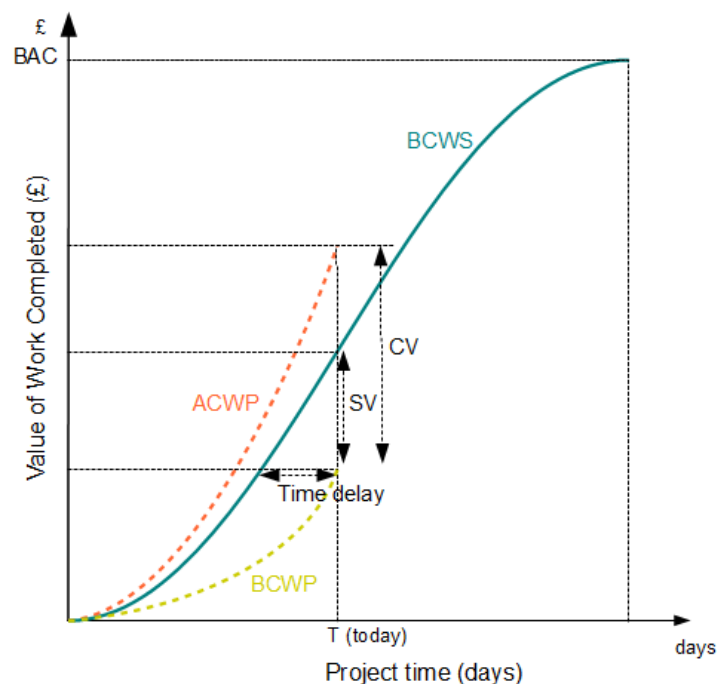


Figure 2.2: EVA analysis showing the BCWS, BCWP and ACWP curves

As discussed earlier, it is important to determine cost and payment (from the client) amounts over time to derive the cash flow profile. Any change in the programme (e.g. delays) can impact when those amounts occur and therefore the cash flow profile. It is thus important to keep track of those and review the cash flow profile, to be able to anticipate periods where cumulative costs are higher than cumulative income and ensure enough cash is available from the company to pass such periods.

2.3.1 COGITO contributions

The COGITO project aims to improve costs and cost predictability. These benefits will be the result of improvements in both project planning and execution, particularly scheduling and schedule monitoring.

During project planning, improvements in costs and cost predictability will be achieved through (semi-)automated detailed workflow modelling, automated planning of collective safety measures, and automated planning of quality control requirements. The cost savings will primarily result from reduced amounts and durations of human effort. Cost predictability will be the result of the enhanced schedule predictability resulting from the statistical data-driven workflow scheduling approach that will be driven by past performance modulated by anticipated work conditions (e.g. weather) to enable the production of realistic durations and also the modelling of uncertainties (construction schedules are commonly produced deterministically and do not convey any knowledge of uncertainty).

During project execution and monitoring, improvements in cost predictability will be achieved through the formal execution of the schedule/workflow, real-time workflow monitoring and continuous review of the remaining work. For progress monitoring, COGITO will integrate app-based progress monitoring tool with fully-automated resource tracking –based monitoring technology. The latter will employ IoT sensors to principally monitor the

location of resources to infer progress. The inferred progress will then be used to automatically revise the detailed workflow optimally and inform all parties of any observed delays (or work going faster than planned).

Therefore, the cost benefits of the above contributions are principally the result of the enhanced schedule and schedule predictability (as also discussed in Section 2.2.1).

2.4 Quality

Quality, as one of the main KPIs considered by the industry, is the focus of dedicated processes during construction projects. *Quality Assurance (QA)* is the term used to refer to the policies and procedures put in place by construction companies – and their clients – to ensure that projects are delivered with the expected quality. *Quality Control (QC)* corresponds to one part of that process. In this paragraph, we first introduce the typical QA process for a construction project, and then present the contributions that COGITO will deliver.

1. **Definition of quality specifications:** The Project Client, and more specifically their Project Manager and Quality Control Engineer (QCE) – or QC Manager, decide the type of quality specifications required for the said project. These specifications are then defined in the project's designs and/or in technical standards. Then, they define the documents required to be produced, which will include:
 - *Works Method Statement (WMS)*: Description of the method used for the execution of the works according to equipment specs, working conditions particularities and technical needs of the tasks;
 - *Material Approval Request (MAR)*: Request for approving the material to be used per scope;
 - *Inspection Test Schedule (ITS)*: Identification of the critical/not critical tasks to be inspected by authorities (project owner, independent body, etc.);
 - *Quality Records Package (QRP)*: Definition of the content of the quality documentation and quality monitoring documents to be delivered after the completion of the project.
2. **Appointing additional, including independent parties:** If extra measurements or tests are required, an appropriate third party (e.g. lab) is appointed. Similarly, if external control is required, an independent body is appointed.
3. **Quality documentation management:** Prior to the execution of works, the quality documents are submitted by the (sub)-contractor and reviewed.
4. **Quality Control:** The QCE ensures that the construction project is performed according to defined quality requirements and specifications chosen. This is done by performing audits and inspections, following at minimum the specific project ITS. If appointed, the independent body will also perform audits and inspections as necessary, following at minimum the specific ITS. The output of audits and inspections is a *Works Inspection Record (WIR)* that includes verifications that:
 - Correct materials are installed;
 - Correct methodology is applied (according to WMS);
 - Proper results are achieved within the defined tolerances.

Each task is verified in a different way. Geometric quality of the execution of works (in-situ construction or installation) is verified by a surveyor, who employs various survey tools (total stations, levels, etc.) to manually make all necessary measurements (and possibly has to conduct subsequent analysis of those results). Material quality is checked through lab tests (e.g. slump tests for concrete). Other checks are conducted visually (e.g. quality of concrete finish) and evidence for those is captured using pictures (now digital).

As the above discussion shows, QA/QC processes are based on the production of significant documentation that relates to each other. Technical specifications are produced during design and added to drawings or referenced to them. WMSs define the construction method required to meet the specifications. One WMS must be produced for each task. ITSs then define, for each WMS, the type of

control/checks that have to be performed. Finally, the WIRs are the records of the inspections/audits/controls presented in the ITS. WIRs directly refer to the ITS and the design specifications, and WIRs can contain various information: lab test, pictures, survey data, etc. At the end of the works of each project, the party responsible for the work officially submits all WIRs and other related relevant quality documentation to the Project Owner.

In practice, linking between the above documents is typically achieved through document ID referencing systems. For example, an ITS will refer to the document containing the relevant work specifications. While the documents now commonly exist in digital formats (e.g. PDF), linkages are typically not digital and it is left to the user to retrieve such documents, when needed. For example, if a project manager is informed that column “x” is out of plumb, it will take them some effort to collect information about which column it actually is, what the survey data are and review the original specifications defined for it. Navigating document versioning can also add to the challenge.

5. **Actions when deficiency is detected:** In case a deficiency is detected, the person who detects it (*QCE* or *independent body*) focuses on resolving the issue immediately on the field. In case it is not corrected immediately on the field, then they notify the *Project Manager* for further decision making. In case it is corrected immediately and it is not a major deficiency, then no further action is required. Three separate decisions about a defect may be made (on site or by the Project Manager):
 - a. Use as is: the defect is minimal and with no consequence;
 - b. Repair: make the product usable, but not in as good a condition as regular product;
 - c. (Scrap and) Re-work to meet specification: this will return the product to the same condition as a regularly produced first run product.

2.4.1 COGITO contributions

QA/QC processes involve lots of documents that need to be related. Besides, for QC, while increasingly efficient survey tools are becoming available to acquire visual and geometric data, the analysis of those data for the checking of specifications remains a human-intensive process. COGITO will contribute to improve performance in those aspects by:

- **Geometric QC:**
 - Digitalising standard geometric specifications so they can be explicitly linked to BIM model components;
 - Automatically matching points from geo/site-referenced laser scanned point clouds to BIM model components;
 - Automatically applying/checking the geometric specifications linked to BIM Model components given the point cloud data matched to those components;
 - Recording the geometric QC results in the DT model in a structured way, e.g. linking them to defined specifications and the corresponding design components. The QC result record in the DT model will effectively be a digital WIR where specifications, design components (ITS) and QC results are populated automatically and linked digitally. This will enable efficient retrieval and visualisation of WIRs and ultimately decision making (e.g. regarding reworks).
- **Visual QC:**
 - Manually and automatically linking visual data (picture) to BIM model components;
 - Automatically detecting common defects in visual data;
 - Recording the visual QC results in the DT platform in a structured way, e.g. linking them to corresponding design components. The QC result recorded in the DT model will effectively be a digital WIR where specifications, design components (ITS) and QC results are populated

automatically and linked digitally. This will enable efficient retrieval and visualisation of WIRs and ultimately decision making (e.g. regarding reworks).

The benefits of the above will mainly be in terms of time savings (and consequent cost savings) when implementing QA/QC processes, but also subsequently when information retrieval is needed (e.g. review by independent body/engineer or client, etc.).

2.5 Safety

Health and Safety (H&S), or more broadly Health, Safety and Environment (HSE)¹⁰, on the construction site is governed by specific regulations. For example, in the UK the regulations are called the *Construction (Design and Management) Regulations* [8]. H&S regulations include rules that cover areas, such as:

- Personal safety. The highest priority is given to this, and it is important to remember that personal safety covers both the safety of workers but also the general public;
- Handling of harmful substances: the handling of harmful substances is also described, with due reference and compliance with REACH [9];
- Protection of the environment: this includes protection against air pollution, noise, vibration, and protection of flora and fauna, surface and ground water, soil, etc.

The process of ensuring health, safety and minimal environmental impact starts by the client issuing a document summarising all information in their possession needed by the designer(s) and contractor(s) to plan and execute their work in an adequate way. For example, in the UK this document is called the **Pre-Construction Information** [10]. The Pre-Construction Information is a live document that evolves as the project progresses from pre-design to pre-construction to completion. It is used by the contractor to develop the **Construction Phase Plan** that should include [10]:

- A description of the project such as key dates and details of key members of the project team;
- The management of the work including:
 - The health and safety aims for the project;
 - The site rules;
 - Arrangements to ensure cooperation between project team members and coordination of their work, e.g. regular site meetings;
 - Arrangements for involving workers;
 - Welfare facilities;
 - Site order and security (e.g. site perimeter signalling, fencing);
 - Fire and emergency procedures (including important phone numbers, a site plan for rescue teams, assembly points, etc.);
 - Site induction provision (reviewing the Personal Protective Equipment (PPE) that must be worn on the construction site, the general procedures to be followed for safe work, review of emergency procedures, etc.);
- The continuous control of any of the specific site risks associated to certain specific works (e.g. underground works).

Other European countries will use their own national regulations (e.g. EKAS¹¹, SUVA¹² and VUV¹³ in Switzerland), with all EU national regulations required to be compliant to the minima set in the European Directives on Safety and Health at Work¹⁴. The establishment of the Construction Phase Plan document and the monitoring and

¹⁰ Sometimes also referred to as Safety & Health and Environment (SHE)

¹¹ Federal Coordination Commission for Occupational Safety <https://www.ekas.ch/>

¹² Swiss National Accident Insurance Fund <https://www.suva.ch/>

¹³ Ordinance on accident prevention

¹⁴ <https://osha.europa.eu/en/safety-and-health-legislation/european-directives>

enforcing of its execution is the task of the HSE Manager, who will be supported by other employees in the context of larger projects.

Following the publication of the Construction Phase Plan during the planning stage, work gets executed. Here, before each Work package gets started, a **Risk Assessment (and) Method Statement (RAMS)** document -- also called simply **Risk Assessment** -- needs to be prepared and reviewed by the employees delivering and overseeing the WP. The RAMS for each WP should¹⁵:

- Identify all *hazards* that could induce injury or illness to the workforce and/or the general public;
- Evaluate the *hazard risk*, that is the likelihood and severity of any injury or illness that could result from the hazard; and
- Take *mitigation actions* to eliminate the hazard, or if it is not possible, control the risk. This can be in the form of Collective Protective Equipment (CPE), Personal Protective Equipment (PPE) site rules, etc. Note that, whenever possible, construction hazard risks should also be “designing out” during the design phase. An example of CPE is fall protection systems. An example of PPE is a harness. An example of mitigation action by design is the selection of non-hazardous materials.

To ensure the health & safety plans and actions set in the Pre-Construction Information and RAMS are executed correctly and timely, the contractor and client will conduct **Safety Audits**. Conducted by the HSE inspector, these audits aim to identify negative (as well as positive) situations, including unsafe conditions, unsafe behaviour or inadequate management behaviour. Following the identification of any such issue, the HSE inspector will engage with the relevant employees, subcontractors and suppliers and agree corrective action to be conducted prior to resume any work.

Unfortunately, despite the systematic issue of RAMSs with their required mitigation actions and the subsequent site audits, accidents may still occur. In fact, the construction industry remains one of the most dangerous sectors of the European economy. It is a legal requirement in the EU, and essentially in all developed countries at least, to record and report details of specified work-related accidents resulting to fatalities, major and minor injuries as well as ill-health. In the UK this requirement is set in the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) [11].

2.5.1 COGITO contributions

Safety assurance processes involve lots of analysis and creation of documents produced manually, with little software support. Besides, while the industry has to report accidents, it captures little to no information regarding near-misses, despite their greater potential for improving safety practice. COGITO will contribute to improve performance in this area in three ways:

- **Safety Planning:** a software tool will be developed that automatically processes the design and planning 4D BIM model to identify hazards over the course of construction and plan necessary safety risk mitigation measures (e.g. Collective Protection Equipment (CPE)). The results will be recorded in the Digital Twin to ease review by HSE and Project Management personnel using a web-based DT visualisation solution. The tool will also generate an audit path through the site to guide the HSE Personnel to locations where those mitigation measures need to be checked for installation. An AR-based visualisation tool will enable the HSE Personnel to visualise on site exactly the location of the identified hazards and defined mitigating measures and make corresponding decisions (confirm conformity or request new work or rework).
- **Safety Monitoring:** a location sensing-based solution will be developed that monitors worker location and detects accident near-misses by monitoring whether they enter hazardous areas that should be avoided (e.g. close to operating equipment, or too close to holes in the ground). The outcome of the analysis would then feed back to the safety planning to ensure mitigating measures better facilitate safe behaviour.

¹⁵ <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>

- **Safety Training:** the outcome of the safety monitoring solution will also be used as input to a VR-based training system that will simulate hazardous environments similar to those observed in the near-miss situations and train workers to operate in them in a safe way.

The primary benefits of the above will mainly be in terms of reduced accidents and near misses and in cost savings to the conducting of safety assurance processes. Secondary benefits from more effective safety planning and monitoring will be reduced risks of project delays and increased operational costs resulting from accidents, and ultimately being an organisation being more attractive to the best workers.

3 Methodology

To ensure the envisioned Construction 4.0 Toolbox delivers value to industry, it was felt critical that the COGITO consortium utilise a design, implementation and validation methodology that follows a UDI approach [12]. In this concept, main stakeholders (principally identified users of the toolbox) are collectively placed at the centre of all research, innovation, demonstration and communication activities. The UDI approach is realised through the COGITO Living Lab (WP9) and thus contributed greatly from the Dissemination and Communication Manager.

Specifically with regard to the scope of this deliverable, industry input and feedback was sought throughout all the stages of defining the Use Cases (UCs) and Business Scenarios (BSs), identifying the relevant main stakeholders, and finally establishing Stakeholder Requirements (SRs) to be considered when determining the COGITO system architecture and ultimately when validating the COGITO solution. The Technical Manager managed the process closely, and the Scientific Manager and Project Coordinator oversaw the process and approved the relevant results.

This section details the process followed. In Section 3.1, we jointly discuss the intertwined processes of establishing the UCs and BSs as well as identifying the main stakeholder groups. Section 3.2 describes the approach followed to elicit Stakeholder Requirements from the main stakeholder groups.

3.1 Use Cases, Business Scenarios, and (Main) Stakeholders

Following the UDI approach described above, the development of the UCs and BSs, and identification of the stakeholders went as follows (see Figure 3.1):

1. The COGITO industry partners were asked to develop a list of typical stakeholders/roles involved in the delivery of construction projects.
2. The industry partners were also asked to review the construction industry digital twin use cases that were provided in the COGITO proposal and summarised in Figure 3.2, and comment on their perceived value and priorities.
3. The technical partners then defined an initial set of Business Scenarios (BSs) and Use Cases (UCs) taken into account the initial input from the industrial partners alongside their own proposed contributions set in the COGITO DoA. For the UCs, the partners were asked to use the template that can be found in Annex 1. The “Main Stakeholders” of those UCs were also distinguished in the process. The Main Stakeholders have been found to be principally those stakeholders that will be the users of the tools involved in each UC, the providers of data required by those tools, and the consumers of the information outputted by those tools. While a broader group of stakeholders could have easily been identified, we followed the view expressed in [12] that stakeholder requirements should principally come from those stakeholders that have “a right to influence the system”.
4. An iterative process followed with meetings and email exchanges between the technical partners and a review group composed of the industry partners, the Task Leaders, the Technical and Scientific Manager. At each iteration the technical partners presented the (revised) UCs and BSs, and the review group provided feedback. On average, three to five iterations have been necessary to reach agreement on the scope and clarity of the UCs and BSs.

The results of this process are reported in Section 4.

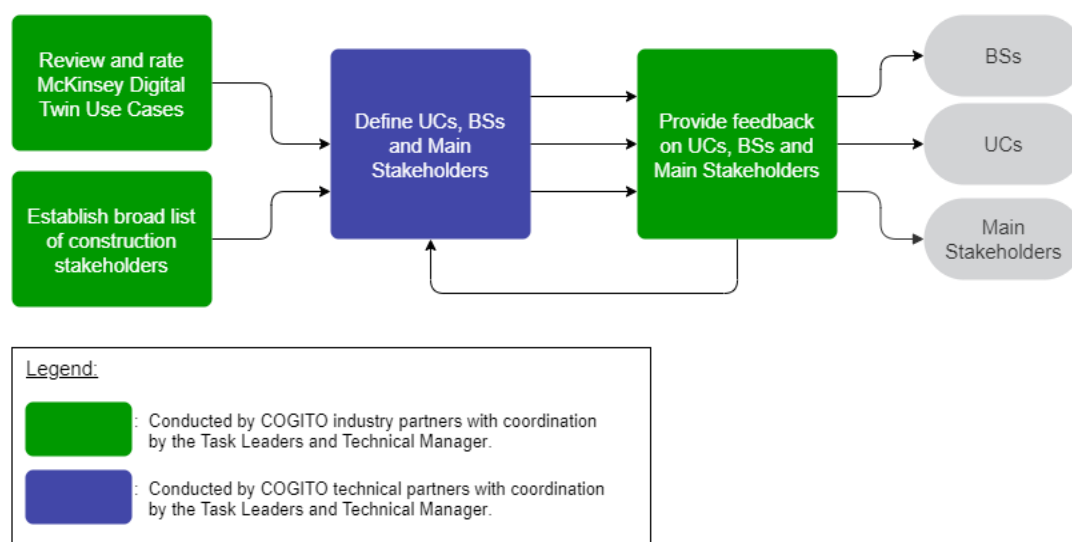


Figure 3.1: COGITO methodology to define UCs and BSs, and identifying the Main Stakeholders.

Design management	Scheduling	Materials management	Crew tracking
<ul style="list-style-type: none"> Visualize drawings and 3-D models on-site, using mobile platforms Update blueprints in the field with markups, annotations, and hyperlinks 	<ul style="list-style-type: none"> Create, assign, and prioritize tasks in real time Track progress online Immediately push work plan and schedule to all workers Issue mobile notifications to all subcontractors 	<ul style="list-style-type: none"> Identify, track, and locate materials, spools, and equipment across the entire supply chain, stores, and work front 	<ul style="list-style-type: none"> Provide real-time status updates on total crew deployed across work fronts, number of active working hours, entry into unauthorized areas, and so on
Quality control	Contract management	Performance management	Document management
<ul style="list-style-type: none"> Offer remote site inspection using pictures and tags shared through app Update and track live punch lists across projects to expedite project closure 	<ul style="list-style-type: none"> Update and track contract-compliance checklists Maintain standardized communication checklists Provide updated record of all client and contractor communications 	<ul style="list-style-type: none"> Monitor progress and performance across teams and work areas Provide automated dashboards created from field data Offer staffing updates and past reports generated on handheld devices 	<ul style="list-style-type: none"> Upload and distribute documents for reviewing, editing, and recording all decisions Allow universal project search across any phase

Figure 3.2: Use cases of digital twin in construction (source: [5]).

3.2 Stakeholder Requirements

Once the BSs and UCs were identified, Stakeholder Requirements (SRs) were gathered. The process of establishing the SRs, summarised in Figure 3.3, includes the following steps:

1. **SR Elicitation:** The most common requirements elicitation method directly involves the main stakeholders, which we broadly defined as the stakeholders with “a right to influence the system” and more specifically identified as the suppliers of information to the COGITO tools involved in the different UCs, the users of those tools, and the consumers of information outputted by those tools. The COGITO team then identified relevant professionals working within and outwith the industry partners through the COGITO Living Lab activities, and employed two methods to collect meaningful SRs from them:
 - a. **SR Workshops:** organised by the two main industrial partners gathering relevant main stakeholders from within their organisations. Note that the workshops were also used to collect additional feedback on the relevance and suitability of the UCs. The design and organisation of the workshops is detailed in Section 3.2.1.
 - b. **SR Questionnaires:** developed by the technical partners (with feedback from the industrial partners) and deployed to collect stakeholder requirements from relevant main stakeholders more broadly within the industrial partner organisations and more widely in industry. The setup and deployment of the questionnaires is detailed in Section 3.2.2.
2. **SR Consolidation and Prioritisation:** this step aims to consolidate and analyse all the information collected through the SR Workshops and Questionnaires, to define a final set of SRs alongside their prioritisation. The approach followed to achieve this step is detailed in Section 3.2.3.

The SRs and their prioritisation constitute important initial guidelines for the design and development of the COGITO solution, including its architecture that is developed as part of T2.4.

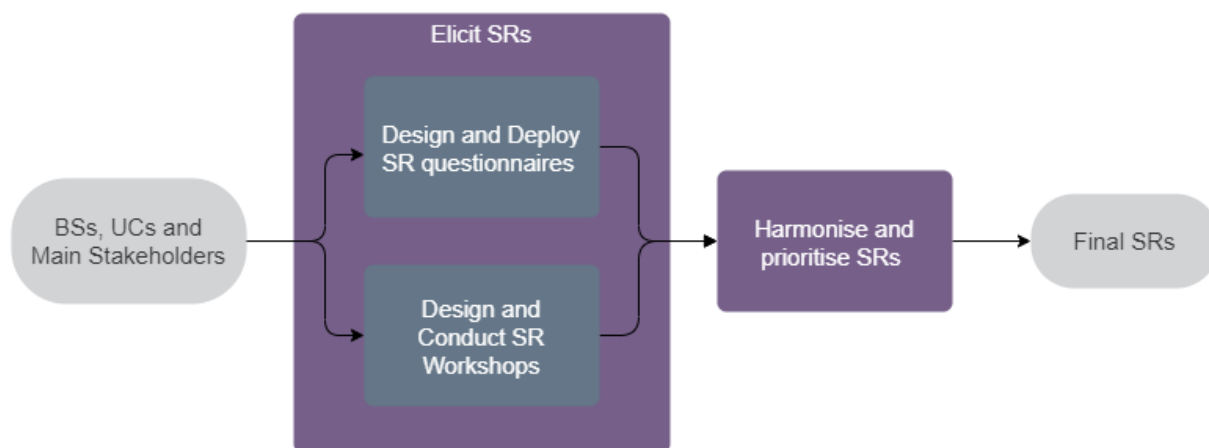


Figure 3.3: COGITO Methodology to elicit the Stakeholder Requirements (SRs) for the defined COGITO UCs.

3.2.1 SR Workshops

Two workshops were held as part of the Living labs and Work package 2 activities. The first workshop was organised on March 29th, 2021 by the industry partner Rhomberg Sersa Rail Group (RSRG) with the attendance of their construction staff and technical partners. The second one was held on April 14th, 2021 by the industry partner Ferrovial (FER) with the attendance of their construction staff and technical partners. Both workshops were also attended by construction staff of our industry partner Olympia Odos concession company (OLOD).

After a short introduction of the project, workshop goals and structure, attendants were divided into 3 working groups to facilitate fluent brainstorming and discussion. The groups were focused on Workflows and planning, Quality control and Health and safety, reflecting the three main areas of application, but also the three Business Scenarios focused on by the consortium about: Workflow, Quality and Safety (see Section 4.3).

The Canvas methodology was used to structure the SR Workshops, more specifically within the breakout groups. Based on the Opportunity Canvas¹⁶, our own canvases were created and populated with target-oriented questions. The developed canvas is shown in Figure 3.4.

The canvas is structured in a way to stress out the actual industry practice and leading to the target of DT-enabled and integrated practice (from left to right), and considering this with varying abstraction levels from the user towards the business perspective (top to bottom).

The exploration and filling of the canvas was conducted in two stages.

Stage 1 (Sections 1 to 4 in the canvas) – Reflection on current practice.

Each group reflected on their area of focus (quality, safety or workflow), identifying relevant stakeholders, and reviewing current practice and challenges faced, including from a business viewpoint. More specifically:

- In order to get the stakeholders with their needs in the first step, the customers and users are listed and discussed (Section 1 on the canvas). The questions for section 1 include:
What types of users and customers would use a digital real time twin? Look for differences in user's goals. Separate users and customers into different types based on those differences that make a difference. It's a bad idea to target "everyone".
- Then, the current challenges and problems faced by these stakeholders are listed and the current solutions and their limitations described (Sections 2 and 3). The questions for section 2 include:
What problems do prospective users and customers have today? What needs, goals, or jobs-to-be-done should a digital real time twin address?

The questions for section 3 including:

How do users address their problems today? List competitive products or work-around approaches your users have for meeting their needs.

- In order to present the current status holistically, the business challenges of these stakeholders are also examined (Section 4). The questions for section 4 include:
How do the customers 'and users' and their challenges above impact their business? If you don't solve these problems for your customers and users, will it hurt their business? How?

Stage 2 (Section 5 in the canvas) - Exploration of Digital Twin-based solutions

Having reflected on current practice, the three groups were then asked to propose how a Digital Twin-based approach could improve their practice, and in particular elevate the problems identified in Stage 1. The aim of this stage was to draw on the creativity of the attendees before biasing their views with the solutions actually proposed by COGITO. The expected outcome was that the groups would indeed converge towards similar ideas. The question for section 5 was:

List product, feature, or enhancement ideas that solve problems for your target audience.

Stage 3 (Section 6 to 9 in the canvas) - Reflection on and Requirements for the COGITO solutions.

Here, the COGITO Technical Manager first gave a presentation of the COGITO solution and the UCs targeted by it. For each UC, the Technical Manager explained how the different relevant COGITO components are envisaged to be used to enable it. Following this presentation, the three groups were asked to reflect on the presented COGITO solution and Use Cases, assess their potential value/priority and also define some requirements for their:

- Usability (section 6): the questions for section 6 include:

¹⁶ <https://miro.com/templates/opportunity-canvas/>

If your target audience has your solution, what will they do differently as a consequence? How will that benefit them?

- Adoption in practice (section 7). The question for section 7 was:

How will customer and users discover and adopt the solution?

In Section 8, the groups were also asked to identify metrics that could be considered to quantify the usability and adoption of the COGITO solution. The question for section 8 is:

What specific user behaviours can you measure that will indicate they try, adopt, use, and place value in the solution? What could be measurable KPIs?

Finally, the groups were asked to assess what would be the business impacts of the proposed solution and what KPIs could be considered to measure them. For this, the question for section 9 was:

What business performance metrics will be affected by the success of this solution? (these usually change as a consequence of users actually buying and using the solution).

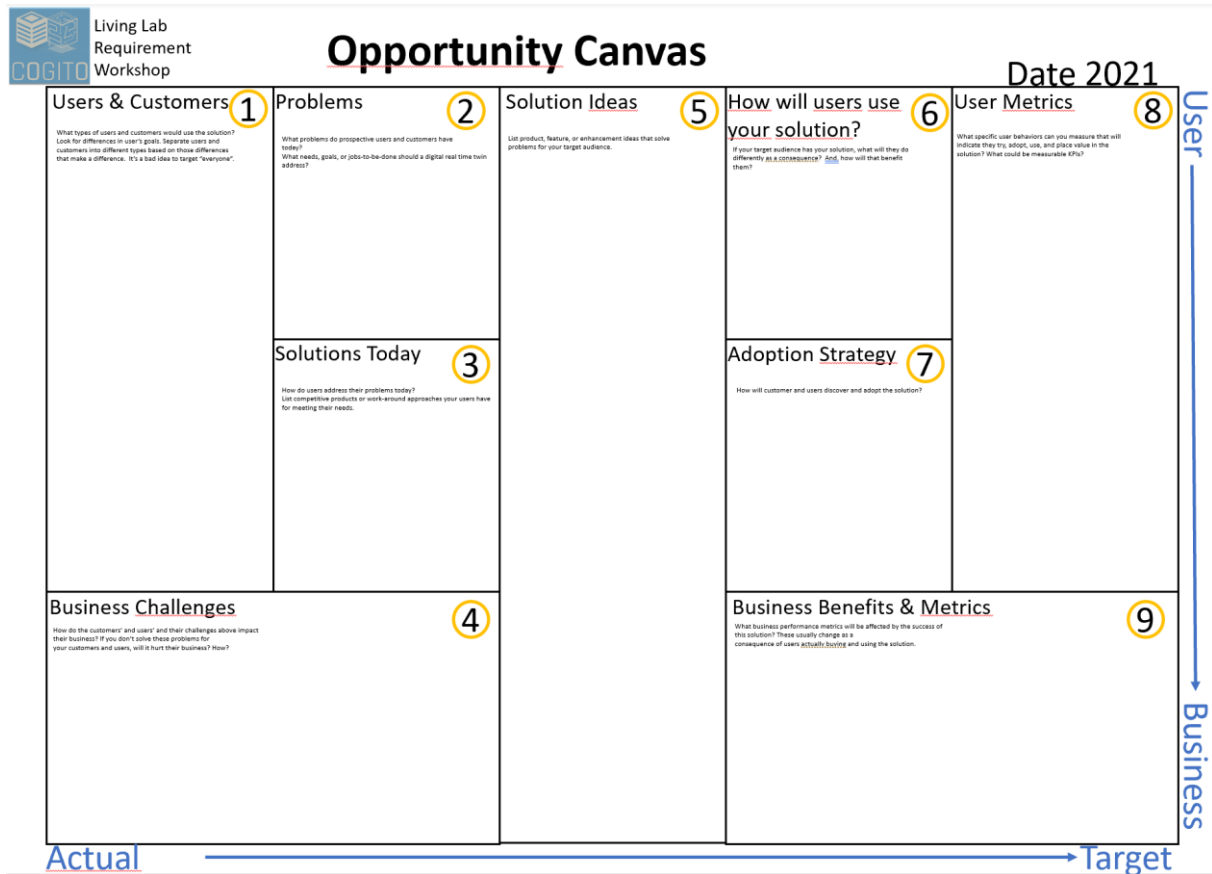


Figure 3.4: Canvas employed in the COGITO SR Workshops.

3.2.2 SR Questionnaires

The second approach employed to collect SRs from the main stakeholders is questionnaires.

The effectiveness of questionnaires depends significantly on the quality of the questions asked and their suitability to the engaged audience, the time required to answer, and the number of people answering the questions.

Figure 3.4 summarises the process followed by the production of the questionnaires and includes the following steps:

1. The technical partners of the tools or components employed in the UCs considered both the BSs and UCs to define questions that they would like to ask to each relevant main stakeholder regarding functionality and usability requirements they may have for that tool. For example, if a UC states that stakeholder A is to use a software tool S to process input data I and produce output data O that will be used by stakeholder B, the questionnaire to stakeholder A could include questions about the format of I and O, their preferred computing platforms on which S would need to be operable, and also their current process to produce O and communicate it to Stakeholder B and the KPIs they may be employed for those (the latter part being more specifically relevant to the work conducted in *T2.3 - Development of an Evaluation Methodology for the Impact of COGITO Tools*). To ease the initial effort of all technical partners in the production of the questions, the T2.1 Task Leaders developed an initial questionnaire for their GeometricQC tool and shared it as example to the other partners.
2. For each Main Stakeholder, the Task Leaders, Technical and Scientific Manager and Project Coordinator then gathered all the questions to that stakeholder, reviewed them, and provided feedback and suggestions for improving and harmonising them. For example, if two partners wanted to ask similar questions to the same main stakeholder, these were aligned and merged. Harmonising was also done when similar questions were asked to two or more stakeholders and so decisions were made to merge those questions into one and have all corresponding stakeholders answer that question. This resulted in a more streamlined integrated questionnaire where many questions would be answered by two or more main stakeholders, thereby enabling the team to collect more meaningful results. Due to their knowledge of construction, the Technical and Scientific Managers also looked at the relevance of the questions to the domain. The speed at which the surveys could be answered (and processed) was considered, with, for example, a number of initially open-ended questions subsequently transformed into closed-ended ones. Finally, many questions were rephrased in lay terms rather than technical language to ensure understanding by all participants.
3. Overall, this review process typically iterated a couple of times before the questionnaires were felt suitable for Step 3.
4. The Industrial Partners were asked to provide feedback to the questionnaires prepared for each Main Stakeholder. The feedback led to some new refinements. This process occurred only once.
5. The Task Leaders then finalised the preparation of the complete questionnaire, integrating the questionnaires for all Main Questionnaires into a web survey tool, and adding consent forms and a final stage for collecting some additional personal information, such as the size of the company the respondent works for, or their email if they wished to receive the COGITO Newsletter.

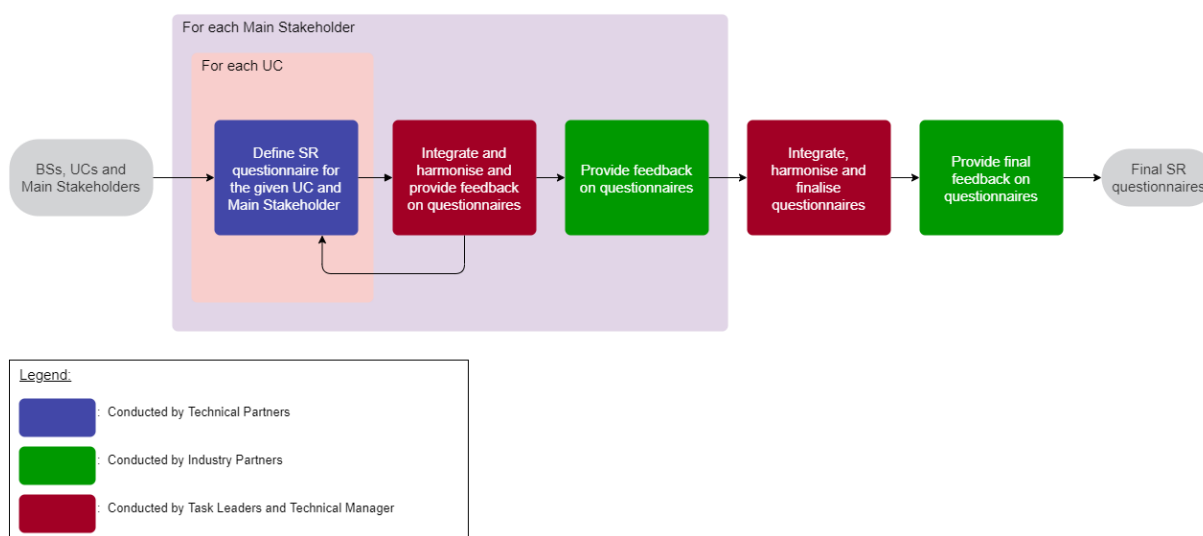


Figure 3.4: Methodology to prepare the SR Questionnaires.

The final, integrated Stakeholder Requirement Questionnaire was issued in two main ways:

- To relevant main stakeholders working in the industry partner organisations, including those who attended the SR Workshops (as their input from the workshop would have only partially covered all aspects present in the questionnaire).
- To relevant main stakeholders working in industry outwith the industry partner organisations. Reaching out to those stakeholders, the networks of all industrial and technical partners as well as sister projects to COGITO were employed by issuing calls for contribution on social media as well as through individual emails sent by the different partners to their networks.

The integrated questionnaire is presented later in Section 5.2.

3.2.3 SR Extraction, Consolidation and Prioritisation

The analysis of the questionnaire responses and workshop canvas was coordinated by the T2.1 Task Leaders but led by the technical partners leading each UC/BS with support from the other partners involved in those UCs/BSs. From the analysis of each of the relevant questionnaire and workshop questions, requirements were defined using the template shown in Annex 3. Each requirement is given a:

- ID;
- short description;
- originator: the Main Stakeholder group(s) from which the requirements arose;
- priority: see discussion below.

The work led to an initial long list of SRs. Their rapid analysis revealed that some of those could easily be taken into account and some others would be more difficult to consider, i.e. some SRs were regarded as likely more critical than others. As a result, with a view to balance the maximisation of the suitability of the COGITO solution to practical use and the time available during the project, a decision was made to consolidate (whenever possible) and prioritise the SRs.

To conduct the prioritisation, the MoSCoW prioritisation categories were used:

- **MUST:** The requirement is essential to achieve the goals of the project. For example, it impacts core aspects of the solution.
- **SHOULD:** The requirement is considered of high priority because it impacts some important functionalities, for example to maximise uptake/integration in practice.
- **COULD:** The requirement is considered just desirable as “nice to have”, but not particularly important feature.

- *WOULD*: The requirement is considered not important and meeting it could be postponed for future execution

To practically allocate the MoSCOW categories, the Technical Partners involved in each of the three areas (Workflow, Quality, and Safety) conducted initial categorisations. These were then reviewed by the Task Leaders, Technical and Scientific Manager and Project Coordinator who provided constructive feedback. The Technical Partners then took the final decisions as to the most appropriate categorisation for each SR.

4 COGITO Business Scenarios, Use Cases and Main Stakeholders

This section presents the BSs and UCs that will be the focus of the COGITO project. They were generated using the methodology described in Section 3. To ease the presentation of the BSs (Section 4.3) and UCs in particular (Section 4.4), this section first presents the COGITO Components that will form the COGITO solution and be developed during the project (Section 4.1) and the COGITO Main Stakeholders identified alongside the definition of the BSs and UCs (Section 4.2).

4.1 COGITO Components

Prior to presenting the defined BSs and UCs, we provide a list of the COGITO components (or tools) initially derived from the DoA and subsequently reviewed and refined while developing the UCs. This high-level review of the COGITO components shall facilitate the understanding of the UCs presented in the following section.

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,

Geometric Data Acquisition (GDA) Tools	<p>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</p> <p>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.</p>
Visual Data Acquisition (VDA) Tools	<p>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.</p>
Location Data Acquisition (LDA) Tools	<p>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.</p>

4.2 COGITO Main Stakeholders

Prior to presenting the defined BSs and UCs, we also provide a list of the Main Stakeholders identified during the elicitation process described in Section 3.1.

As summarised in Figure 3.1, the list of Main Stakeholder was derived in two steps. First, the industrial partners identified a broad list of stakeholders they felt were possibly relevant based on their knowledge of the COGITO project. Involving the industry partners at that stage was important since they have a detailed knowledge of all the stakeholders of construction projects in general. This initial broad list of stakeholders included stakeholders ranging from the architects to BIM modellers, project manager, and all construction workers. Then, as the UCs (and BSs) were developed and refined, the initial list was narrowed to include those stakeholders that are directly identified in the UCs, i.e. directly involved in the processes described in UCs.

Table 2 lists the 10 Main Stakeholders identified as result of this process. For each Main Stakeholder, the table provides a description of the role of that stakeholder in construction projects and also lists in which UC that stakeholder is involved (see Section 4.4).

Table 2 – The Main Stakeholders identified in COGITO UCs.

COGITO user/role	Description	UCs
Project Manager (PM)	The Project Manager is the person who monitors and controls all the aspects of the project and makes sure that the involved people achieve the objectives on time and cost, performance, and quality. The project manager is also the person who coordinates the design team, ensuring that the project can be effectively executed with the appropriate information and understanding.	1.1 1.2 4.1 4.2
Site Manager (SM)	The Site Manager (also called Construction Manager or General Foreman) is the person who oversees site operations on a day-to-day basis, and ensures that work is done safely, on time, within budget	1.1 1.2 4.1 4.2

	and to the right quality standards. Site Managers have in-depth knowledge of construction methods.	
Quantity Surveyor (QS)	The Quantity Surveyor works closely and helps the Project Managers to deliver the project on time, within scope, and budget. The Quantity Surveyor provides guidelines, estimates, and forecast of labour, material, and overhead costs, oversees the monitoring of progress on site and consequent estimation of the value of work completed, which supports the PM in the management of contracts.	1.2
Foreman (F)	The Foreman is in charge of a group of workers forming a construction crew. The Foreman is usually a senior worker.	1.2 3.3
Worker (W)	A construction Worker is a tradesperson, labourer, or professional employed in the physical construction of the building or infrastructure asset.	1.2 3.3
Quality Manager (QM)	The Quality Manager is the person in charge of planning for the collection and review the QC reports verifying if each element of the project complies with the standards and regulations, and is safe and does not present any risk to the project. The QM may also go on site and conduct inspections, and through such process collect additional data (e.g. photographs). The QM has to work closely with other members of the team, such as Project Manager, Engineers, Surveyors	2.1 2.2 4.1 4.2
Surveyor (S)	The Surveyor is the person in charge of acquiring the data from surveys of sites using tools like total stations, levels, laser scanners, or cameras. The surveyors will also likely conduct the computations required from the data to infer whether works is conducted according to specifications, as well as compile the QC reports. The surveyor works closely with the Quality Manager.	2.1 2.2
HSE Manager (HSEM)	The HSE Manager is the person in charge of the compliance of all health and safety legislations. HSE Manager also assists with the creation and management of health and safety monitoring systems and policies in the workplace. HSE Manager works with HSE Trainer to improve the health and safety standards in the workplace.	3.1 3.2 4.1 4.2
HSE Supervisor (HSES)	HSE Supervisor is responsible of monitoring health and safety risks at the workplace and advising employees on how to avoid them. HSE Supervisor also manages emergency procedures (such as fire alarm drills).	3.1 3.2
HSE Trainer (HSET)	HSE Trainer is in charge of training the employees of the construction site to improve the health and safety standards in the workplace and the fulfilment of the health and safety regulations.	3.3

It is interesting to note that none of these stakeholders include BIM-related professionals, like BIM Managers and Coordinators (see list of BIM roles in Table 3). The reason is that these roles were not found to be directly involved in the delivery of the defined UCs. Nonetheless, it must be acknowledged that important input to the COGITO solution (e.g. 4D BIM model including material, and possibly cost information) is the output of BIM processes overseen and coordinated by BIM Managers and Coordinators, and the envisioned COGITO Digital Twin platform will build on (and extend) BIM data models. Therefore, while these are not considered as Main Stakeholders of the COGITO solution, their involvement was still considered important and they were invited to provide feedback to the UCs and join the SR Workshops.

Table 3 – BIM Roles in construction projects.

COGITO user/role	Description
BIM Project Coordinator/Manager	The BIM Project Coordinator (or Manager) leads and coordinates the process of generating the project digital information (models and other data). They ensure/coordinate communication of digital (BIM) information and consistency among project participants that produce and exchange the information.
BIM Coordinator	The BIM Coordinator leads and coordinates the process of generating the project digital information (models and other data) within the project participant organisation. Note that the BIM Coordinator and BIM Manager can be (and often are) the same person.
BIM Manager	The BIM Manager is usually someone who oversees the implementation of Building Information Modelling (BIM) within an organisation. They develop and monitor BIM processes (i.e. quality assurance). For the project, they also serve as the main point of contact to agree and resolve information exchange between participants and ensuring that submissions by their organisations meet the BEP requirements. They work closely with the BIM Coordinator of their organisation, and interact with the BIM managers of other participants as well as the BIM Project Coordinator/Manager. Note that the BIM Coordinator and BIM Manager can be (and often are) the same person.

4.3 COGITO Business Scenarios

Following the process described in Section 3.1, **3 Business Scenarios (BSs)** were generated alongside the UCs supporting them. The BSs are:

- **BS1:** Construction company improves schedule (and cost) predictability through effective workflow modelling and resource tracking.
- **BS2:** Construction company conducts (visual and geometric) Quality Control of executed works more systematically and efficiently.
- **BS3:** Construction company reduces accidents through continuous monitoring and effective communication of hazards, as well as contextualised training.

The three BSs are in the areas of Schedule/Cost, Quality and Safety respectively, which are the main areas of contribution and impact that were focussed on in the COGITO project DoA.

The UCs are presented in Section 0. The relationship between the BSs and UCs is thus presented subsequently in Section 4.5.

4.4 Use Cases Description

This section presents the detailed descriptions of the COGITO Use Cases. Each UC table identifies the Main Stakeholders and COGITO components involved in its execution, the pre-condition of the UC, the UC path describing how the Stakeholders use the components (or the component work automatically) to complete the UC, and the post-condition of the UC. Each table finally lists the partners involved in the delivery of the UC and the prioritisation that was given by the industry partners to each UC during the SR Workshops.

For **BS1**, the justifications for the priorities are as follows:

- **UC-1.1 Workflow Planning: *Medium-High priority*.** Workflow planning was of medium to high importance for the participants, because of the potential to bring order and detail in the project

planning as well as better understanding of what is to be done during construction. They were, however, aware of the fact, that it depends on input quality delivered by pre-project activities (e.g., architectural design and contracts preparation).

- **UC-1.2 Workflow Execution and Monitoring: High priority.** Workflow monitoring have been the most important use case to the participants, because without monitoring there cannot be a control over the project's current state, thus causing management difficulties.
- **UC-4.1 Digital Command Centre: High priority.** Participants expressed their bad current experience with a lot of information gathered from different sources and document versions using different applications. They have recognised the value of the proposed component, which can provide them with all information needed using 3D visualisation of the BIM. It could be a possible game changer in their daily routine, saving them time.
- **UC-4.2 In-situ DT visualisation: Low priority.** The proposed tool was mainly seen as an interesting step forward, but compared to other project management related use cases, a bit too far away from the current state on construction sites and less urgent. This analysis contributed to the decision of the COGITO team not to include UC-4.2 into BS1.

For **BS2**, the justifications for the priorities are as follows:

- **UC-2.1 Geometric QC: Medium-High priority.** Geometric QC was of high importance for the participants, because of the potential time saving and information integration delivered. However, it was noted that uptake may prove challenging due to the more significant disruption to practice this entails, for example in comparison to UC 2.2.
- **UC-2.2 Visual QC: High priority.** Despite the fact they showed some concerns about the effectivity of the automated visual defect detection, they thought that it is easy to adopt and use in a realistic scenario.
- **UC-4.1 Digital Command Centre: High priority.** This component can save a lot of time to different stakeholders who need to retrieve and analysis QC-related information.
- **UC-4.2 In-situ DT visualisation: Medium priority.** The tool concept was well received but the technological implications make it more complicated to be easily adopted. However, it has the advantage that it would constitute an excellent interface for acquiring images processed by the visualQC tool, and visualising the results in real-time.

For **BS3**, the justifications for the priorities are as follows:

- **UC-3.1 Safety Planning: Medium-High priority.** The participants underlined the limitations in current practice of safety planning and hazard identification which leads to high risk and increased overall costs. SafeConAI will facilitate hazard identification and safety planning for HSE personnel in construction.
- **UC-3.2 Real-time Safety Monitoring: High priority.** The participants showed interest in monitoring and proactive alarming of potential safety risks from the perspective of safety managers.
- **UC-3.3: Safety-augmented Digital Twin for safety training: Medium-High priority.** The participants highlighted the significance of safety training in creating a safety culture in their organisations and hence, VirtualSafety tool was of high importance because it will allow for safety training in virtual environment and personalised feedback.
- **UC-4.1 Digital Command Centre: Medium priority.** This component was not highly prioritised because, while it certainly will support Management (e.g. PM and HSEM) in getting overviews of safety information, it has a less direct impact on safety as UC3.1 to UC3.3.
- **UC-4.2 In-site DT visualisation: Low priority.** This component was discussed positively but was not highly prioritised. For example, the participants mentioned the availability of updated safety information on-site with the use of new technologies (e.g., on-site 'BIM kiosks') as an additional feature.

4.4.1 UC-1.1: Efficient and Detailed project workflow planning using the project's construction schedule and as-planned BIM model

UC ID	UC-1.1
Use Case Name	Efficient and Detailed project workflow planning using the project's construction schedule and as-planned BIM model
Related Business Scenarios	BS-1: Construction company improves schedule (and cost) predictability through effective workflow modelling and resource tracking
Description	A detailed workflow of the construction project is derived from the 4D BIM model that links tasks, resources and asset components, and task durations are derived using a data-driven approach. The workflow is secured using blockchain technology.
Involved Main Stakeholders	Project Manager (PM) Site Manager (SM)
COGITO components involved	Work Order Definition and Monitoring tool (WODM); Process Modelling and Simulation tool (PMS); Digital Twin Platform (DTP); BlockChain network SLAs Manager (BC-SLAM); BlockChain network Smart Contracts (BC-SC).
Pre-conditions	Construction drawings; specifications; as-planned BIM model and schedule are fully defined (4D BIM).
Use Case Path	<p>1) For each activity defined in the construction schedule (4D BIM) located in the Digital twin platform (DTP), the PM/SM defines appropriate workflows using predefined workflow templates in the Process modelling and simulation tool (PMS).</p> <p>2) Particular building design component information (e.g. location, material quantity) extracted from the 4D BIM are associated (automatically or by the PM/SM) to respective workflow activities using PMS.</p> <p>3) The PM/SM prepares and runs simulations using the PMS to identify optimal initial detailed project workflow according to historical data.</p> <p>4) The PMS sends the optimal workflow chosen by the PM/SM in form of a Process Model output to the Work order definition and monitoring tool (WODM).</p> <p>5) For each task required in the chosen initial workflow, the SM defines Work Orders, particular work instructions and assigns resources (people, equipment) and a responsible person (Foreman/Worker) using the WODM.</p> <p>6) The SM connects already designed SLAs and KPIs provided by the BlockChain network SLAs manager (BC-SLAM) to respective Work Orders, and defines stakeholder(s) responsible for the SLAs' fulfilment. The SLA is then saved in the BC-SLAM.</p> <p>7) Based on the detailed Work Orders the Blockchain network smart contracts (BC-SC) is automatically instantiated, taking into account the SLAs, KPIs, participating actors and involved stakeholders of the particular task or tasks, and creates a decentralized network.</p>
Post Condition	Initial detailed project workflow, work orders and blockchain network are defined.
Business Impact	Thorough planning using COGITO tools allows detailed orchestration and monitoring of the project execution

Realisation Description	
Leading Partner	NT
Contributing Partners	BOC, QUE, UEDIN, UCL, UPM
Priority	Medium-High

4.4.2 UC-1.2: Systematic and secure execution, monitoring and updating of the project workflow

UC ID	UC-1.2
Use Case Name	Systematic and secure execution, monitoring and updating of the project workflow
Related Business Scenario(s)	BS-1: Construction company improves schedule (and cost) predictability through effective workflow modelling and resource tracking
Description	Project is executed according to the planned workflow (see UC-1.1), as well as continuously monitored and updated.
Involved Main Stakeholders	Project Manager (PM) Site Manager (SM) Quantity Surveyor (QS)/Foreman (F)/Worker (W)
COGITO components involved	Work Order Definition and Monitoring tool (WODM); Work Order Execution Assistance tool (WOEA); Digital Twin Platform (DTP); Process Modelling and Simulation tool (PMS); Blockchain Smart Contracts (BC-SC); Location Data Acquisition Tool (LDA).
Pre-conditions	Initial detailed project workflow; Work orders and blockchain network are defined.
Use Case Path	<ol style="list-style-type: none"> 1) The Foreman/Worker is notified through the Work Order Execution Assistance tool (WOEA) about tasks they have to accomplish. <ol style="list-style-type: none"> 1.1) If connection to particular building design component is available, Worker/Foreman can display appropriate information using the WOEA. 2) Worker executes (Foreman oversees execution of) assigned work orders. 3) Progress data is collected in two ways: <ol style="list-style-type: none"> 3.1) The Location data acquisition tool (LDA) monitors resources (material, workers, and equipment) and updates the Digital twin platform (DTP) with the monitoring data. 3.2) QS/Foreman/Worker reports work progress using the WOEA to the WODM (this is much lower frequency and may only include input on work completion). 4) The resource monitoring data and progress input from the Foreman/Worker are then used jointly by the PMS to estimate progress and update the workflow model. Once the simulation model has been developed and calibrated using real data, it is used to optimise processes and workflows in the PMS (in the next step and in the UC-1.1). 5) The workflow model is then transmitted by the PMS in form of a Process Model output to the WODM that updates the Work Orders (required/expected start and finish of tasks that have not started yet) accordingly. 6) The WODM updates the digital twin model (in the DTP) as well as the Blockchain smart contracts (BC-SC) accordingly. <ol style="list-style-type: none"> 6.1) Taking into account that Actors (PM, SM, Foreman/Worker) and Tasks are aspects (Peer Nodes) of a BC-SC, during the assigned task execution these tasks are updated accordingly in order to ensure their proper delivery considering also the automated verification upon the Service Level Agreements (SLAs) of the

	<p>project and particular task. Performance of the Smart contract is exposed to the SM by the WODM through the BC-SC.</p> <p>6.2) SM and PM are notified of work completion/status by the WODM.</p> <p>7) If relevant to the particular work order, the WODM may invoke quality control and/or safety processes (UC-2.1+UC-2.2, and UC-3.1 respectively).</p>
Post Condition	Project is executed according to the planned schedule (UC-1.1_WF-Planning) and is continuously monitored and updated.
Business Impact	Continuous monitoring and feedback of actual project execution status facilitates stakeholders to be properly informed and projects to be successfully managed
Realisation Description	
Leading Partner	NT
Contributing Partners	UCL, UPM, QUE, BOC, UEDIN
Priority	High

4.4.3 UC-2.1: Automated geometric tolerance compliance checking in 3D point cloud data and allocation to DT building component

UC ID	UC-2.1
Use Case Name	Automated geometric tolerance compliance checking in 3D point cloud data and allocation to DT building component
Related Business Scenario(s)	BS-2 - Construction companies conduct (visual and geometric) Quality Control of executed works more systematically and efficiently
Description	Acquire accurate geometric data and check geometric tolerance specifications automatically by matching that data to the BIM model and apply standard tolerance control methods.
Involved Main Stakeholders	Quality Manager (QM); Surveyor (S); Project Manager (PM); Site Manager (SM).
COGITO components involved	Geometric Data Acquisition Tools; GeometricQC Tool (gQC); DT Platform (DTP); Work Order Definition and Monitoring tool (WODM).
Pre-conditions	(4D) As-planned BIM model in the DT Platform; Tolerance specification standards; Scan-vs-BIM algorithm for matching points to BIM objects.
Use Case Path	<p>1) The GeometricQC tool (semi-)automatically allocates each relevant specification and control method to the corresponding components in the BIM model (which is part of the DT model).</p> <p>2) The Work Order Definition and Monitoring tool (WODM) notifies the Surveyor about which elements have been built and are ready to be scanned for geometric control.</p> <p>3) The Surveyor acquires laser scanned point cloud data of the site (especially the components under construction), ensuring the data is geo-referenced and loads it to the DT platform.</p> <p>4) The DT Platform (DTP) informs the GeometricQC Tool (gQC) that point cloud data are available to be analysed. The GeometricQC Tool (gQC) then associates the cloud points to the BIM components (concrete or steel).</p> <p>5) Given these point-component associations, the GeometricQC Tool (gQC) automatically applies the relevant specification control method to assess whether the components are executed within the corresponding geometric tolerance specification.</p> <p>6) The outcome is recorded in the DT Platform (DTP) by the GeometricQC Tool (gQC).</p> <p>7) The Work Order Definition and Monitoring tool (WODM) is notified by the GeometricQC Tool (gQC) of the completion of the task.</p> <p>8) The PM/SM/QM are notified by the Work Order Definition and Monitoring tool (WODM) of the QC outputs.</p>
Post Condition	Geometric tolerances have been checked and are stored in the DT Platform, generating the necessary alerts to the involved stakeholders.

Business Impact	Systematic and automated control and structured recording of geometric execution tolerances (defined using industry standards).
Realisation Description	
Leading Partner	UEDIN
Contributing Partners	UCL, UPM, NT
Priority	Medium-High

4.4.4 UC-2.2: (Semi-)Automated detection of construction defects from visual input captured using AR and drones

UC ID	UC-2.2
Use Case Name	(Semi-)Automated detection of construction defects from visual input captured using AR and drones
Related Business Scenario(s)	BS-2 - Construction companies conduct (visual and geometric) Quality Control of executed works more systematically and efficiently
Description	Capture visual data from the site, automatically detect regions of risk in infrastructure (i.e. concrete defects, cracks, material displacements) and estimate their severity.
Involved Main Stakeholders	Quality Manager (QM); Surveyor (S); Project Manager (PM); Site Manager (SM);
COGITO components involved	Visual Data Acquisition Tools with means for localising the data; VisualQC Tool (vQC); DT Platform (DTP); Work Order Definition and Monitoring tool (WODM).
Pre-conditions	Deep Learning Image Processing Algorithm for defect detection; (4D) As-planned BIM/DT model
Use Case Path	<p>1) The Work Order Definition and Monitoring tool (WODM) notifies the Surveyor/QM about a completed work that needs to be quality controlled.</p> <p>2) The Surveyor/QM captures on-site visual data through mobile device, AR HMDs, multimodal UAV-mounted cameras, or other image sources. The data and metadata (that allow linking this information to the existing BIM components) is uploaded into the DT Platform.</p> <p>3) The DT Platform informs the VisualQC Tool that visual data are available to be analysed. The VisualQC Tool gets the data and automatically detects defects (i.e. concrete defects such as cracks) and estimates their severity.</p> <p>4) The outcome is recorded in the DT model by the VisualQC Tool and the DT Platform notifies Work Order Definition and Monitoring tool (WODM) of the completion of the task.</p> <p>5) The PM/SM are informed by the Work Order Definition and Monitoring tool (WODM) about the detected defects and mitigating work requirements.</p>
Post Condition	Defective regions are systematically recorded, stored in the DT Platform, and communicated to the site management for prompt decision.
Business Impact	Systematic and automated monitoring of and structured (semantic) recording of defects
Realisation Description	
Leading Partner	CERTH
Contributing Partners	UCL, UPM

Priority	High
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4.4.5 UC-3.1: BIM-based safety planning and hazard prevention before construction starts

UC ID	UC-3.1
Use Case Name	BIM-based safety planning and hazard prevention before construction starts
Related Business Scenario(s)	BS-3: Construction companies reduce accidents through continuous monitoring and effective communication of hazards, as well as contextualised training
Description	Given a 4D BIM, the SafeConAI tool (a) identifies regions where specific hazards are, (b) suggests mitigation measures that are added to the BIM/DT model. Definitions for hazards and mitigation measures are taken from official standards (e.g. BG Bau).
Involved Main Stakeholders	HSE Manager / HSE Supervisor
COGITO components involved	DT Platform (DTP); SafeConAI (with 3D user interface);
Pre-conditions	BIM Model + Construction Schedule are provided by the design and planning team; Internal/External HSE best practices, rules and regulations; HSE communication/information exchange protocols/standards;
Use Case Path	<ol style="list-style-type: none"> 1) The HSE Manager/Supervisor inputs/selects the formalised safety code rules into the SafeConAI. 2) SafeConAI fetches 4D BIM model from DT Platform. 3) For each time step in the given 4D BIM: <ol style="list-style-type: none"> 3.1) SafeConAI automatically generates spatial artefacts enabling the detection of hazardous areas. 3.2) Given the hazard spatial artefacts, SafeConAI generates "hazard region" objects. 3.3) Given the "hazard region" objects, SafeConAI generates mitigation strategies for each hazard object. 3.4) SafeConAI generates a report (from a template) on the safety spatial artefacts, hazards, and mitigation measures, including a section of justifications and resource allocation. 3.5) SafeConAI also generates an "audit path" for a HSE Manager/Supervisor to tour the construction site and visualize the safety information (hazards and mitigating measures) in situ using AR technology (see UC-4.2). 4) SafeConAI submits all the results (spatial artefacts, hazard regions, mitigation strategies and report) to the DT Platform. 5) Using the SafeConAI user interface, the HSEM is able to navigate the 4D DT/BIM model augmented with the generated safety information.
Post Condition	4D BIM/DT model augmented with: <ul style="list-style-type: none"> • 3D regions representing the spatial artefact (e.g. visibility spaces, range spaces, functional spaces, operational spaces). • 3D regions representing hazards alongside all relevant information (e.g. hazard types, traceability information back to corresponding BG Bau safety code). • 3D regions representing mitigation strategies applied to each hazard region (again with relevant information) • An audit path to efficiently control the above regions on site.

	These are generated in accordance with internal/external HSE best practices, rules and regulations
Business Impact	Safety hazards are identified and mitigated in a proactive manner to minimize safety risks
Realisation Description	
Leading Partner	AU
Contributing Partners	UCL
Priority	Medium-High

4.4.6 UC-3.2: Monitoring, reporting, and proactive alarming of safety risks on outdoor construction sites

UC ID	UC-3.2
Use Case Name	Monitoring, reporting, and proactive alarming of safety risks on outdoor construction sites
Related Business Scenario(s)	BS-3: Construction companies reduce accidents through continuous monitoring and effective communication of hazards, as well as contextualised training
Description	This Use Case is about utilizing location data of resources (equipment and personnel) on the construction site to avoid collision close-calls and accidents (def. as contact collisions that could lead to injuries and fatalities), and collateral damage (def. as damage to machinery or temporary facilities or materials/as-built structures).
Involved Main Stakeholders	HSE Manager (HSEM) / HSE Supervisor; Worker.
COGITO components involved	DT Platform (DTP); ProActiveSafety.
Pre-conditions	4D (as-built) BIM/DT model augmented with safety risk and mitigation information stored in the DT platform (produced through UC3.1); Location tracking solution for involved resources (personnel, machines); Rules and regulations.
Use Case Path	<p>1) ProActiveSafety processes the location tracking data from the individual resources to estimate and predict their trajectories.</p> <p>2) ProActiveSafety processes the trajectories for proactively estimating potential collisions (e.g. based on equipment proximity restriction zones), falls (e.g. based on hazard proximity zones), etc.</p> <p>3) For each anticipated risk, ProActiveSafety sends an alarm to the corresponding Workers.</p> <p>4) ProActiveSafety calculates statistics on all estimated near-accidents to update the safety parameters/rules employed in UC3.1.</p> <ul style="list-style-type: none"> Changes to the construction site layout will be suggested that impact future behavior of workers and equipment. Simulations predict potential future hazardous zones and measures. The impact of changes to the construction site layout is assessed. <p>5) ProActiveSafety informs HSE Manager of outputs.</p>
Post Condition	Construction equipment and Workers are monitored in run-time and collision or fall accidents avoided. Safety measures are parameterised based on continuously captured location/close-call data.
Business Impact	Accidents related to collisions with equipment or other hazards are prevented, thereby improving safety records, and thereby improving project schedule and cost predictability.
Realisation Description	
Leading Partner	AU

Contributing Partners	UCL
Priority	High

4.4.7 UC-3.3: Safety-augmented Digital Twin is used for construction safety training

UC ID	UC-3.3
Use Case Name	Safety-augmented Digital Twin is used for construction safety training
Related Business Scenario(s)	BS-3: Construction companies reduce accidents through continuous monitoring and effective communication of hazards, as well as contextualised training
Description	This use case demonstrates how safety data collected in the DT platform from the UC3.1, UC3.2 and UC3.3 can be used to create personalised construction safety education and training.
Involved Main Stakeholders	HSE Trainer; Foreman/Worker
COGITO components involved	DT Platform (DTP); VirtualSafety.
Pre-conditions	Safety rules and regulations; DT model augmented with all safety-related information (including worker trajectory information).
Use Case Path	<ol style="list-style-type: none"> 1) VirtualSafety component retrieves the safety-augmented 4D model and other safety data stored in the DT Platform that was outputted by SafeConAI through UC-3.1 and UC-3.2. 2) VirtualSafety component generates a (serious) game. 3) Foreman/Worker plays the training game under the supervision of the Safety Trainer. 4) VirtualSafety-based training is complemented with additional input through questionnaires and interviews. 5) Given the personalised feedback based on performance in VirtualSafety, the HSE Trainer tracks/benchmarks the performance of the employee and even overall organisation over time.
Post Condition	Worker is trained on specific subjects relevant to their activities with the aim to reduce accidents and even close-calls.
Business Impact	Safety awareness is improved, contributing to the reduction of accidents (and even close-calls) on site, with schedule and cost benefits.
Realisation Description	
Leading Partner	AU
Contributing Partners	UCL, UPM
Priority	Medium-High

4.4.8 UC-4.1: Remote visualisation of DT model information (Data Acquisition, Workflow, Safety, Quality) using the Digital Command Centre (DCC)

UC ID	UC-4.1
Use Case Name	Remote visualisation of DT model information (Data Acquisition, Workflow, Safety, Quality) using the Digital Command Centre (DCC)
Related Business Scenario(s)	BS-1: Construction company improves schedule (and cost) predictability through effective workflow modelling and resource tracking BS-2: Construction companies conduct (visual and geometric) Quality Control of executed works more systematically and efficiently BS-3: Construction companies reduce accidents through continuous monitoring and effective communication of hazards, as well as contextualised training
Description	DCC is the DT Platform's viewer that renders the 3D BIM model, IoT data and annotations generated by the QC, HSE and Workflow tools in different layers.
Involved Main Stakeholders	Project Manager (PM); Site Manager (SM); HSE Manager (HSEM); Quality Manager (QM).
COGITO components involved	Digital Twin Platform (DTP); Digital Command Centre (DCC).
Pre-conditions	As-planned (e.g., BIM model, BPMN) and as-built (e.g., IoT data, images and QC, H&S and Workflow tools' annotation) data are compliant to the COGITO data models and are available through the Digital Twin Platform's endpoints; A Unity library with the required helper functions is available.
Use Case Path	1) The PM/SM/HSEM/QM signs-in to the DCC application (e.g., WebGL) and selects the project for which he/she would like to monitor the status. 2) Relevant information is being queried from the Digital Twin Platform and different layers of information are being generated. 3) The user can navigate the rendered 3D BIM model. They can also activate the layers (domains) of DT information for display and analysis. 4) Having activated one of the relevant layers, the user can click on specific elements of the 3D BIM model or IoT devices represented by nodes, the PM can view the progress on these elements' construction, reported defects or geometric deviations, HSE issues or workers/heavy machinery tracking data, along with associated data.
Post Condition	The DCC is a solution for the PMs to visualise/navigate the DT data, but not edit it.
Business Impact	The DCC provides a cross-platform flexibility to the PM. The PM is able to access, view and present the overall status of a construction project through the web without installing any application to his/her device(s).
Realisation Description	

Leading Partner	Hypertech
Contributing Partners	UCL
Priority	High, with breakdown: <ul style="list-style-type: none">• BS1 (Workflow): High;• BS2 (Quality): High;• BS3 (Safety): Medium.

4.4.9 UC-4.2: On-site visualisation of QC and Safety Planning information using AR/mobile device

UC ID	UC-4.2
Use Case Name	On-site visualisation of QC and Safety Planning information using AR/mobile device
Related Business Scenario(s)	BS-2: Construction company conducts (visual and geometric) Quality Control of executed works more systematically and efficiently BS-3: Construction companies reduce accidents through continuous monitoring and effective communication of hazards, as well as contextualised training
Description	<p>During the construction phase, visualise on site:</p> <ul style="list-style-type: none"> • QC information (regions of risk where construction defects have been detected through the GeometricQC and VisualQC Tools) in order to help effectively define the required remedy activities. • Safety information (planned regions of hazards or hazard mitigation measures) in order to check hazard mitigation measures have been implemented and report missing ones.
Involved Main Stakeholders	Project Manager (PM); Site Manager (SM); HSE Manager (HSEM); Quality Manager (QM).
COGITO components involved	DT Platform (DTP) (with Data Model); Digital Twin visualisation with AR (DigiTAR) tool (Mobile/Wearable AR Solution); Work Order Definition and Monitoring tool (WODM).
Pre-conditions	(Means for localisation of AR goggles on site); VisualQC, GeometricQC or SafeConAI have been performed and the QC, respectively Safety, information is stored in the DT (see UC-2.1, UC-2.1 and UC-3.1)
Use Case Path	<p>1) In the QC context:</p> <p>1.1) The PM/SM/QM walks on site with the DigiTAR with the visualisation mode set to “QC”, in which case the QC information is loaded up from the DT Platform (DTP).</p> <p>1.2) the user can then look at defects in situ and (if necessary) confirm them and organise remedial works.</p> <p>1.3) Defect confirmation and any defect remedial task are recorded in the DT Platform (DTP) by the DigiTAR Tool.</p> <p>1.4) The Work Order Definition and Monitoring tool (WODM) that adds the remedial task to the overall workflow and adjusts the project workflow/schedule accordingly (see UC-1.2).</p> <p>1.5) The Work Order Definition and Monitoring tool (WODM) is notified by the DigiTAR of the completion of the QC control task.</p> <p>2) In the Safety context:</p> <p>2.1) The PM/SM/HSEM walks on site with the DigiTAR with the visualisation mode set to “Safety”, in which case the safety information is loaded up from the DT Platform (DTP).</p> <p>2.1) the user can then confirm (hazards) and hazard mitigation features have been implemented as planned, and (if necessary) organise any hazard mitigation work.</p>

	<p>2.2) Control confirmation and any addition hazard mitigation work required are recorded in the DT Platform (DTP) by the DigiTAR Tool.</p> <p>2.3) The Work Order Definition and Monitoring tool (WODM) that adds the hazard mitigation task to the overall workflow and adjusts the project workflow/schedule accordingly (see UC-1.2).</p> <p>2.4) The Work Order Definition and Monitoring tool (WODM) is notified by the DigiTAR of the completion of the safety control task.</p>
Post Condition	<p>PM/SM/QM can systematically view and contextualise defect records, and if necessary, organise remedial works.</p> <p>PM/SM/HSEM can systematically view and contextualise anticipated hazards and planned hazard mitigation measures, confirm them, and if necessary, organise remedial works.</p>
Business Impact	<p>Effective communication of QC information and planning of required remedial works.</p> <p>Effective communication of Safety information and planning of required remedial works.</p>
Realisation Description	
Leading Partner	CERTH
Contributing Partners	UCL, UPM, NT, (UEDIN, AU)
Priority	<p>Medium-Low, with breakdown:</p> <ul style="list-style-type: none"> • BS1 (Workflow): Low; • BS2 (Quality): Medium; • BS3 (Safety): Low.

4.5 Summary

Table 4 and Figure 4.1 present the association between the BSs and UCs. While these associations are quite straightforward to understand, short explanations are provided below.

For BS1, UC-1.1 will take the as-planned 4D BIM model (i.e. 3D BIM model and construction schedule), and the list of resources that can be allocated to the delivery of the project as input. It then supports the semi-automated generation of detailed workflows where each task (or work order) is linked to specific components in the design and specific resources allocated to complete that task. Each task is linked to others through precedence relationships and given a start and end date. UC-1.2 then executes the workflow generated in UC-1.1 and monitors it continuously through the processing of IoT data capturing resource location on site in particular. UC-4.1 enables the construction and management teams to visualise workflow execution and progress remotely and access all related data to support effective decision making. Once again, at this stage of the project and following discussions with the industry partners (including during the workshops), it was felt the UC-4.2 may not bring significant value to BS-1 and was thus left out of it. This decision may be revisited as the project progresses.

For BS2, UC-2.1 and UC-2.2 are independent from one another. UC-2.1 is about automating the processing of geometric QC data to control compliance to geometric tolerance specifications. UC-2.2 supports the analysis of digital pictures acquired on site to detect and monitor defects. In both cases, the QC results are stored and semantically linked to the corresponding building components in the DT. UC-4.1 and UC-4.2 then enables the quality and management teams to visualise the QC results remotely as well as on site (overlaid to the completed works) and access all related data to support effective decision making.

For BS3, UC3.1, 3.2 and 3.3 are fairly independent from one another. UC-3.1 enables the automated detection of safety hazards and generation of corresponding mitigation measures (e.g. collective protective equipment) given the input as-planned 4D model. The safety planning data are saved in the DT, and UC-4.1 and UC-4.2 then enable the review of those planned solutions and their effective implementation on site. UC-3.2 monitors the location of workers and equipment and aims to detect safety near-misses by detecting when they enter hazardous areas. UC-4.1 will enable the HSE and management teams to visualise those detections to make effective and prompt decisions (e.g. re-emphasize the corresponding risks to workers, improve training (see UC-3.3 afterwards) or update rules for the planning/modelling of mitigation measures). Finally, UC-3.3 uses VR serious game environments replicating dangerous situations identified in UC-3.2 and therefore ensure training is informed and driven by real observations of behaviour on site.

Table 4. The association of the UCs to the BSs.

BS-1:	Construction company improves schedule (and cost) predictability through effective workflow modelling and execution monitoring
UC-1.1	Efficient and Detailed project workflow planning using the project's construction schedule and as-planned BIM model
UC-1.2	Systematic and secure execution, monitoring and updating of the project workflow
UC-4.1	Remote visualisation of DT model information (Workflow, Safety, Quality) using the Digital Command Centre (DCC)
BS-2:	Construction company conducts (visual and geometric) Quality Control of executed works more systematically and efficiently
UC-2.1	Automated geometric tolerance compliance checking in 3D point cloud data and allocation to DT building component
UC-2.2	(Semi-)Automated detection of construction defects from visual input captured using AR and drones

UC-4.1	Remote visualisation of DT model information (Workflow, Safety, Quality) using the Digital Command Centre (DCC)
UC-4.2	On-site visualisation and annotation of DT model information (Safety, Quality) using AR
BS-3: Construction companies reduce accidents through continuous monitoring and effective communication of hazards, as well as contextualised training	
UC-3.1	BIM-based safety planning and hazard prevention before construction starts
UC-3.2	Monitoring, reporting, and proactive alarming of safety risks on outdoor construction sites
UC-3.3	Safety-augmented Digital Twin is used for construction safety training
UC-4.1	Remote visualisation of DT model information (Workflow, Safety, Quality) using the Digital Command Centre (DCC)
UC-4.2	On-site visualisation and annotation of DT model information (Safety, Quality) using AR

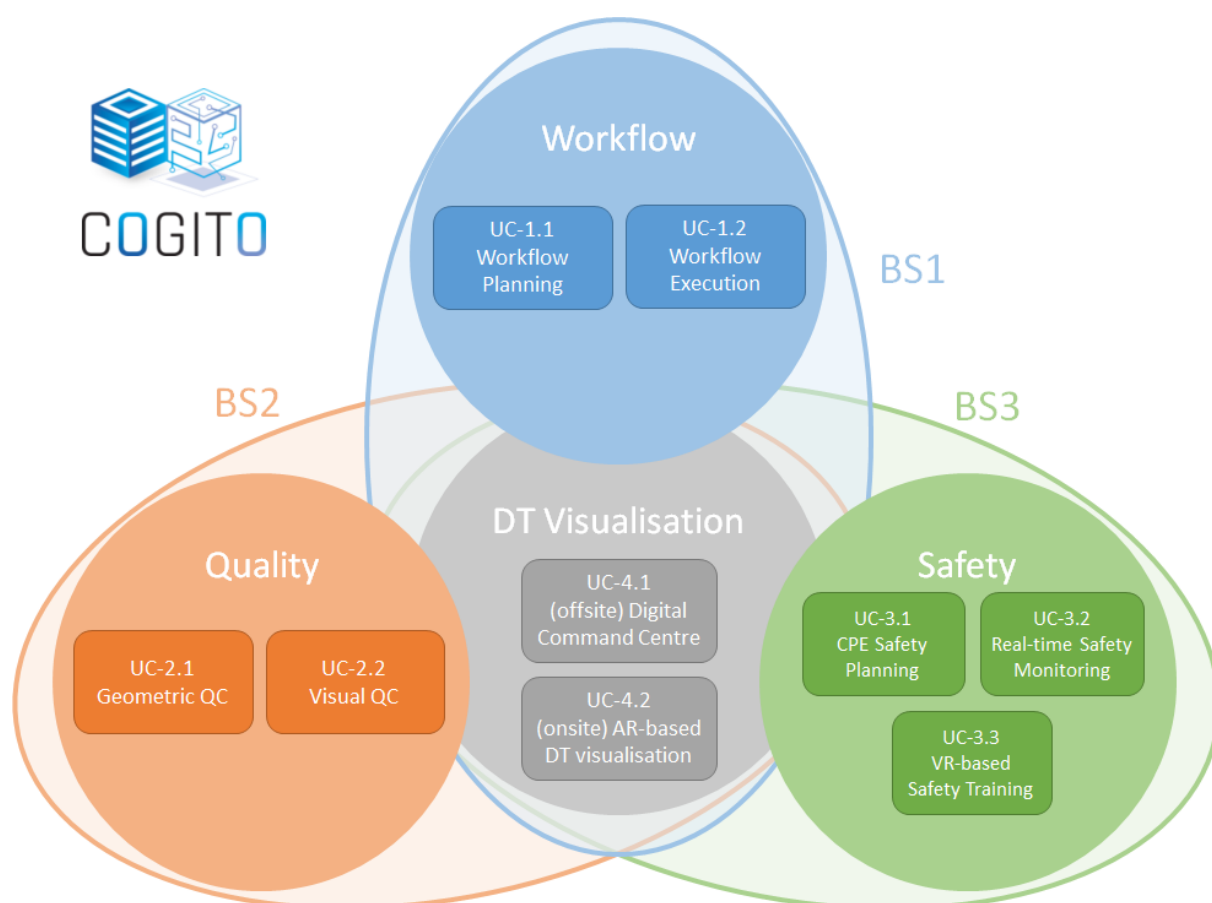


Figure 4.1: Visualisation representation of the Use Cases and Business Scenarios.

Table 5 lists for each BS:

- The UCs involved in its delivery along with the priority associated to each UC (see Section 4.4);

- The Main Stakeholders involved in each UC (see Section 4.2);
- The COGITO Components employed in each UC (see Section 4.1).

Table 5 - Overview table for each COGITO BS.

BS	UC [priority]	Main Stakeholders involved	COGITO Components involved
BS-1	UC-1.1 [Medium-High]	<ul style="list-style-type: none"> • Project Manager; • Site Manager. 	<ul style="list-style-type: none"> • Work Order Definition and Monitoring tool (WODM); • Process Modelling and Simulation tool (PMS); • Digital Twin Platform (DTP); • BlockChain network SLAs Manager (BC-SLAM); • BlockChain network Smart Contracts (BC-SC).
	UC-1.2 [High]	<ul style="list-style-type: none"> • Project Manager; • Site Manager; • Quantity Surveyor / Foreman / Worker. 	<ul style="list-style-type: none"> • Work Order Definition and Monitoring tool (WODM); • Work Order Execution Assistance tool (WOEA); • Digital Twin Platform (DTP); • Process Modelling and Simulation tool (PMS); • BlockChain Smart Contracts (BC-SC); • Location Data Acquisition Tool (LDA).
	UC-4.1 [High]	<ul style="list-style-type: none"> • Project Manager; • Site Manager. 	<ul style="list-style-type: none"> • Digital Twin Platform (DTP) • Digital Command Centre (DCC)
	UC-2.1 [Medium-High]	<ul style="list-style-type: none"> • Quality Manager; • Surveyor; • Project Manager; • Site Manager 	<ul style="list-style-type: none"> • Geometric Data Acquisition Tools; • GeometricQC Tool (gQC); • DT Platform (DTP); • Work Order Definition and Monitoring tool (WODM).
	UC-2.2 [High]	<ul style="list-style-type: none"> • Quality Manager; • Surveyor; • Project Manager; • Site Manager 	<ul style="list-style-type: none"> • Visual Data Acquisition Tools; • VisualQC Tool (vQC); • DT Platform (DTP); • Work Order Definition and Monitoring tool (WODM).
BS-2	UC-4.1 [High]	<ul style="list-style-type: none"> • Project Manager; • Site Manager; • Quality Manager 	<ul style="list-style-type: none"> • Digital Twin Platform (DTP) • Digital Command Centre (DCC)
	UC-4.2 [Medium]	<ul style="list-style-type: none"> • Project Manager; • Site Manager; • Quality Manager 	<ul style="list-style-type: none"> • DT Platform (DTP); • Digital Twin visualisation with AR (DigiTAR) tool; • Work Order Definition and Monitoring tool (WODM).
	UC-3.1 [Medium-High]	<ul style="list-style-type: none"> • HSE Manager / Supervisor 	<ul style="list-style-type: none"> • Digital Twin Platform (DTP) • SafeConAI
BS-3	UC-3.2 [High]	<ul style="list-style-type: none"> • HSE Manager / Supervisor • Worker 	<ul style="list-style-type: none"> • Digital Twin Platform (DTP) • ProActiveSafety
	UC-3.3 [High]	<ul style="list-style-type: none"> • HSE Trainer • Foreman / Worker 	<ul style="list-style-type: none"> • Digital Twin Platform (DTP) • VirtualSafety

UC-4.1 [High]	<ul style="list-style-type: none"> • Project Manager; • Site Manager; • HSE Manager 	<ul style="list-style-type: none"> • Digital Twin Platform (DTP) • Digital Command Centre (DCC)
UC-4.2 [Medium-Low]	<ul style="list-style-type: none"> • Project Manager; • Site Manager; • HSE Manager 	<ul style="list-style-type: none"> • DT Platform (DTP); • Digital Twin visualisation with AR (DigiTAR) tool; • Work Order Definition and Monitoring tool (WODM).

5 COGITO Stakeholder Requirements

In this section, the COGITO Stakeholder Requirements (SRs) are defined. The requirements have been derived from the responses to the SR Questionnaire and SR Workshop.

Section 5.1 first presents the outcome of the two SR Workshops held by the Industry Partners. Rhomberg Sersa Rail Group (RSRG) and Ferrovial (FER). Section 5.2 then presents the developed and deployed SR Questionnaire and some statistics about the collected answers. Finally, Section 5.3 presents the final Stakeholder Requirements.

5.1 SR Workshop implementation

For the Rhomberg Sersa Rail Group (RSRG) Workshop, the product and innovation department of RSRG organised an online call with several professionals from the railway construction industry. In total 15 people with different roles (Site Manager, BIM Manager, Health and Safety Manager as well as Quality Manager) joined the meeting and discussed the topics and worked out the canvas. Together with participants of the COGITO consortium, in total 33 people attended the workshop. Figure 5.1 shows a screenshot of the online speakers at the beginning of the meeting and Figure 5.2 shows a screenshot of the speakers working on the Canvas during the workshop. Figure 5.3 shows the completed canvas at the end of the workshop.

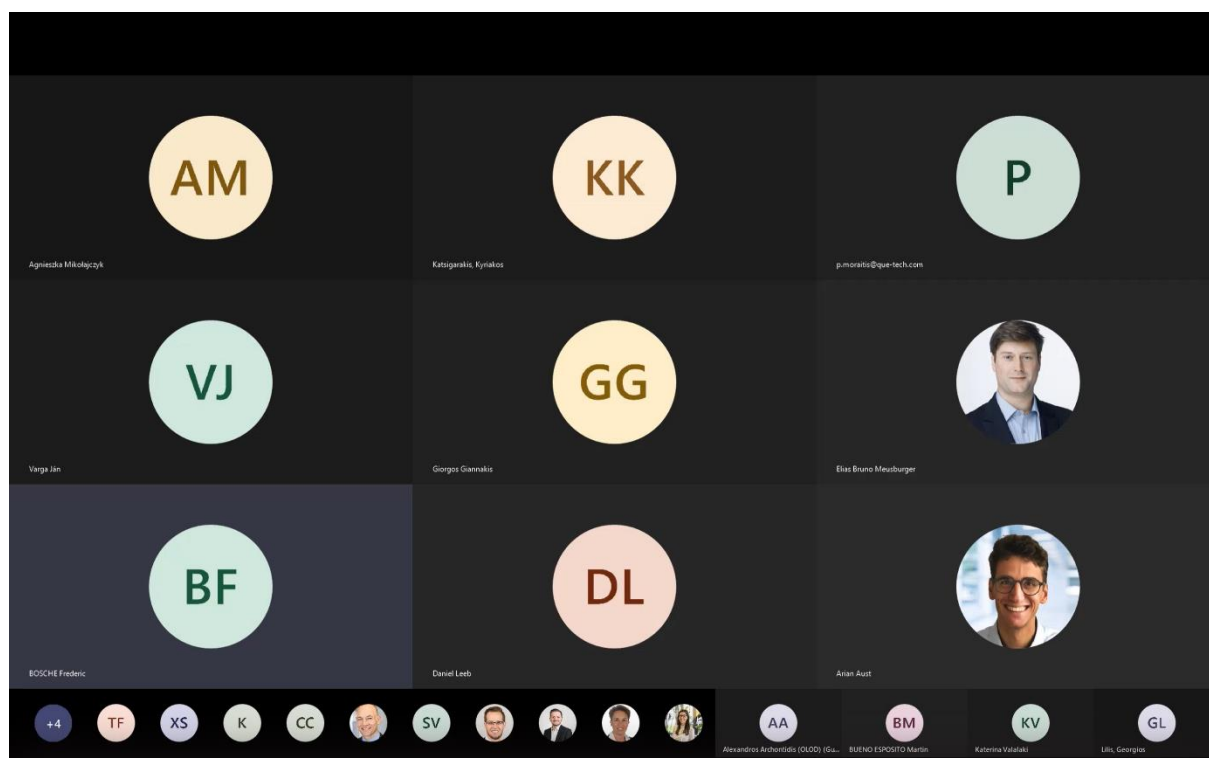


Figure 5.1: Rhomberg Sersa Rail Group Workshop - Screenshot of the speakers at the beginning of the workshop

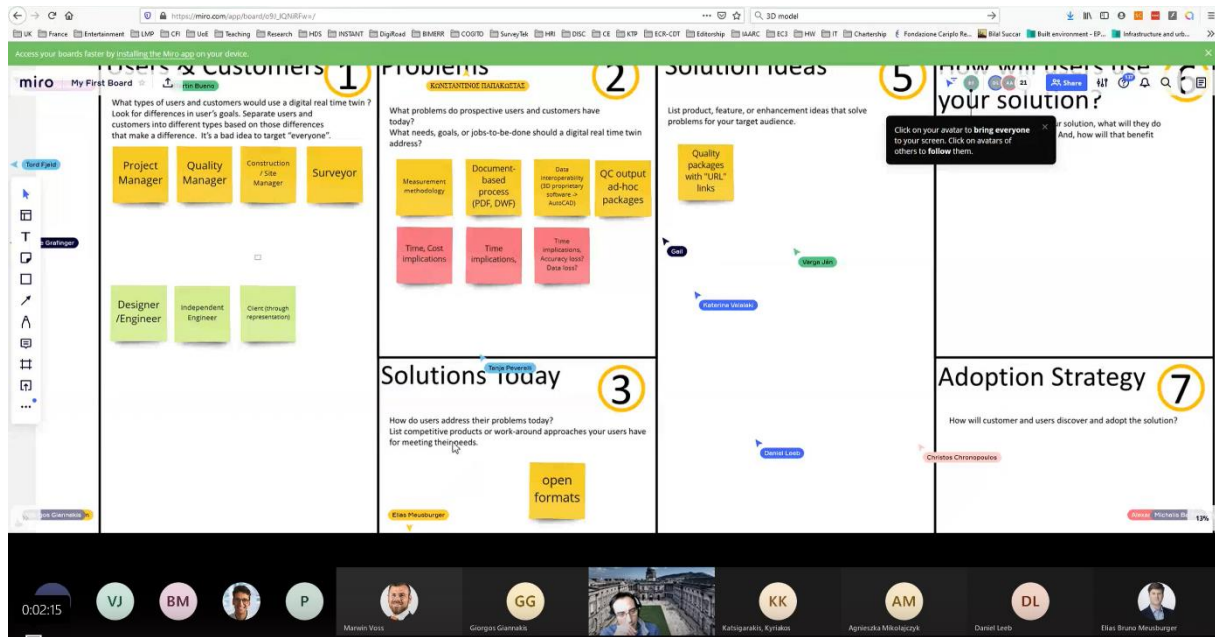


Figure 5.2: Rhomberg Sersa Rail Group Workshop - Screenshot of the speakers working on the Canvas during the workshop.

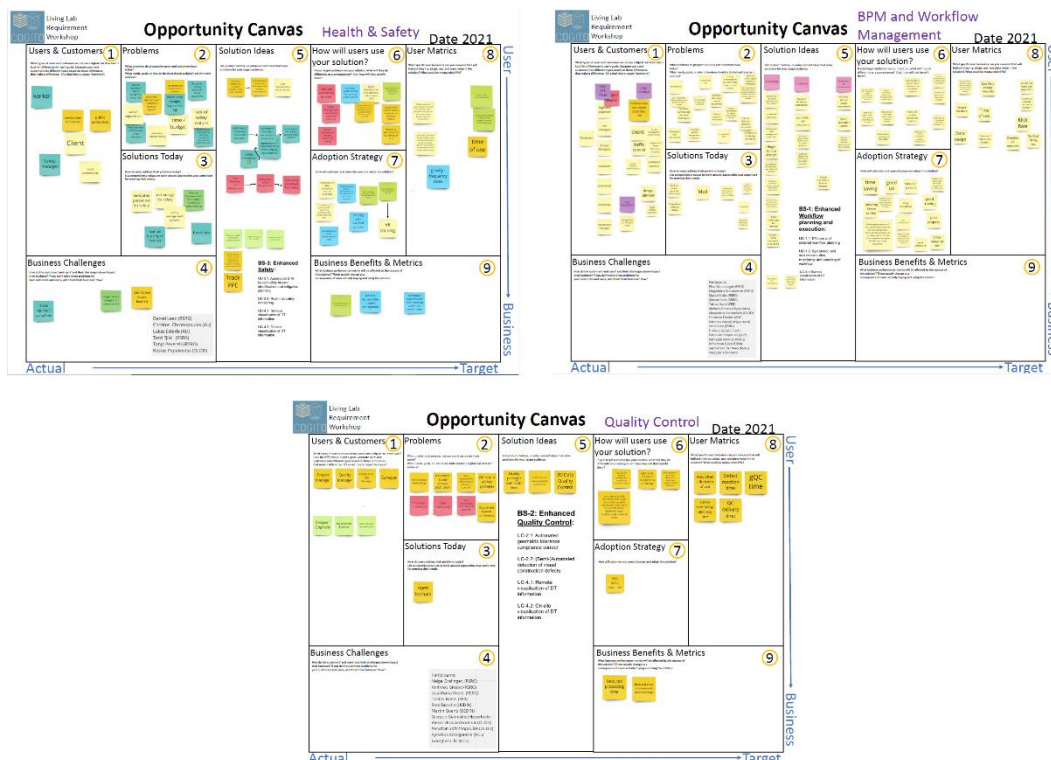


Figure 5.3: Rhomberg Sersa Rail Group Workshop – the Miro board at the end of the workshop.

For the Ferrovial (FER) Workshop, the Innovation department from Ferrovial Construction engaged various AEC professionals from the company for their participation in the living lab activities in general, but for the Requirements workshop in particular.

From the 35 people that were contacted, which included Project Managers, BIM designers, Site coordinators), approximately attended the workshop. In addition, 5 people from the third industry partner OLOD participated,

so at the end, there were 25 participants that can be considered as “end users”. Finally, 10 participants from COGITO Technical partners (Hypertech, UEDIN, NT, BOC, AU) were present as well to support and stir the discussions as needed within the respective breakout rooms. The overall total of 35 attendees means that an average of 12 people were present in each breakout room, which was found excellent for having meaningful discussions and reaching consensus.

Figure 5.1 shows a screenshot of the online speakers at the beginning of the meeting during the project introduction, and Figure 5.2 shows a screenshot of the complete workshop Miro board at the end of the workshop.

The MIRO boards from the two workshops were shared for analysis with the technical partners, and more specifically the UC leaders. This analysis enabled the team to

- Confirm and refine the needs (i.e. limitations of current practice) identified in the DoA.
- Assess the value of the proposed COGITO UCs/Tools and set their respective Priorities (Low, Medium, High).
- Extracting some meaningful Stakeholder Requirements (which may overlap or complement those coming from the survey).

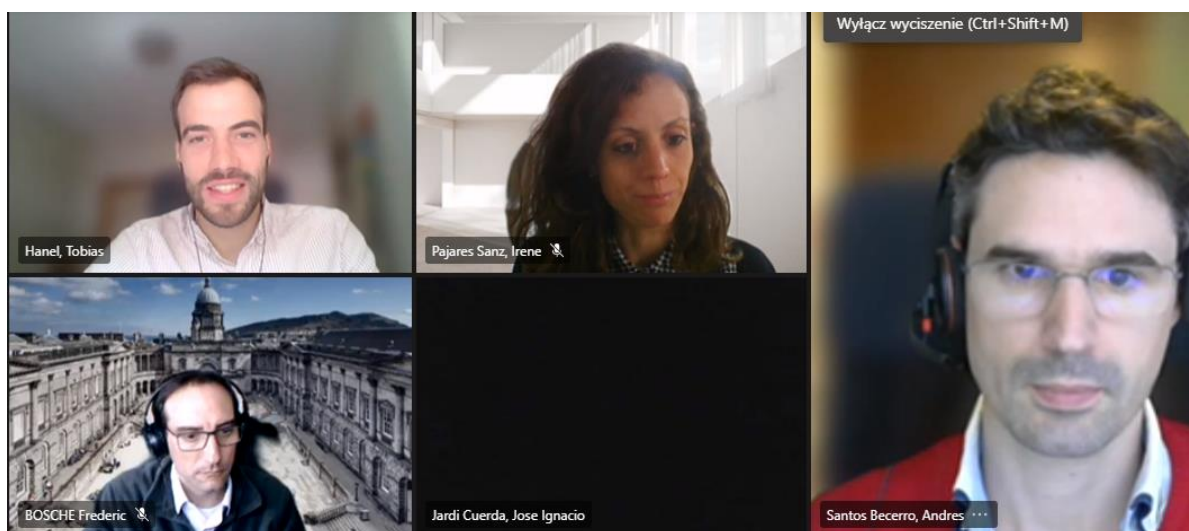


Figure 5.1: Ferrovial Workshop - Screenshot of the speakers at the beginning of the workshop.

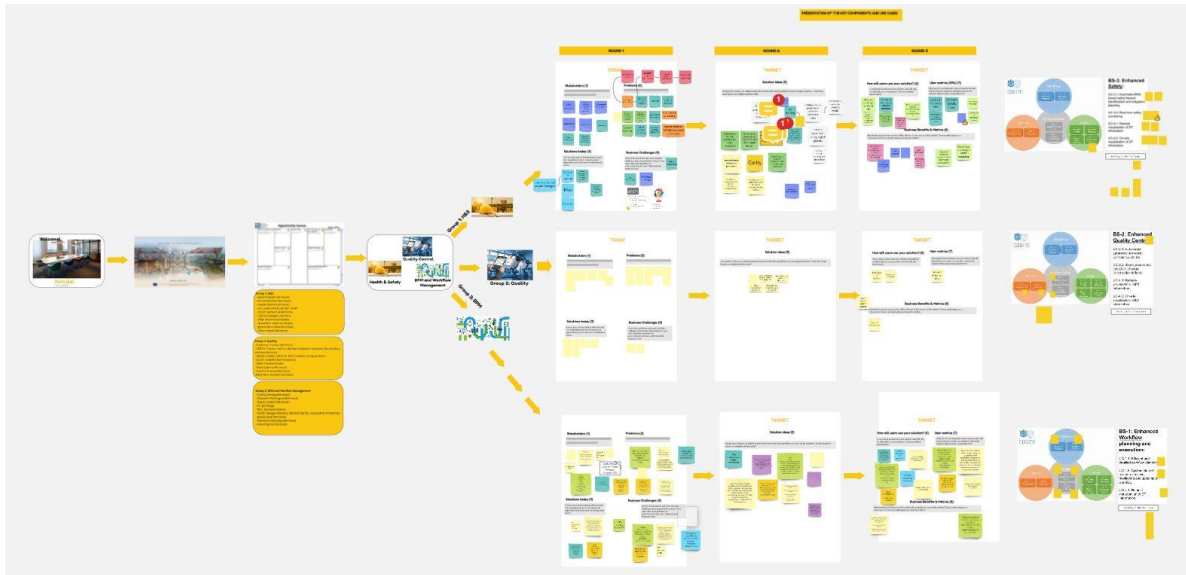


Figure 5.2: Ferrovia Workshop – the Miro board at the end of the workshop.

5.1.1 Outcome Summaries

In this section, we summarise the outcomes of the activities conducted in the three breakout groups (across the two Workshops).

Workflow:

The Workflow/Time workshop breakout groups identified an extended list of stakeholders, broadly aligned with the list resulting from our initial discussions with the industry partners' representatives, and including the main stakeholders specifically identified with regard to the COGITO Use Cases. Next, the main challenges/issues faced when planning and executing schedules/workflows corresponded to those identified in the COGITO proposal, including: Information quality and flow related problems (e.g. a lot of different information sources and lack of a single source of truth), project management difficulties (many stakeholders involved, inaccurate data on progress, inadequate coordination, frequent change orders), quality of input information (design errors discovered during construction, lack of detailed planning), and technology-related problems (interoperability issues and resistance to technological change).

All identified problems usually lead to project delays, lower overall quality, unsatisfied customers and working crew, increased number of accidents, loss of company prestige or reputation, and corresponding loss of new contracts or business opportunities.

Regarding the Business Scenario BS1, UC-1, UC-1.2 and UC-4.1 were all found highly valuable. UC-4.2 (In-situ DT visualisation) was also considered, but its value was not felt to be that significant. This led to the decision to leave it out of BS1 (a decision that could be reconsidered at a later stage in the project).

The breakout groups also discussed a list of potential KPIs that could be measured to assess the impact of the COGITO solution. These, as well as related information collected in the SR Questionnaire, will be presented in D2.3.

Finally, the breakout group discussions identified a number of URs which have been collected and are presented in Section 5.3 below, collectively with those collected through the SR Questionnaire.

Quality:

The Quality workshop breakout groups identified a narrower list of stakeholders compared to the Workflow group, but this list fully aligned with that already identified by the consortium.

The groups discussed current practice in Quality Assurance / Quality Control (QA/QC) and the challenges faced. That discussion confirmed that QA/QC processes are based on the production and integration of a significant amount of documentation before, during, and after the execution of works. For example, work orders need to include specific quality requirements and specifications that may be obtained from a number of other documents produced by the design, engineering and construction teams, including CAD drawings. It was reported that, although there is an increasing effort to digitalise the process and structure the information, current practice mainly uses web-based document management systems (e.g. MS Sharepoint), where documents may be stored by type but the cross-referencing is not done digitally. Instead, document reference numbers are listed as in current practice and the user must still often retrieve those documents by themselves. During the execution phase, the QMs and PMs have to also submit and keep track of a lot of QC documentation, both internally and to be reviewed by external inspectors. These discussions aligned well with the review of practice given in Section 2.4. In addition, it was reported that QC activities can often be time-consuming, resulting in work orders delays, cost increases and a slow flow of information. Furthermore, survey data requires manual registration in a common coordinate system and therefore are not ready to process promptly. Besides, survey data may sometimes turn out to be incomplete (or without sufficient accuracy), thus requiring additional data acquisition. Another issue raised is the lack of broadly supported survey data format and the consequent interoperability difficulties faced continuously and requiring constant ad-hoc workarounds to be able to open, share and edit the different files between the different software solutions, leading to, in most of the cases, data and accuracy loss, time delays implications. Additional complications include the fact that the QC packages do not integrate regulations and specifications that need to be checked, adding to the amount of manual work (e.g. information retrieval) required to complete QC tasks. Finally, the workshops participants raised concerns about the slow flow of information, between both internal and external stakeholders. There are concerns regarding the lack of transparency in the QC process, mainly due to disconnected processes and data sources, which can lead to distrust of the QC results. There is not a platform that can extract and produce detailed QC reports and allow the QMs and PMs to share the information and submit it to the (local) authorities in a trustworthy and transparent way. In particular, this last point is paramount to save a lot of time and reduce delays, especially when it involves the interaction with the external inspector who has to validate some QC results before work can proceed further.

As a result of the above analysis, the participants highlighted how a Digital Twin should link all documentations together in a robust way, so that information can be retrieved effectively, and QC processes expedited. The COGITO QC solution and UCs were thus received favourably, because it precisely aims to address those challenges. Another key aspect of the COGITO solution is that it will help automate the processing of survey data for automated compliance control, which shall further speed up QC works. As such the participants provided a positive reaction to the COGITO's proposed UCs. The participants showed interest and enthusiasm for the GeometricQC tool (UC-2.1) and VisualQC tool (UC-2.2), although there is some scepticism as to the accuracy of such automated processes. An interesting comment was made about the possible use of the VisualQC tool to possibly monitor the evolution of defects. Finally, the offsite and onsite DT visualisation tools (UC-4.1 and UC-4.2) were also found relevant to address the need for integrated information visualisation.

The discussions summarised above led to the establishment of corresponding SRs that were integrated with those collected from the SR Questionnaire and are reported collectively in Section 5.3.

Safety:

The Safety workshop breakout groups identified several stakeholders including not only the expected ones, such as construction companies, safety managers and public authorities, but also included local communities, shareholders and suppliers of equipment (e.g., PPE, tools) in the list. Although it was clear to the lead technical partners that these were not the main stakeholders.

The groups discussed the existing problems of safety in construction and provided the solutions available according to the participants' experience. The absence of safety culture together with the lack of safety training

and detailed reporting procedures for accidents, incidents and near-misses (close-calls) was highlighted in the discussions of the groups, which leads to inability to make use of 'lessons learnt' to improve safety performance. Additionally, the groups identified the lack of resources (e.g., time and budget), the prioritisation of productivity over safety as well as interoperability issues of the used platforms as major problems in current practice. Interestingly, last minute changes, such as unexpected weather conditions, was identified as another problem. The workshop breakout groups then discussed the available solutions used in current practice. The use of safety management systems, alignment with existing health and safety standards (e.g., ISO 45001 [13]) and allocating responsibility for safety to dedicated safety personnel were reported by the participants. Other solutions included manual tracking of hazards, digital file sharing tools (e.g., MS SharePoint) and heuristics. Regarding the business challenges, the participants highlighted the legal and ethical implications related to the use of modern information and communication technologies in construction. Another important aspect mentioned in the groups was the resistance to change that might be an obstacle in applying new technologies in practice. The groups discussed several ideas as solutions to the existing problems of safety practice in the construction industry, the majority of which are related to the use of modern technologies. For example, the use of drones and digital glasses for risk inspection of inaccessible areas and tools (e.g., web-based platform) to facilitate accident, incident and close-calls reporting, feedback and dissemination of information. Furthermore, the groups suggested using augmented reality (AR) tools to visualise safety issues and artificial intelligence (AI) for access control, PPE tracking, geo-fencing and geo-localisation, and hazard identification and prediction. Other provided solutions, include the clarification of processes and responsibilities as well as the required standardization efforts. Subsequently, the participants considered the strategies to achieve application and adoption of the provided solutions. Specifically, the groups discussed the potential of new technologies in reducing the workload of safety responsible personnel as well as of the workforce, while allowing them to work more productively. However, concerns were raised regarding the potential change of working behaviour as a result of tracking as well as the possibility of affecting negatively the situational awareness of personnel. It is also likely though, that the suggested solutions induce positive changes in both working behaviour and situational awareness. Regarding the adoption strategies, focus was put on enhancing physical or virtual safety training by certified training personnel, availability of updated safety information on-site with the use of new technologies (e.g., 'BIM kiosks') learning from experience that can be transferred to future construction projects.

The breakout group discussions identified several SRs which have been collected and are presented in Section 5.3 below, collectively with those collected through the SR Questionnaire.

Finally, the safety breakout groups identified relevant user and business metrics, and the associated benefits. For example, the time of use and the number of reported cases was mentioned. In addition, several participants suggested the use of accident (or incident/close-call) frequency and gravity rates as well as the number of lost time due to injuries within a given accounting period, relative to the total number of hours worked in that period (i.e., LTIFR). The importance of establishing precise near-miss incident indicators was highlighted, while a combination of KPIs could allow for balancing their individual strengths and weaknesses. As a result, the participants anticipated that the discussed solutions in construction safety will lead to fewer accidents and hence, reduced absences, less paperwork and better planning and control of resources. Most importantly, lessons learnt will facilitate creating a safety culture which will long term benefit businesses in the construction industry.

5.2 SR Questionnaire implementation

As discussed earlier, the development of the SR Questionnaires followed an iterative approach aimed at ensuring quality and also harmony within the integrated questionnaire. The structure of the integrated questionnaire resulting from that effort can be found in Figure 5.3. The questionnaire includes 9 pages:

- Page 1: COGITO introduction and consent form.
- Page 2: Questions about **Computing Systems** used by **all Main Stakeholders**.
- Page 3: Questions about **Workflow** planning and execution asked to the **Project Manager and Site Manager** stakeholders.

- Page 4: Questions about **Workflow** planning and execution asked to the **Quantity Surveyor** stakeholders
- Page 5: Questions about **Workflow** planning and execution asked to the **Foremen** stakeholders.
- Page 6: Questions about **Quality Control** (and Quality Assurance) asked to the **Project Manager and Site Manager** stakeholders.
- Page 7: Questions about **Quality Control** (and Quality Assurance) asked to the **Surveyor** stakeholders.
- Page 8: Questions about **HSE** asked to **HSE Personnel** (e.g. HSE Manager and Supervisor).
- Page 9: Advertisement of the COGITO Newsletter inviting interested responded to visit the Newsletter sign-up page
- Page 10: Thank you message

Overall, the integrated questionnaire included 118 questions (including a few duplicates to accommodate the questionnaire structural constraints), split as summarised in Figure 5.1. The full integrated SR Questionnaire can be found in Annex 2. While most of the questions are aimed at the collection of SRs, other questions are also aimed at collecting information and confirming the consortium's existing understanding of current practice and challenges associated to it.

As a result of the involvement of certain Main Stakeholders in one or more areas (Workflow, Quality and/or Safety), the duration for answering the questionnaire was estimated to range from 10min (for Quantity Surveyor, Surveyor, HSE Personnel) to 25min (for Project Manager and Site Manager).

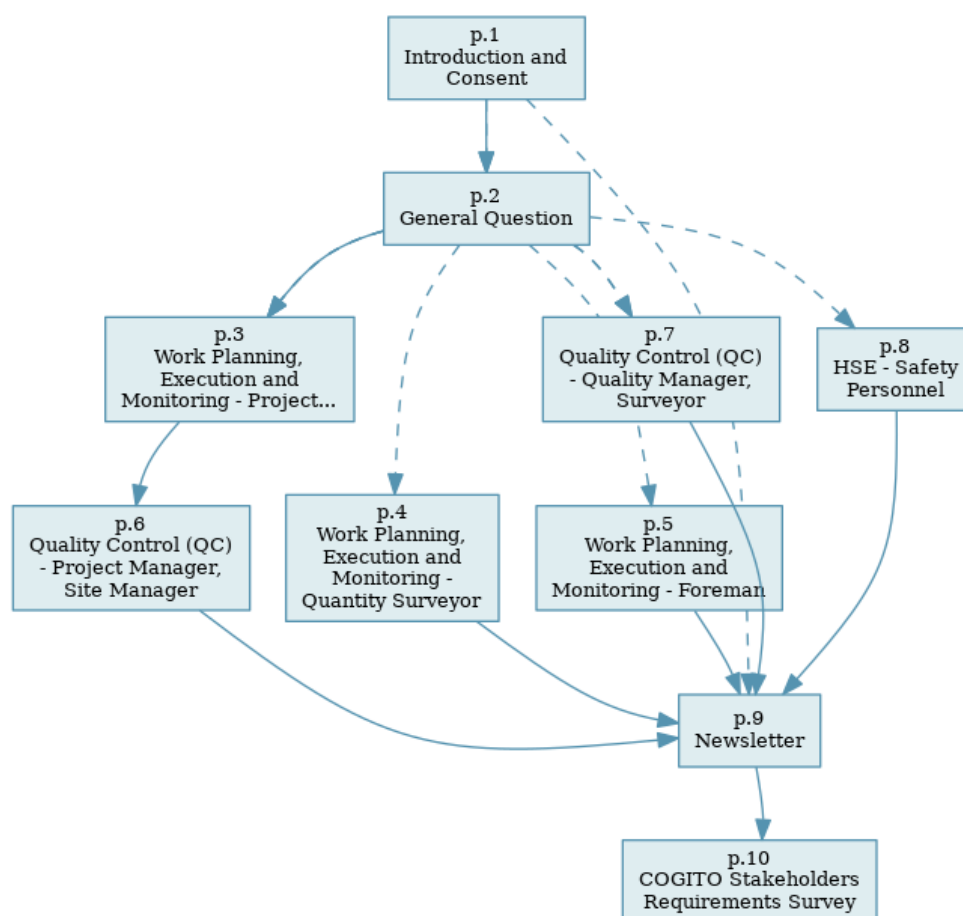


Figure 5.3: The structure of the COGITO SR questionnaire.

5.3 Final Stakeholder Requirements

The analysis of the SR Questionnaire responses and SR Workshop outputs led to the definition of 75 SRs, categorised as follows:

- 33 *MUST* SRs.
- 24 *SHOULD* SRs.
- 12 *COULD* SRs.
- 6 *WOULD* SRs.

The following subsections summarise the requirements collected in four areas:

- Computing systems.
- Workflow planning, execution and monitoring.
- Quality control (and quality assurance).
- Safety (HSE) assurance and monitoring.

The table in each area highlights (in bold) those SRs that have been prioritised as *MUST* or *SHOULD*.

5.3.1 Requirements about Computing Systems

The SRs regarding computing systems are summarised in Table 6. In total, there are 11 SRs split into:

- 6 *MUST* SRs.
- 1 *SHOULD* SRs.
- 2 *COULD* SR.
- 2 *WOULD* SR.

Table 6 –Requirements on Computing Systems

ID	Main Stake-holder	Description: <i>The Computing solution...</i>	Type	Priority
COGI-CS-1	PM/HSE/QM	[DCC, WODM, PMS, BC, SafetyConAI, VirtualSafety, gQC] Runs on desktop or laptop PC	• Operational	Must
COGI-CS-2	SM/HSE/QM	[DigiTAR, WOEa] Runs on laptop and be usable on the construction site (remote access)	• Operational	Should
COGI-CS-3	Foreman	[WOEA] runs on mobile phones or tablets, without brand restriction.	•Operational •Design constraint	Must
COGI-CS-4	PM/SM/ HSE/QM	runs on Windows	• Operational	Must
COGI-CS-5	PM/SM/ HSE/QM	runs on Mac	• Operational	Could
COGI-CS-6	PM/SM/ HSE/QM	runs on Android	• Operational	Would
COGI-CS-7	PM, SM, QM, HSE	allows access to the whole data in one location	•Operation •Functional •Design constraint	Must

COGI-CS-8	PM, SM, QM, HSE	maintains communication and data security	•Legal •Design constraint	Must
COGI-CS-9	PM	differentiates data and system access levels and modification rights	•Legal •Functional •Design constraint	Must
COGI-CS-10	PM	[DigiTAR] allows visual comparison of current to planned status, either by AR glasses, mobile phones, or tablets	•Functional •Design constraint	Could
COGI-CS-11	PM	implements automatic metadata extraction from documents	•Functional •Design constraint	Would

5.3.2 Requirements about Workflow Planning, Execution and Monitoring

The SRs for Workflow Planning, Execution and Monitoring are summarised in Table 7. In total, there are 29 SRs split into:

- 10 *MUST* SRs.
- 13 *SHOULD* SRs.
- 4 *COULD* SR.
- 2 *WOULD* SR.

Table 7 – Requirements about Workflow Planning, Execution and Monitoring

ID	Main Stakeholder	Description: <i>The Workflow Planning, Execution and Monitoring solution ...</i>	Type	Priority
COGI-WF-1	PM	allows the PM and Client to share information (design data, photos, videos, schedules, design issues, cost)	•Functional •Design constraint	Could
COGI-WF-2	PM	allows the PM and Site Manager to share information (design data, photos, RAMs, design issues, schedules, work orders, work reports, materials, schedule and usage, equipment usage, costs)	•Functional •Design constraint	Must
COGI-WF-3	PM	allows the PM and the Quantity Surveyor to share information (design data, photos, RAMS, design issues, schedules, work orders, materials schedule and usage, equipment usage, costs)	•Functional •Design constraint	Should
COGI-WF-4	PM	allows the PM and Quality Manager to share information (design data, photos,	•Functional •Design constraint	Should

		design issues, schedules, work orders, materials schedule and usage, costs)		
COGI-WF-5	SM	allows the SM to share information with Subcontractors, Foreman, and Workers (design data, photos, RAMs, design issues, schedules, work orders, equipment usage)	•Functional •Design constraint	Should
COGI-WF-6	PM, SM	[PMS, WODM, DCC] allows the PM and SM to efficiently detect and prioritise delays and cost escalation elements	•Functional	Should
COGI-WF-7	PM	[PMS, WODM, DCC] allows the PM to extract reports about: project time performance, project cost performance, costs per unit, resource consumption	•Functional	Must
COGI-WF-8	PM, SM	[PMS, WODM] uses BIM models to support scheduling and budgeting	•Functional	Should
COGI-WF-9	PM, SM	[WODM] issues work orders that include detailed method statements	•Design constraint •Functional	Should
COGI-WF-10	PM, SM	[WODM] allows work orders assignment to specific workers/crews.	•Functional	Should
COGI-WF-11	PM	[WODM, WOE, DCC] updates the activity status during work execution and monitoring	•Functional	Should
COGI-WF-12	PM, SM	[WODM, DCC] allows display of activity description, planned duration and activities relationship	•Functional	Should
COGI-WF-13	PM, SM	[WODM] defines work orders containing work description, location, start and end, construction drawings or BIM, safety measures, materials and equipment needed, quality measures, etc.	•Functional •Design constraint	Must
COGI-WF-14	PM, SM	[WODM, WOE, DCC] allows work progress reports	•Functional	Must
COGI-WF-15	PM, SM	[WODM, WOE, DCC] updates work progress weekly	•Operational	Must
COGI-WF-16	PM	[PMS] updates the project schedule at least monthly	•Operational •Functional •Process	Must
COGI-WF-17	PM	[DCC] uses BIM model to show tasks status information	•Functional	Should
COGI-WF-18	PM, SM, QM, HSE	displays only current information or document versions, related to the project, to all stakeholders	•Operational •Legal •Design constraint	Must
COGI-WF-19	PM, SM	[WODM, WOE, DCC] Enables quick and easy reporting.	•Performance •Design constraint	Must

COGI-WF-20	PM	[PMS] incorporates risk prediction and critical path finding during scheduling	•Functional	Could
COGI-WF-21	SM	[PMS, WODM] facilitates resource allocation during scheduling	•Functional	Should
COGI-WF-22	PM, SM	[PMS] supports conflict predictions and solving during scheduling (e.g., networks relocation before excavation work)	•Functional	Could
COGI-WF-23	PM	[PMS, WODM] incorporates health and safety planning	•Functional •Design constraint	Should
COGI-WF-24	PM	[PMS, WODM] incorporates quality control planning	•Functional •Design constraint	Should
COGI-WF-25	PM	[WODM, DCC] accesses the project execution monitoring off site	•Functional •Design constraint	Must
COGI-WF-26	SM	[WOEA] allows efficient reporting of work completion (using sensor data or simple app interface)	•Functional •Design constraint	Could
COGI-WF-27	PM, SM, QM, HSE	offers simple, easy to use, and intuitive interface to avoid workforce over-burdening	•Operational •Design constraint	Must
COGI-WF-28	HSE	facilitates pre-construction training sessions (e.g., by using BIM models in augmented reality)	•Operational •Functional •Design constraint	Would
COGI-WF-29	PM, SM, QM, HSE	facilitates swift tool adoption by easily available video tutorials and other learning materials online	•Operational	Would

5.3.3 Requirements about Quality Control (and Quality Assurance)

The SRs for Quality Control (and Quality Assurance) are summarised in Table 8. In total, there are 27 SRs split into:

- 15 *MUST* SRs.
- 6 *SHOULD* SRs.
- 4 *COULD* SRs.
- 2 *WOULD* SRs.

Table 8 – Requirements about Quality Control (and Quality Assurance)

ID	Main Stakeholder	Description: <i>The Quality Control (and Quality Assurance) solution ...</i>	Type	Priority
COGI-QC-1	PM	allows the PM and SM to share information (design data, photos, videos, documents, notes, rework orders)	• Functional • Design constraint	Must

COGI-QC-2	PM/SM/QM	allows the PM/SM and QM/Surveyor to share information (design data, photos, documents, notes, rework orders)	<ul style="list-style-type: none"> • Functional • Design constraint 	Must
COGI-QC-3	PM/SM	allows the PM/SM and Engineer to share information (photos, documents, notes, rework orders)	<ul style="list-style-type: none"> • Functional • Design constraint 	Would
COGI-QC-4	PM/SM	allows the PM and SM to share information (photos, documents, notes, rework orders) with Subcontractor	<ul style="list-style-type: none"> • Functional • Design constraint 	Could
COGI-QC-5	QM	allows the QM to share information (design data, photos, videos, documents, (re)work orders) with the Foreman	<ul style="list-style-type: none"> • Functional • Design constraint 	Must
COGI-QC-6	QM	allows the QM and Surveyor to share information (design data, photos, videos, documents, (re)work orders)	<ul style="list-style-type: none"> • Functional • Design constraint 	Could
COGI-QC-7	QM	allows the QM to share information (information about the carried inspection and schedules) with other stakeholders, like client, managing director, environmental government, etc	<ul style="list-style-type: none"> • Functional • Design constraint 	Would
COGI-QC-8	PM/QM	supports systematic quality control on earthworks, substructure, concrete works	<ul style="list-style-type: none"> • Performance 	Should
COGI-QC-9	PM/QM	supports systematic quality control on weld points and connection points	<ul style="list-style-type: none"> • Performance • Functional 	Should
COGI-QC-10	PM	notifies PM of QC results at least on a weekly basis, and ideally on a daily basis	<ul style="list-style-type: none"> • Functional • Performance 	Must
COGI-QC-11	PM	automates QC-related activities	<ul style="list-style-type: none"> • Functional • Operational 	Must
COGI-QC-12	QM	updates the construction schedule to take into account rework resulting for detected QC problems	<ul style="list-style-type: none"> • Functional • Design constraint • Performance 	Must
COGI-QC-13	QM	issues re-work orders that identify and link to the elements that need rework	<ul style="list-style-type: none"> • Functional 	Must
COGI-QC-14	QM	issues re-work orders that contain schedule of works required to complete the rework	<ul style="list-style-type: none"> • Functional 	Could
COGI-QC-15	QM	monitors and issue reports on: man-hours spent on QC activities; cost of rework due to late-detection of defects or failures; number of late-detected defects or failures	<ul style="list-style-type: none"> • Functional 	Must
COGI-QC-16	QM	[gQC] handles point clouds standard formats (E57, PLY)	<ul style="list-style-type: none"> • Functional • Design constraint 	Must
COGI-QC-17	QM	[gQC] shows geometric QC results on the BIM model with a detailed colour map	<ul style="list-style-type: none"> • Functional 	Must

		depicting deviations between as-built and as-designed		
COGI-QC-18	QM	[gQC] shows geometric QC results on the BIM model with text annotations with detailed information	• Functional	Should
COGI-QC-19	QM	issues QC result reports that include: survey measurements; pictures	• Functional • Design constraint	Must
COGI-QC-20	QM	issues QC result reports that include: links to the BIM model with annotations of the survey result	• Functional • Design constraint	Should
COGI-QC-21	QM	[vQC] handles images in PNG/JPEG format	• Functional • Design constraint	Must
COGI-QC-22	QM	[vQC] handles videos in XML and AVI/MPG/MP4 format	• Functional • Design constraint	Could
COGI-QC-23	QM	[DCC, DigiTAR] allows the QM to visualise and validate automated defect detections	• Functional • Design constraint • Performance	Must
COGI-QC-24	QM	[DCC, DigiTAR] shows visualQC results using: graphic indicator; colourisation; and text	• Functional • Design constraint	Must
COGI-QC-25	QM/PM	[DCC, DigiTAR] shows visualQC defect with contextual information (link to components, defect history, etc)	• Functional • Design constraint	Should
COGI-QC-26	QM/PM	[DCC] allows defects prioritisation	• Design constraint	Should
COGI-QC-27	QM/PM	[DCC] allows an advance information search/retrieval (severity, location, type, etc)	• Functional • Design constraint	Must

5.3.4 Requirements about Safety (HSE) Assurance and Monitoring

The SRs for Safety are summarised in Table 9. In total, there are 8 SRs split into:

- 2 *MUST* SRs.
- 4 *SHOULD* SRs.
- 2 *COULD* SR.
- 0 *WOULD* SR.

Table 9 – Requirements about Safety (HSE)

Req ID	Main Stakeholder	Description The HSE solution ...	Type	Priority
COGI-SF-1	HSE	allows the HSE personnel to share information (checklists, photos, safety plans/RAMs, regulations, standards, safety best practices, documents) with the Project Manager, Engineer, Site Manager and other HSE personnel	<ul style="list-style-type: none"> •Functional •Design constraint 	Must
COGI-SF-2	HSE	allows the HSE personnel to share information (checklists, photos, safety plans/RAMs, safety best practices, documents) with Foreman and Workers	<ul style="list-style-type: none"> •Functional •Design constraint 	Should
COGI-SF-3	HSE	[SafetyConAI, DCC, DigiTART] allows the HSE personnel to validate the automated hazard identification	<ul style="list-style-type: none"> •Functional •Design constraint 	Could
COGI-SF-4	HSE	[DigiTAR] allows to employees to provide feedback and identify hazards	<ul style="list-style-type: none"> •Functional •Design constraint •Process 	Should
COGI-SF-5	HSE	[ProActiveSafety] keeps safety records	<ul style="list-style-type: none"> •Functional •Design constraint 	Should
COGI-SF-6	HSE	[ProActiveSafety] warns workers about the hazards and safety measures (visual instructions, alarms)	<ul style="list-style-type: none"> •Functional •Design constraint 	Must
COGI-SF-7	HSE	[ProActiveSafety, DigiTAR] includes location data, photos or sketches, time recording, condition of hazard in the generated safety reports	<ul style="list-style-type: none"> •Design constraint 	Should
COGI-SF-8	HSE	[Virtual Safety] Allows the training to be directed using real cases examples and practice	<ul style="list-style-type: none"> •Operational •Functional •Design constraint 	Could

6 Conclusions

This document presented the User-Driven Innovation (UDI) methodology followed to elicit the Stakeholder Requirements (SRs) for the COGITO solution, and the outcome of that process that was applied between M1 and M6 of the COGITO project.

In line with the UDI methodology, the process engaged with industry partners at each of its steps (through the COGITO Living Lab framework) to identify the Main Stakeholders, develop meaningful Use Cases (UCs) and elicit Stakeholder Requirements.

The main results reported in this deliverable include:

- A list of Main Stakeholders (groups) related to the COGITO project and the use cases it particularly aims to deliver.
- The UCs and Business Scenarios (BSs) they support. Each UC identifies the COGITO components and Main Stakeholders involved, the expected input data, a detailed path through the UC identify the interactions among the Stakeholders and Components, and the output data/results.
- The Stakeholder Requirements (SRs) in relation to the defined UCs. The SRs were elicited through two dedicated Workshops with industry partners and a Questionnaire issued to the industry partners and the sector more broadly.

The submission of this deliverable marks the end of Task T2.1 “Elicitation of Stakeholder Requirements” and the achievement of milestone MS1 “End-user requirements elicitation & documentation”. These results form the basis for the design and development of the COGITO system architecture (which will be reported in deliverable D2.4) and subsequently all the work conducted in the technical WPs WP3-WP7. Later, the UCs and SRs will also guide the evaluation phase of the project at the pilot premises (WP8).

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ANNEX 1: UC TEMPLATE

UC ID	UC-x
Use Case Name	Name of the Use Case
Related Business Scenario(s)	BS _i
Description	Short summary of what the use case is about
Involved Main Stakeholders	The least of Stakeholders actively involved or impacted by the UC.
COGITO components involved	Which COGITO tools/components are involved in the use case. E.g. the DT Platform, Data Model, etc.
Pre-conditions	Any existing data, tools, etc. that needs to be available for the use case to be implemented
Use Case Path	Step-by-step description of the Use Case. "Stakeholder X does Y with tool Z. Then, ..."
Post Condition	What is the output product/state resulting from the implementation of this Use Case.
Business Impact	The impact of this Use Case on business, in particular in comparison with current practice.
Realisation Description	
Leading Partner	Acronym of the partner leading this Use Case.
Contributing Partners	Other partners involved in enabling this Use Case.
Priority	

ANNEX 2: SR QUESTIONNAIRE

Page 1: COGITO Introduction and Consent

PROCEDURES OF THE STUDY AND CONSENT FORM

This survey is being carried out within the European research project “COstruction phase diGital Twin mOdel” (COGITO) funded under the Horizon 2020 framework programme for research and innovation.

The information gathered will be used exclusively for research purposes to capture and understand the expectations of potential users of the COGITO tools and other stakeholders.

Participation in research is completely voluntary and you will not be asked about your name nor any personal data. You have the right to decline to take part in the project; to decline to answer any questions and to stop taking part in the project at any time. Your recorded data managed within COGITO will be anonymized and stored in a form which does not permit identification of data subjects. Information will be held and used only for the purpose of the project COGITO on research servers at University of Edinburgh and at University of Edinburgh for processing. The collection, storage and protection of data will comply with all European and national legislation. Since no personal data are collected and all collected data will be secured and protected, there is no risk involved in participating in the survey. On the other hand, through this survey we **invite you to co-create together with COGITO partners the solutions developed in the project**. The research findings will be analysed and presented to adjust the COGITO tools to the different stakeholders needs, requirements and expectations.

The duration of the survey is ca. 10 - 25 minutes (depending on your role)

More information on the procedures of the study can be find [here](#).

Should you have any questions, you can contact the COGITO project Technical Manager Dr. Frédéric Bosché (f.bosche@ed.ac.uk).

Thanks you very much for taking part in this research!

To formalise your consent to participate, please check the relevant box below:

This part of the survey uses a table of questions, [view as separate questions instead?](#)

Please respond to the following consent: * *Required*

	Yes	No
I have read the above mentioned information about the purpose, expected duration and procedures of the study	<input type="checkbox"/>	<input type="checkbox"/>
I have been given adequate time to decide on my participation in the research	<input type="checkbox"/>	<input type="checkbox"/>
I agree to the use of the collected data, also within a 5-year period after the termination of the COGITO project	<input type="checkbox"/>	<input type="checkbox"/>

I agree to participate in this survey. * *Required*

Please select ▾

Next >

Page 2: General Questions on Computing Systems

What is your role in projects? * *Required*

Please select

Which is the main computing device that you use for your work? * *Required*

- ☐ None
- ☒ Desktop Computer
- ☐ Laptop
- ☐ Phone
- ☐ Smartphone
- ☐ Tablet
- ☐ Other

What operating system does this main device use? ⓘ **Required**

- ☐ Windows
- ☐ Linux
- ☐ Android
- ☐ iOS
- ☐ Other

< Previous

Next >

Page 3: Work Planning, Execution and Monitoring - Project Manager and Site Manager

The COGITO project aims to develop a **set of tools to deliver more efficient and effective work planning, execution and monitoring**.

To support the development of those tools, we would like to ask you a set of questions about the systems and processes you currently employ for activities related to work planning, execution and monitoring.

This part of the survey uses a table of questions, [view as separate questions instead?](#)

What computer software / tool do you use for the following tasks?

	Software / Tool
Work with construction drawings	<input type="text"/>
Work with Building Information Models (BIMs)	<input type="text"/>
Plan and monitoring constructions schedules	<input type="text"/>
Plan and monitoring construction costs	<input type="text"/>
Plan and monitoring materials deliveries/consumption	<input type="text"/>
Plan and monitoring plant/equipment deliveries/usage	<input type="text"/>
Work with Risk Assessment and Method Statements (RAMSs)	<input type="text"/>
Work with Work Orders	<input type="text"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the following stakeholders, **what** information do you exchange with them **for work planning, execution and monitoring?** (Please select at least one option per row, if you don't share that information with any stakeholder select "None of them". Please keep empty the column corresponding to your role.) * Required

	Client	Project Manager	Site Manager	Quantity Surveyor	Engineer (Civil, M&E, Construction)	HSE Manager / Supervisor	Quality Manager	Foreman / Site worker	Sub-contractor	None of them
(Annotated) 2D drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) 3D models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Voice recordings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Risk Assessment and Method Statements (RAMSs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design issues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Schedule	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work orders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Materials schedules	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Materials usage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Equipment usage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how often** do you exchange that work planning, execution and monitoring information? (Please select one option per column. If you don't exchange information with any stakeholder select "Never". Select also "Never" for the column corresponding to your role.) * Required

	Client	Project Manager	Site Manager	Quantity Surveyor	Engineer (Civil, M&E, Construction)	HSE Manager / Supervisor	Quality Manager	Foreman / Site worker	Sub-contractor
Very frequently (nearly daily)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequently (e.g. once a week)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Occasionally (e.g. once every few weeks)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

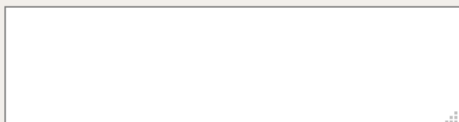
For the same stakeholders, **how** do you exchange that work planning, execution and monitoring information? (please select at least one option per column, if you don't exchange information with any stakeholder select "No exchange of documents/information". Select "No exchange of documents/information" for the column corresponding to your role.) * Required

	Client	Project Manager	Site Manager	Quantity Surveyor	Engineer (Civil, M&E, Construction)	HSE Manager / Supervisor	Quality Manager	Foreman / Site worker	Sub-contractor
Via Email	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a cloud file sharing service (e.g. Box, Dropbox, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a web-based project management software	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Printed documents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No exchange of documents/information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

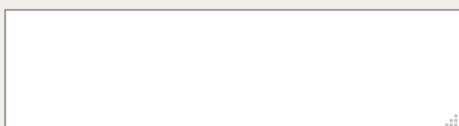
What construction activities are most vulnerable to delays? * Required



What construction activities are most vulnerable to cost escalation? * Required



How are construction delays recorded and reported? * Required



Which of the following Key Performance Indicators (KPIs) do you use to monitor project schedule/cost performance? * Required

- ☐ Project time performance (i.e. completed ahead or behind schedule)
- ☐ Project cost performance (i.e. above or below budget)
- ☐ Individual activity time performance (i.e. completed ahead or behind schedule)
- ☐ Individual activity cost performance (i.e. above or below budget)
- ☐ Earned Value Analysis KPIs at project level (SPI, CPI, CV and SV)
- ☐ Earned Value Analysis KPIs for individual activities (SPI, CPI, CV and SV)
- ☐ Costs per unit (e.g. cubic or square meters)
- ☐ Units per man-hour (e.g. cubic or square meters)
- ☐ Resource consumption (people, materials)
- ☐ Costs spent on rework (material, workforce)
- ☐ Time spent on rework
- ☐ Lost man-hours (idle time, safety related, time spent searching for material/workers)
- ☐ Man-hours spent on gathering progress information (e.g. man-hours of quantity surveying)
- ☐ Costs of gathering progress information (e.g. man-hours of quantity surveying)
- ☐ Time spent on information sharing (e.g. meetings)
- ☐ Other

Work Planning (Scheduling and Budgeting)

Do you use BIM models to support your scheduling/budgeting activities? * *Required*

- ☐ No, and I don't see how this would be helpful
- ☐ No, but I could certainly benefit from access to BIM models.
- ☐ Yes

Do you find that method statements provide enough detail in the way the work has to be conducted (construction tasks, workflow) ? * *Required*

- ☐ No
- ☐ Yes

Work Execution and Monitoring

What computer software / tool do you use to support your work execution and monitoring activities?

* *Required*



Which of the following information would you like to be available in the schedule during work execution and monitoring? (you can select multiple options) * *Required*

- ☐ Activity description
- ☐ Planned activity duration
- ☐ Precedence relationships between activities
- ☐ Actual activity status
- ☐ Other

How do you assign work orders to foremen / site workers? (you can select multiple options) *

Required

- ☐ Orally
- ☐ Printed work orders
- ☐ Digital work orders

What kind of information do you include in the work orders / instructions to Foremen or Site Workers? * *Required*

- ☐ Work description
- ☐ Location
- ☐ Expected start and finish dates
- ☐ Construction drawings / Building Information Model (BIM)
- ☐ Materials needed
- ☐ Equipment needed
- ☐ Safety measures /RAMSs
- ☐ Quality specifications
- ☐ Other

Which of the following tasks are typically part of every work order (as opposed to be the subject of dedicated work orders)? (you can select multiple options) * *Required*

- ☐ Quality control
- ☐ Health and Safety check
- ☐ None
- ☐ Other

How do you check work progress status? (you can select multiple options) * *Required*

- ☐ Personal inspection / no formal report
- ☐ Oral report from Foreman
- ☐ Hand-written report received from Foreman
- ☐ Printed report received from Foreman
- ☐ Digital document received from Foreman
- ☐ Foreman reports through mobile application
- ☐ Other

How often do you check work progress status? * *Required*

- ☐ Daily
- ☐ Once a week
- ☐ Once a month
- ☐ After work order is done
- ☐ Never
- ☐ Other

How often do you formally update the project schedule? * *Required*

- ☐ Daily
- ☐ Once a week
- ☐ Once a month
- ☐ After each work order is completed
- ☐ Never
- ☐ Other

Do you use BIM models to support your work execution and monitoring activities? * *Required*

- ☐ No, and I don't see how this would be helpful
- ☐ No, but I could certainly benefit from access to BIM models.
- ☐ Yes

Final thoughts

Do you ever feel frustrated with the technologies and processes currently employed in schedule/cost planning and monitoring activities? If so, which ones (for example, lack of support, things that slow you down, etc.)? *Optional*

Would you like to give us any additional information about your current practice and experience regarding work planning, execution and monitoring ? Or do you have any comment about the questions we asked? *Optional*

Page 4: Work Planning, Execution and Monitoring - Quantity Surveyor

The COGITO project aims to develop a **set of tools to deliver more efficient and effective work planning, execution and monitoring**.

To support the development of those tools, we would like to ask you a set of questions about the systems and processes you currently employ for activities related to work planning, execution and monitoring.

This part of the survey uses a table of questions, [view as separate questions instead?](#)

What computer software / tool do you use for the following tasks?

	Software / Tool
Work with construction drawings	<input type="text"/>
Work with Building Information Models (BIMs)	<input type="text"/>
Plan and monitoring constructions schedules	<input type="text"/>
Plan and monitoring construction costs	<input type="text"/>
Plan and monitoring materials deliveries/consumption	<input type="text"/>
Plan and monitoring plant/equipment deliveries/usage	<input type="text"/>
Work with Risk Assessment and Method Statements (RAMSs)	<input type="text"/>
Work with Work Orders	<input type="text"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the following stakeholders, **what** information do you exchange with them **for work planning, execution and monitoring?** (please select at least one option per row, if you don't share that information with any stakeholder select "None of them") * Required

	Client	Project Manager	Site Manager	Engineer (Civil, M&E, Construction)	HSE Manager / Supervisor	Quality Manager	Foreman / Site worker	Sub-contractor	None of them
(Annotated) 2D drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) 3D models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Voice recordings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Risk Assessment and Method Statements (RAMSs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design issues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Schedule	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work orders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Materials schedules	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Materials usage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Equipment usage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

For the same stakeholders, **how often** do you exchange that work planning, execution and monitoring information? (Please select one option per column, if you don't exchange information with any stakeholder select "Never") * Required

	Client	Project Manager	Site Manager	Engineer (Civil, M&E, Construction)	HSE Manager / Supervisor	Quality Manager	Foreman / Site worker	Sub-contractor
Very frequently (nearly daily)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequently (e.g. once a week)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Occasionally (e.g. once every few weeks)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how** do you exchange that work planning, execution and monitoring information? (please select at least one option per column, if you don't exchange information with any stakeholder select "No exchange of documents/information")

	Client	Project Manager	Site Manager	Engineer (Civil, M&E, Construction)	HSE Manager / Supervisor	Quality Manager	Foreman / Site worker	Sub-contractor
Via Email	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a cloud file sharing service (e.g. Box, Dropbox, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a web-based project management software	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Printed documents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No exchange of documents/information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

What construction activities are most vulnerable to delays? * Required

What construction activities are most vulnerable to cost escalation? * Required

How are construction delays recorded and reported? * Required

Which of the following Key Performance Indicators (KPIs) do you use to monitor project schedule/cost performance? * Required

- ☐ Project time performance (i.e. completed ahead or behind schedule)
- ☐ Project cost performance (i.e. above or below budget)
- ☐ Individual activity time performance (i.e. completed ahead or behind schedule)
- ☐ Individual activity cost performance (i.e. above or below budget)
- ☐ Earned Value Analysis KPIs at project level (SPI, CPI, CV and SV)
- ☐ Earned Value Analysis KPIs for individual activities (SPI, CPI, CV and SV)
- ☐ Costs per unit (e.g. cubic or square meters)
- ☐ Units per man-hour (e.g. cubic or square meters)
- ☐ Resource consumption (people, materials)
- ☐ Costs spent on rework (material, workforce)
- ☐ Time spent on rework
- ☐ Lost man-hours (idle time, safety related, time spent searching for material/workers)
- ☐ Man-hours spent on gathering progress information (e.g. man-hours of quantity surveying)
- ☐ Costs of gathering progress information (e.g. man-hours of quantity surveying)
- ☐ Time spent on information sharing (e.g. meetings)
- ☐ Other

Work Planning (Scheduling and Budgeting)

Do you use BIM models to support your scheduling/budgeting activities? * *Required*

- ☐ No, and I don't see how this would be helpful
- ☐ No, but I could certainly benefit from access to BIM models.
- ☐ Yes

Do you find that method statements provide enough detail in the way the work has to be conducted (construction tasks, workflow) ? * *Required*

- ☐ No
- ☐ Yes

Work Execution and Monitoring

What computer software / tool do you use to support your work execution and monitoring activities?
* *Required*

Which of the following information would you like to be available in the schedule during work execution and monitoring? (you can select multiple options) * *Required*

- ☐ Activity description
- ☐ Planned activity duration
- ☐ Precedence relationships between activities
- ☐ Actual activity status
- ☐ Other

What kind of information do you include in the work orders / instructions to Foremen or Site Workers? * *Required*

- ☐ Work description
- ☐ Location
- ☐ Expected start and finish dates
- ☐ Construction drawings / Building Information Model (BIM)
- ☐ Materials needed
- ☐ Equipment needed
- ☐ Safety measures /RAMSs
- ☐ Quality specifications
- ☐ Other

Which of the following tasks are typically part of every work order (as opposed to be the subject of dedicated work orders)? (you can select multiple options) * *Required*

- ☐ Quality control
- ☐ Health and Safety check
- ☐ None
- ☐ Other

How do you check work progress status? (you can select multiple options) * *Required*

- ☐ Personal inspection / no formal report
- ☐ Oral report from Foreman
- ☐ Hand-written report received from Foreman
- ☐ Printed report received from Foreman
- ☐ Digital document received from Foreman
- ☐ Foreman reports through mobile application
- ☐ Other

How often do you check work progress status? * *Required*

- ☐ Daily
- ☐ Once a week
- ☐ Once a month
- ☐ After work order is done
- ☐ Never
- ☐ Other

How often do you formally update the project schedule? * *Required*

- ☐ Daily
- ☐ Once a week
- ☐ Once a month
- ☐ After each work order is completed
- ☐ Never
- ☐ Other

Do you use BIM models to support your work execution and monitoring activities? * *Required*

- ☐ No, and I don't see how this would be helpful
- ☐ No, but I could certainly benefit from access to BIM models.
- ☐ Yes

Final thoughts

Do you ever feel frustrated with the technologies and processes currently employed in schedule/cost planning and monitoring activities? If so, which ones (for example, lack of support, things that slow you down, etc.)? *Optional*

Would you like to give us any additional information about your current practice and experience regarding work planning, execution and monitoring ? Or do you have any comment about the questions we asked? *Optional*

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Page 5: Work Planning, Execution and Monitoring - Foreman

The COGITO project aims to develop a **set of tools to deliver more efficient and effective work planning, execution and monitoring**.

To support the development of those tools, we would like to ask you a set of questions about the systems and processes you currently employ for activities related to work planning, execution and monitoring.

This part of the survey uses a table of questions, [view as separate questions instead?](#)

What computer software / tool do you use for the following tasks?

	Software / Tool
Work with construction drawings	<input type="text"/>
Plan and monitoring materials deliveries/consumption	<input type="text"/>
Plan and monitoring plant/equipment deliveries/usage	<input type="text"/>
Work with Risk Assessment and Method Statements (RAMSs)	<input type="text"/>
Work with Work Orders	<input type="text"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the following stakeholders, **what** information do you exchange with them **for work planning, execution and monitoring?** (please select at least one option per row, if you don't share that information with any stakeholder select "None of them") * Required

	Site Manager	HSE Manager / Supervisor	Site worker	None of them
(Annotated) 2D drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Voice recordings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Risk Assessment and Method Statements (RAMSs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design issues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work orders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Work progress/status reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Materials schedules/usage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Equipment schedules/usage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how often** do you exchange that work planning, execution and monitoring information? (Please select one option per column, if you don't exchange information with any stakeholder select "Never") * Required

	Site Manager	HSE Manager / Supervisor	Site worker
Very frequently (nearly daily)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequently (e.g. once a week)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Occasionally (e.g. once every few weeks)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how** do you exchange that work planning, execution and monitoring information? (please select at least one option per column, if you don't exchange information with any stakeholder select "No exchange of documents/information" * Required

	Site Manager	HSE Manager / Supervisor	Site worker
Via Email	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a cloud content management and file sharing service (e.g. Box, Dropbox, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a mobile and web-based project management software	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Printed documents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No exchange of documents/information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Work Execution and Monitoring

How do you receive work orders from the Project Manager or Site Manager? (you can select multiple options) * *Required*

- ☐ Orally
- ☐ Hand-written documents
- ☐ Printed documents
- ☐ Digital documents
- ☐ Through a mobile application
- ☐ Other

What kind of information is provided with work needed? (you can select multiple options) * *Required*

- ☐ Work description
- ☐ Work location
- ☐ Expected start and finish dates
- ☐ Construction drawings
- ☐ Building Information Model (BIM)
- ☐ Materials needed
- ☐ Equipment needed
- ☐ Safety measures / RAMSs
- ☐ Quality specifications
- ☐ Other

Which of the following tasks are typically part of every work order (as opposed to be the subject of dedicated work orders)? (you can select multiple options) * *Required*

- ☐ Quality control
- ☐ Health and safety check
- ☐ None
- ☐ Other

How do you report actual activity progress/status? (you can select multiple options) * *Required*

- ☐ Orally
- ☐ Through hand-written reports
- ☐ Through printed reports
- ☐ Through digital reports
- ☐ Through mobile application
- ☐ Other

How often do you report actual activity progress/status? * *Required*

- ☐ Daily
- ☐ Once a week
- ☐ Once a month
- ☐ After work order is done
- ☐ Never
- ☐ Other

What would be your preferred way to report actual activity progress/status? * *Required*

- ☐ Orally
- ☐ Through hand-written reports
- ☐ Through printed reports
- ☐ Through digital reports
- ☐ Through mobile application
- ☐ None, I think it's a waste of time or it should not be my responsibility to report progress/status
- ☐ Other

If you encounter construction delays (or work going faster than planned), do you have to report any additional information? * *Required*

- ☐ No
☐ Yes

What construction activities are most vulnerable to delays? * *Required*

What construction activities are most vulnerable to cost escalation * *Required*

Final thoughts

Do you ever feel frustrated with the technologies and processes currently employed in schedule/cost planning and monitoring activities? If so, which ones (for example, lack of support, things that slow you down, etc.)? *Optional*

Would you like to give us any additional information about your current practice and experience regarding work planning, execution and monitoring ? Or do you have any comment about the questions we asked? *Optional*

Page 6: Quality Control (QC) - Project Manager and Site Manager

The COGITO project aims to develop a set of tools to deliver more efficient, systematic and robust construction quality control (QC) activities.

To support the development of those tools, we would like to ask you a set of questions about the systems and processes you currently employ for QC activities.

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the following stakeholders, **what** information do you exchange with them for Quality Control (QC) purposes? (Please select at least one option per row, if you don't share that QC information with any stakeholder select "None of them". Please keep empty the column corresponding to your role.) * Required

	Project Manager	Site Manager	Quality Manager	Surveyor	Engineer (Civil, M&E, Construction)	Quantity Surveyor	HSE Manager / Supervisor	Foreman / Worker	Subcontractor	None of them
(Annotated) 2D drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) 3D models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Digital Videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Total station surveys	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Laser scanning point clouds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photogrammetric point clouds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Documents/notes/text	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Re)Work orders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how often** do you exchange that QC information? (Please select one option per column, if you don't exchange information with any stakeholder select "Never". Select also "Never" for the column corresponding to your role.) * Required

	Project Manager	Site Manager	Quality Manager	Surveyor	Engineer (Civil, M&E, Construction)	Quantity Surveyor	HSE Manager / Supervisor	Foreman / Worker	Subcontractor
Very frequently (nearly daily)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequently (e.g. once a week)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Occasionally (e.g. once every few weeks)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how** do you exchange that QC information? (Please select at least one option per column, if you don't exchange information with any stakeholder select "No exchange of documents/information". Select also "No exchange of documents/information" for the column corresponding to your role.) * Required

	Project Manager	Site Manager	Quality Manager	Surveyor	Engineer (Civil, M&E, Construction)	Quantity Surveyor	HSE Manager / Supervisor	Foreman / Worker	Subcontractor
Via Email	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a cloud file sharing service (e.g. Box, Dropbox, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a web-based project management software	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Printed documents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No exchange of documents/information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Which construction activity or general area in the construction process (earthworks, substructure, superstructure, MEP, etc) do you think require **more** frequent QC data acquisition? * *Required*

When conducting concrete or steel works, are there areas of particular interests from a QC viewpoint? (e.g. column-beam-slab connections, steel welding points/ bolts) * *Required*

How often would you like to get notifications/updates about the outcome of QC processes? * *Required*

- ☐ Daily
- ☐ Weekly
- ☐ Monthly (e.g. at monthly project meetings)
- ☐ As soon as any defect is found
- ☐ As soon as major defects (only) are found
- ☐ Other

How would you like to be notified about the completion of a QC check? (you can select more than one option) * *Required*

- ☐ By email
- ☐ App notification
- ☐ Printed results/report
- ☐ Other

Which of the following Key Performance Indicators (KPIs) do you use to monitor project/organisation performance in terms of Quality Control (QC)? * *Required*

- ☐ Man-hours spent on QC activities per project (e.g. per €1,000 of project budget)
- ☐ Cost of QC activity per project (e.g. per €1,000 of project budget)
- ☐ Man-hours spent on QC activities per year (e.g. per €1,000 of company turnover)
- ☐ Cost of QC activity per year (e.g. per €1,000 of company turnover)
- ☐ Number of late-detected defects or failures
- ☐ Cost of rework due to late-detected defects or failures
- ☐ Schedule impact of rework due to late-detected defects or failures
- ☐ Other

Final thoughts

Do you ever feel frustrated with the technologies and processes currently employed in your QC activities? If so, which ones (for example, lack of support, things that slow you down, etc.)? *Optional*

Would you like to give us any additional information about your current QC practice and experience? Or do you have any comment about the questions we asked? *Optional*

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Page 7: Quality Control (QC) - Quality Manager, Surveyor

The COGITO project aims to develop a **set of tools to deliver more efficient, systematic and robust construction quality control (QC) activities**.

To support the development of those tools, we would like to ask you a set of questions about the systems and processes you currently employ for QC activities.

This part of the survey uses a table of questions, [view as separate questions instead?](#)

How often do you use the following surveying technologies to acquire visual and/or geometric data on site in relation to quality control activities? *(Please select one option per row, if you don't use that technology, select "Never used")* * Required

	Never used	Once per project	Once per month	Twice per month	Once per week	Once per day	Once per hour	Real time
Total Station	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Laser Scanning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Digital Cameras	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Digital Video Cameras	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Depth Cameras	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wearable Augmented Reality (AR) Headsets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smartphones	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tablets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Drones	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Satellite	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the following stakeholders, **what** information do you exchange with them for Quality Control (QC) purposes? (Please select at least one option per row, if you don't share that QC information with any stakeholder select "None of them". Please keep empty the column corresponding to your role.) * Required

	Project Manager	Site Manager	Quality Manager	Surveyor	Engineer (Civil, M&E, Construction)	Quantity Surveyor	HSE Manager / Supervisor	Foreman / Worker	Subcontractor	None of them
(Annotated) 2D drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) 3D models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Digital Videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Total station surveys	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Laser scanning point clouds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Annotated) Photogrammetric point clouds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Documents/notes/text	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Re)Work orders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how often** do you exchange that QC information? (Please select one option per column, if you don't exchange information with any stakeholder select "Never". Select also "Never" for the column corresponding to your role.) * Required

	Project Manager	Site Manager	Quality Manager	Surveyor	Engineer (Civil, M&E, Construction)	Quantity Surveyor	HSE Manager / Supervisor	Foreman / Worker	Subcontractor
Very frequently (nearly daily)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequently (e.g. once a week)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Occasionally (e.g. once every few weeks)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how** do you exchange that QC information? (Please select at least one option per column, if you don't exchange information with any stakeholder select "No exchange of documents/information". Select also "No exchange of documents/information" for the column corresponding to your role.) * Required

	Project Manager	Site Manager	Quality Manager	Surveyor	Engineer (Civil, M&E, Construction)	Quantity Surveyor	HSE Manager / Supervisor	Foreman / Worker	Subcontractor
Via Email	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a cloud content management and file sharing service (e.g. Box, Dropbox, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a mobile and web-based project management software	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Printed documents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No exchange of documents/information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Is there another important stakeholder (group of stakeholders) with whom you exchange QC information? If so, which one? What information do you exchange? How often? How? *Optional*

Which construction activity or general area in the construction process (earthworks, substructure, superstructure, MEP, etc) do you think require **more** frequent QC data acquisition? * *Required*



When conducting concrete or steel works, are there areas of particular interests from a QC viewpoint? (e.g. column-beam-slab connections, steel welding points/ bolts) * *Required*



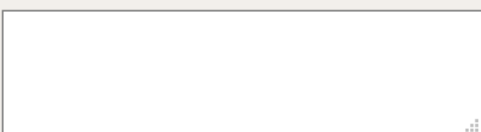
Do you think Construction Schedules should be updated if rework is required due to defects identified during QC activities? * *Required*

- ☐ Yes, always
- ☐ Yes, only for significant defects
- ☐ No, all rework can typically be absorbed by existing activities

What kind of information is needed to organize defect-related rework? (you can select more than one option) * *Required*

- ☐ Element that needs a rework
- ☐ Schedule of work to complete the rework
- ☐ Resources required
- ☐ Assessment of impact on existing activities
- ☐ Other

If you use any specific software package to organise rework, which one is it? *Optional*



Which of the following Key Performance Indicators (KPIs) do you use to monitor project/organisation performance in terms of Quality Control (QC)? * *Required*

- ☐ Man-hours spent on QC activities per project (e.g. per €1,000 of project budget)
- ☐ Cost of QC activity per project (e.g. per €1,000 of project budget)
- ☐ Man-hours spent on QC activities per year (e.g. per €1,000 of company turnover)
- ☐ Cost of QC activity per year (e.g. per €1,000 of company turnover)
- ☐ Number of late-detected defects or failures
- ☐ Cost of rework due to late-detected defects or failures
- ☐ Schedule impact of rework due to late-detected defects or failures
- ☐ Other

Geometric QC

Do you use BIM models to support QC activities? * *Required*

- ☐ No
- ☐ Yes

Do you use Laser Scanning or Photogrammetric Point Clouds for acquiring as-built geometric data? * *Required*

- ☐ Yes
- ☐ No

Do you use Total Stations for acquiring as-built geometric data? * *Required*

- ☐ Yes
- ☐ No

If QC results could be visualised on the 3D (BIM) model of the project, how would you like them to be visualised? (You can select more than one). * *Required*

- ☐ Each object in the model with a single colour marking pass/no pass
- ☐ Each object in the model with a detailed colour map showing deviations between the as-designed geometry and the as-built survey data (for points, lines or/and surfaces)
- ☐ Each object in the model with text annotations with detailed information of the quality control results)
- ☐ I don't think this would be useful
- ☐ Other

In case you need to generate reports of the QC results (digital and/or printed versions), what information should such report include in addition to text content? (you can select more than one) * *Required*

- ☐ Survey measurements
- ☐ Pictures
- ☐ (Link to) BIM model with annotations of survey results
- ☐ Other

Visual QC

Which of the following devices do you use to capture data (images/video/etc.) for Visual QC activities? (You can select more than one options) * *Required*

- ☐ Depth Cameras
- ☐ Wearable AR Headsets
- ☐ Smartphones
- ☐ Tablets
- ☐ Drones
- ☐ Satellite
- ☐ Other

In which format do you store the data for processing and analysis? (You can select more than one options) * *Required*

- ☐ XML
- ☐ JSON
- ☐ TXT
- ☐ PNG/JPEG
- ☐ AVI/MPG/MP4
- ☐ Other

For how long have you been using your current visual inspection system? * *Required*

- ☐ <1 year
- ☐ 1-3 years
- ☐ 3-5 years
- ☐ >5 years

Do you have a library of visual defects (e.g. that you can refer to for comparison, etc.)? * *Required*

- ☐ Yes
- ☐ No

How confident do you feel about detecting defects with your naked eye and estimating their severity? * *Required*

- ☐ Completely confident
- ☐ Fairly confident
- ☐ Somewhat confident
- ☐ Slightly confident
- ☐ Not confident at all

Would you trust a system that would automatically detect visual defects and estimate their severity? * *Required*

- ☐ Yes
- ☐ No

If QC results could be visualised, what would be the best annotation type to indicate the defect type and the estimation of its severity? * *Required*

- ☐ Text only
- ☐ Colourisation
- ☐ Graphic indicator
- ☐ Combination of the above
- ☐ Other

Do you use AR technology to support Visual QC activities? * *Required*

- ☐ Yes
- ☐ No

Final thoughts

Do you ever feel frustrated with the technologies and processes currently employed in your QC activities? If so, which ones (for example, lack of support, things that slow you down, etc.)? *Optional*

Would you like to give us any additional information about your current QC practice and experience? Or do you have any comment about the questions we asked? *Optional*

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Page 8: Safety – HSE Personnel

The COGITO project aims to develop a **set of tools to more efficient, systematic and robust planning and monitoring of Safety on site**.

To support the development of those tools, we would like to ask you a set of questions about the systems and processes you currently employ for activities related to safety planning and monitoring.

What is your specific role with respect to HSE in the project? * *Required*

- ☐ HSE Manager
- ☐ HSE Supervisor
- ☐ HSE Inspector
- ☐ HSE Trainer
- ☐ Other

Does your organisation have and follow a "safety culture"? * *Required*

- ☐ Yes
- ☐ No
- ☐ I don't know

This part of the survey uses a table of questions, [view as separate questions instead?](#)

To what extent do you agree with the following statements? *(Please select one option per row)* *
Required

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Everyone receives compulsory health and safety training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Systems are in place to identify and deal with hazards	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Workplace health and safety is considered extremely important	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There is an active health and safety committee in our organisation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Health and safety procedures are clearly communicated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

To what extent are the safety rules followed according to your experience? * Required

- ☐ All safety rules are followed without exception
- ☐ People generally follow the safety rules
- ☐ The safety rules are guidelines, sometimes followed, sometimes not

To what extent can injuries and/or fatalities be prevented? * *Required*

- ☐ All
- ☐ Almost all
- ☐ Many
- ☐ Some
- ☐ Few
- ☐ None

Which safety best practices do you follow? (you can select multiple options) * *Required*

- ☐ Proactive safety approach
- ☐ Comprehensive safety planning (including Risk Assessment and Method Statement (RAMS))
- ☐ Safety management system
- ☐ Incident reporting system
- ☐ Training
- ☐ Worker participation
- ☐ Inspections
- ☐ Other

This part of the survey uses a table of questions, [view as separate questions instead?](#)

Which is the main device that you use in your safety-related work? (Please select at least one option per column, if you don't use any device for that safety-related work select "None of them") * *Required*

	Safety planning	Safety inspection	Hazard identification	Communicate hazards	Prepare reports
Desktop computer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Laptop	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Phone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smartphone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tablet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
None of them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the following stakeholders, **what** information do you exchange with them for Health & Safety purposes? (Please select at least one option per row, if you don't share that H&S information with any stakeholder select "None of them") * Required

	Client	Project Manager	Site Manager	Architect	Engineer	Foreman	Workers	Subcontractor	Other HSE personnel	None of them
Checklist	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Photos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2D drawings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3D models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Laser scans	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Technical specifications	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Safety plans / Risk Assessment and Method Statement (RAMS)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Regulations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Standards	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Safety best practices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Documents/notes/text	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how often** do you exchange safety-related information? (Please select one option per column, if you don't exchange information with any stakeholder select "Never") * Required

	Client	Project Manager	Site Manager	Architect	Engineer	Foreman	Workers	Sub-contractor	Other HSE personnel
Instantly (e.g. matter of seconds)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Very frequently (e.g. daily)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequently (e.g. once a week)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Occasionally (e.g. once every few weeks)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This part of the survey uses a table of questions, [view as separate questions instead?](#)

For the same stakeholders, **how** do you exchange safety-related information? (please select at least one option per column, if you don't exchange information with any stakeholder select "No exchange of documents/information" * *Required*

	Client	Project Manager	Site Manager	Architect	Engineer	Foreman	Workers	Sub-contractor	Other HSE personnel
Printed documents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via Email	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fax	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Via a cloud file sharing service (e.g. Box, Dropbox, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No exchange of documents/information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Hazard identification

What hazard identification methods do you use? * *Required*

- ☐ What-if analyses
- ☐ Employee reviews/feedback
- ☐ Simulation
- ☐ Experience-based hazard identification (e.g., lessons-learned)
- ☐ Accident analysis and record keeping
- ☐ Checklists
- ☐ Audits (walkthrough HSE audits)
- ☐ Other

Which of the following devices do you use to document hazards on a construction site? *Select all that apply* * *Required*

- ☐ Hand-written notes
- ☐ Digital note taking tools
- ☐ Photo cameras
- ☐ Video cameras
- ☐ Laser scanner
- ☐ Drones
- ☐ Other

Safety Management

This part of the survey uses a table of questions, [view as separate questions instead?](#)

What safety records do you keep in your organization and in which form? (please select at least one column per row, if you don't keep records of that information, select "Not applicable") * Required

	Printed version	Digital format (e.g. pdf, etc)	Web-based (e.g. database, etc)	Not-applicable
Close call (aka. near miss) reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Incident reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Recordable accident reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Meeting minutes of safety/review committees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Do you use Building Information Modelling (BIM) in safety planning and management? * Required

- ☐ Yes
☐ No

Which methods, tools or technologies do you use for safety inspections and control? Please specify process and use of technology (if applicable) * Required

What techniques do you apply for warning workers from hazards? (you can select multiple options)

* Required

- ☐ Verbal instructions (e.g., toolbox meetings)
- ☐ Visual instruction (e.g., signs)
- ☐ Physical obstructions (e.g., guardrails)
- ☐ Mechanised alarm notifications (e.g., beepers)
- ☐ Proactive alert systems (e.g., smart watches)
- ☐ Other

In case you need to generate a safety inspection report, what information would you include in addition to textual content? *Select all that apply* Optional

- ☐ Location data
- ☐ Time recording
- ☐ Condition of hazard
- ☐ Reason (e.g., immediate and underlying causes)
- ☐ Photos or sketches
- ☐ Link to 3D model with annotations (i.e., comments)
- ☐ Other

Safety Training and Evaluation

How frequently does your workforce receive HSE training? * Required

- ☐ At the beginning of their employment
- ☐ For each project
- ☐ Before assigning a critical task
- ☐ Annual retraining
- ☐ As determined by employer
- ☐ Other

What techniques do you use for safety education and training? * *Required*

- ☐ Instructor-led training
- ☐ Case studies
- ☐ Q&A sessions
- ☐ Hands-on training
- ☐ E-learning
- ☐ Computer-based training (e.g., off-the-shelf training programs, virtual reality)
- ☐ Other

How do you evaluate safety training effectiveness? * *Required*

- ☐ Personal observation
- ☐ Written exams
- ☐ Interviews
- ☐ Random feedback
- ☐ Safety bench-marking (e.g., progression of incidents over time)
- ☐ Other KPIs (please specify in the "Other" option)
- ☐ Other

Final thoughts

Do you ever feel frustrated with the technologies and processes currently employed in your Safety-related activities? If so, which ones (for example, lack of support, things that slow you down, etc.)?

Optional

Would you like to give us any additional information about your current Safety practice and experience? Or do you have any comment about the questions we asked? *Optional*

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Page 9: Newsletter

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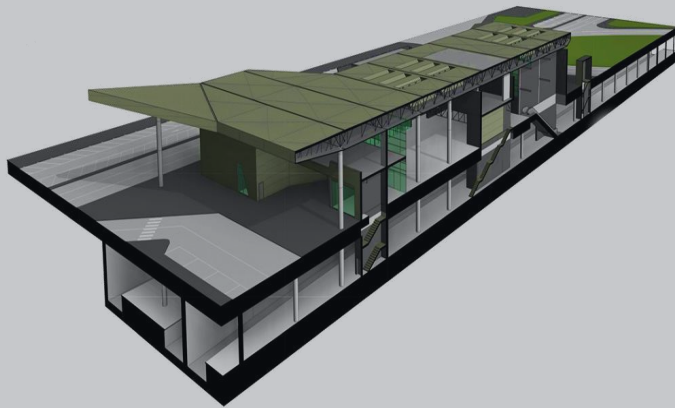
Page 10: Thank you

COGITO Stakeholders Requirements Survey

Thank you very much for participating in this COGITO survey!

SR TEMPLATE

Requirement ID	Description	Originator	Type	Priority
XX-01	Brief description	Main Stakeholder group providing the requirement: <ul style="list-style-type: none"> • Project Manager; • Site Manager; • Quantity Surveyor; • Foreman; • Quality Manager; • Surveyors; • HSE Personnel (Manager, Inspector, or Trainer) 	<ul style="list-style-type: none"> • Functional; • Performance; • Design constraint; • Operational; • Legal; • Process; • Pilot Specific 	<ul style="list-style-type: none"> • MUST; • SHOULD; • COULD; • WOULD



COGITO

CONSTRUCTION PHASE
DIGITAL TWIN MODEL

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958310