ISO/IEC TR 30172

Edition 1.0 2023-10

TECHNICAL REPORT

Internet of things (IoT) - Digital twin – Use cases

colour inside

ISO/IEC TR 30172:2023-10(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 35.020; 35.240

ISBN 978-2-8322-7604-4

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INTERNET OF THINGS (IoT) – DIGITAL TWIN – USE CASES

FOREWORD

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ISO/IEC TR 30172 has been prepared by subcommittee 41: Internet of Things and Digital Twin, of ISO/IEC joint technical committee 1: Information technology. It is Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
JTC1-SC41/335/DTR	JTC1-SC41/363/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document provides use cases of digital twin applications in various domains using the template modified from IEC 62559-2 use case template and ISO/IEC TR 22417 use case template. Use case templates used in ISO/IEC JTC 1/AG 8, ISO/IEC JTC 1/AG 11 and ISO/IEC JTC 1/SC 41/AG 25 are also considered for the template in this document.

The use case template includes two parts: Description of use case; Drawings or diagrams depicting the use case. To collect use cases, the first step is to identify application domains of digital twin (DTw) systems and to provide a use case template. Contributors were requested to submit use cases using the provided template.

For improving the quality of the use case description, a guidance is provided to contributors. The guidance includes DTw concepts and reference models for preparing use cases.

By investigating use cases, it is possible to find the new technical requirements from the market, accelerating the transformation of science and technology achievements.

The use case template helps to group and categorize the use cases according to the identified application domains. Readers of this document can find use cases that relate to the desired application domain and can find original submissions of use cases in Annex A, which includes all submissions of use cases.

INTERNET OF THINGS (IoT) – DIGITAL TWIN – USE CASES

1 Scope

This document provides a collection of representative use cases of digital twin applications in a variety of domains, for example, smart manufacturing and smart cities.

This document is applicable to all types of organization (for example, commercial enterprises, government agencies, and not-for-profit organizations).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
digital twin
DTw
digital representation of a target *entity* (3.2) with data connections that enable convergence between the physical and digital states at an appropriate rate of synchronization

Note 1 to entry: Digital twin has some or all of the capabilities of connection, integration, analysis, simulation, visualization, optimization, collaboration, etc.

Note 2 to entry: Digital twin can provide an integrated view throughout the life cycle of the target entity.

[SOURCE: ISO/IEC 30173:–, 3.1.1]

3.2
entity
<digital twin> thing (physical or non-physical) having a distinct existence

EXAMPLE Person, object, event, idea, process, etc.

[SOURCE: ISO/IEC 20924:2021, 3.1.18, modified – The domain "<digital twin>" and the example have been added.]

3.3
physical entity
entity in the physical world that can be the subject of sensing and/or actuating

[SOURCE: ISO/IEC 20924:2021, 3.1.27]

3.4
digital entity
computational element comprising data elements and procedural elements

[SOURCE: ISO/IEC 30173:–, 3.1.5]

3.5
life cycle
evolution of a system, product, service, project or other human-made entity from conception through retirement

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.21]

3.6
conformity
process of analysis to determine whether a digital twin meets the specified requirements and to form a judgement as to whether the digital entity is fit for its corresponding physical entity

3.7
reliability
ability of an item to perform a required function under given conditions for a given time interval

[SOURCE: IEC 62657-1:2017, 3.1.12, modified – Note 1 to entry and note 2 to entry have been deleted.]

3.8
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

[SOURCE: ISO 9000:2015, 3.8.12, modified – The notes to entry have been deleted.]

3.9
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

[SOURCE: ISO 9000:2015, 3.8.13, modified – The notes to entry have been deleted.]

3.10
robustness
degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.3555]

3.11
fidelity
ability to accurately describe the relevant aspects of the physical counterpart within a well-defined set of conditions by its digital model

3.12
traceability
ability to trace the history, application or location of an object

[SOURCE: ISO 9000:2015, 3.6.13, modified – Note 1 to entry and note 2 to entry have been deleted.]

3.13
synchronization
<digital twin>action of making the states of target and digital entity synchronized, using network for real time system

[SOURCE: ISO/IEC 30173:–, 3.1.20]

3.14
reconfigurability
ability of an artefact to be changed through configuration changes rather than having to modify its underlying structure or its code or both

3.15
interoperability
ability of two or more different systems to exchange information and to use the information that has been exchanged

[SOURCE: ISO/TS 27790:2009, 3.39, modified – In the definition, "systems or components" has been replaced by "different systems".]

4 Abbreviated terms

2D	two dimensional
3D	three dimensional
AI	artificial intelligence
APP	application
BIM	building information modelling
DTw	digital twin
ERP	enterprise resource planning
GIS	geographic information system
HVAC	heating, ventilation, and air conditioning
IED	intelligent electronic device
KPI	key performance indicator
LGA	land grid array
MES	manufacturing execution system
MQTT	message queuing telemetry transport
PC	personal computer
PLC	programmable logic controller
R&D	research and development
SCADA	supervisory control and data acquisition

5 Applications

5.1 Application domains

DTw application domains can be classified into industry-based categories, and specific use cases can serve as examples for each category. The application domains listed below are the targeted areas for collecting use cases related to DTw; however, there may be other areas that are not included in this list.

– building or construction

– urban
– energy
– healthcare
– manufacturing
– home appliance
– mining
– telecommunications
– aerospace
– marine
– environmental monitoring
– transport

5.2 Life cycle stage coverage

The following life cycle stages, based on ISO/IEC 30173:–[1], are considered as target phases to collect use cases:

– inception
– design and development
– verification and validation
– deployment
– operation and monitoring
– re-evaluation
– retirement.

6 Use cases

6.1 Overview

Twelve use cases, based on the use case template described in Annex A, have been collected in Annex B. Some use cases include trademarks such as company names, product names, or service names. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC.

The template provided in Annex A includes two parts: description of use case, and drawings or diagrams depicting the use case.

– Description of use case includes the following elements: name of use case, application area, version management, basic information to use case, scope of use case, objectives of use case, entities that need to be modelled as digital entities in use case, actors, life cycle of the digital twin system in use case, key performance indicators (KPIs) of use case, digital infrastructures.
– Drawings or diagrams depicting the use case includes the following elements: drawing of use case, data flow diagram of use case, sequence diagram(s) of use case, deployment diagram(s) of use case.

6.2 Properties

Description of the use case includes the following.

– Name of the use case to be provided by the contributor of the use code.

[1] Under preparation. Stage at the time of publication: ISO/IEC FDIS 30173:2023.

- Digital twin application area or context of use.
- Version management: the status of the version of the use case.
- Basic information to use case: descriptions of basic information of the use case that includes:
  1) conditions (limitations) of use;
  2) maturity of the use case, for example, in business operation, realized in demonstration project, realized in R&D, in preparation, visionary;
  3) generic, regional or national relation;
  4) vertical application area, for example, automotive industry, petrochemical industry, and aviation industry;
  5) keywords for classification, for example, system integration, performance evaluation, information exchange, IT security, and AI application.
- Scope of use case: the scope that defines the aspects covered by the limits use case or indicates the purview and limitations of the use case.
- Objectives of use case: the intention of the use case, in other words, what is to be accomplished and who will be benefited by the use case and how.
- Narrative of use case.
- Entities that need to be modelled as digital entities in the use case.
- Actors: people, organizations or systems.
- Life cycle of the digital twin system in use case: refers to 5.3 life cycle stage(s) or phase(s) coverage.
- Key performance indicators (KPIs) of use case.
- Digital infrastructures: description of digital infrastructures employed in the use cases.
- Referred standards and standardization committees.
- Referred papers or patent.
- Relation with other known use cases, for example, common requirements.
- Challenges and issues: descriptions of challenges and issues in the use case.
- Data security, privacy, and trustworthiness: issues relating to description of data, privacy, and trustworthiness in the use case.
- User requirements and interactions with other actors.

See Clause A.2 for details.

6.3 Basic statistics

6.3.1 Use cases by application domain

6.3.1.1 Use cases in Annex B

Distribution of use cases in Annex B by application domain is shown in Figure 1.

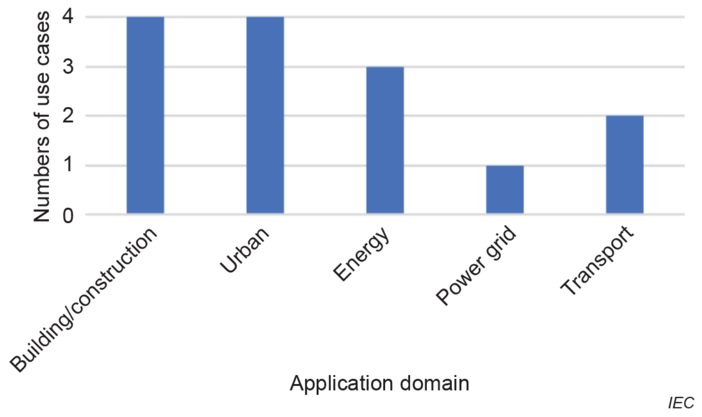


Figure 1 – Distribution of use cases collected in Annex B by application domains

6.3.1.2 Use cases in report of AG 11

Twenty-eight use cases have been collected from JTC 1/AG 11 report on DTw. The use case names and application fields are shown in Table 1. Statistics on distribution of use cases in JTC 1/AG 11 report by application domain are shown in Figure 2.

Table 1 – List of use cases in JTC 1/AG 11 report

Use case name	Application domain
Optimization of production execution	Manufacturing
Dicastal Morocco factory	Manufacturing
Product intelligent manufacturing production line	Manufacturing
Product Intelligent Assembly Process Simulation and Optimization	Manufacturing
Electro-hydraulic servo valve assembly process	Manufacturing
On Digital Twin in Additive Manufacturing	Manufacturing
Digital Twin for massive smart manufacturing	Manufacturing
Visual monitoring system for small and medium-sized machining automatic production line	Manufacturing
Visual monitoring system for assembly process	Manufacturing
The generative design and additive manufacturing of mass customized footwear lattices	Manufacturing
Research and Application of Digital Twin Technology in Joint Ship Hull Workshop	Manufacturing
Integrated Digital System for Smart Ship Pipeline Factory	Manufacturing
Luxury cruise sheet section turning device	Manufacturing
Dynamic scheduling of manufacturing tasks between multiple robots	Manufacturing
On-machine measurement for tool-life optimization	Manufacturing
Advanced Metrology	Manufacturing
Integrated Digital System for Smart Ship Pipeline Factory	Manufacturing
Digital Twin Technology Applied to the Automated Driving Test and Evaluation System	Manufacturing
Digital twin system of tobacco industry chain	Manufacturing
Research on the construction and application of digital twin in intelligent oil and gas pipeline network	Energy
Smart Cities with Digital Twin Technology	Urban
Digital Twin City Smart Control Cloud-Platform	Urban
Elderly Healthcare Services Using Digital Twin	Healthcare

Use case name	Application domain
Prototype Twinning	Prototyping
Digital Intelligence Huaguoyuan	Community
Digital Twin of Supply Chain for Automotive Industry	Supply Chain
Use of AI systems digital twins for conformity assessment	General Scenario
Digital Twin Solution for Thermal Fluid Systems based on Flownex	General Scenario

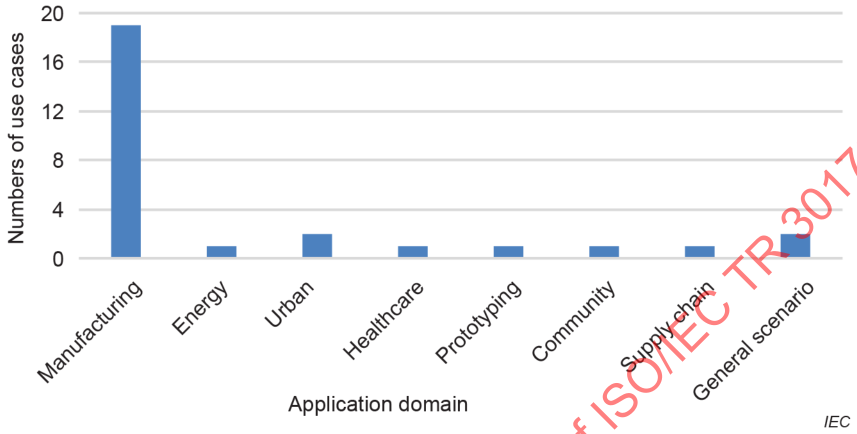


Figure 2 – Statistics on adopted key technologies from use cases in JTC 1/AG 11 report

6.3.1.3 Use cases in IEC SRD 62913-2-3 and IEC SRD 62913-2-4

A list of described use cases in IEC SRD 62913-2-3 and IEC SRD 62913-2-4 can be also considered:

- IEC SRD 62913-2-3-S050 "Process data related to the smart home behaviour to aggregate (forecasting, real-time), assess the value of, and certify flexibilities"
- IEC SRD 62913-2-3-S053 "Process data related to the Smart Building behaviour to aggregate (forecasting, real-time), assess the value of, and certify flexibilities"
- IEC SRD 62913-2-3-S069 "Elaborate a charge or discharge schedule"
- IEC SRD 62913-2-3-S079 "Forecast electricity price"
- IEC SRD 62913-2-3-S080 "Forecast power demand"
- IEC SRD 62913-2-3-S091 "Perform renewable energy forecasts"
- IEC SRD 62913-2-4-S007 "Forecast FCR capacity of an EV aggregate"

6.3.2 Use cases by status of life cycle

Distribution of each of the Annex B use case by status of life cycle is shown in Table 2.

Table 2 – List of use cases by status of life cycle

Status of life cycle	Numbers of use cases
Inception phase	4
Design and development phase	6
Installation phase	4
Deployment phase	11
Operation and monitoring phase	4
Re-evaluate phase	3
Retirement phase	2

7 Use case summaries

Table 3 shows summary information for each of the use cases, including use case name, application domain, and status.

Table 3 – List of use cases

Corresponding clause number	Use case name	Application domain	Status of life cycle
B.1	Smart building operation based on digital twins	Building or construction	Deployment phase
B.2	Digital twin based industrial smart park design and construction	Urban	Deployment phase
B.3	Digital twin based smart city management system	Urban	Re-evaluate phase
B.4	Construction and application of digital twins for a large oil and gas processing facility	Energy	Deployment phase
B.5	Monitoring of Water	Building or construction	Deployment phase; Installation phase
B.6	Smart grid operation based on digital twin	Power grid	Deployment phase; Operation and monitoring phase
B.7	Construction-phase digital twin model	Building or construction	Design and development phase
B.8	Consumer behavioural digital twin for energy demand prediction	Building or construction	Design and development phase; Deployment phase; Installation phase
B.9	Greater Hobart Digital Twin	Urban	Design and development phase
B.10	NSW Spatial Digital Twin	Urban	Deployment phase
B.11	Sydney Trains Engineering and Maintenance Digital Twin	Transport	Inception phase
B.12	TfNSW Infrastructure Delivery Digital Twin	Transport	Inception phase; Design and development phase

Corresponding clause number	Use case name	Application domain	Status of life cycle
B.13	From grid planning to grid operation and maintenance, based on grid digital twin(s)	Energy	Inception phase; Design and development phase; Verification and validation phase; Deployment phase; Operation and monitoring phase; Re-evaluate phase; Retirement phase
B.14	Electrical field level subsystem digital twin, as the basis for its specification, commissioning, operation and maintenance	Energy	Inception phase; Design and development phase; Verification and validation phase; Deployment phase; Operation and monitoring phase; Re-evaluate phase; Retirement phase

Annex A
(informative)

Use case template

A.1 General

This Annex A is the template used for collecting use cases. The terms used in that template were defined in 5.1.

The template is based on:

– IEC 62559-2
– ISO/IEC TR 22417
– template developed by JTC 1/AG 8
– template developed by JTC 1/SC 41/AG 25
– template developed by JTC 1/AG 11

A.2 Description of use case

A.2.1 Name of use case

ID	Name of use case For example, xx (Application area)-xx(Application scenario)-xx(National Body)

A.2.2 Digital twin application area or context of use

Application area or context of use For example, manufacturing, agriculture, digital marketing, education, energy, finance technology, healthcare, home or service robotics, ICT, logistics, and city management.

A.2.3 Version management

Changes or version For example, V1.0	Date For example: xx(year)-xx(month)-xx(day)	Name Author(s) or committee	Approval status (optional) For example: draft, for comments, for ballot

A.2.4 Basic information to use case

Source(s) or literature (optional)	**Link (optional)**	**Conditions (limitations) of use (optional)**
Maturity of use case		
☐ in business operation ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
Vertical application area For example, Automotive industry, petrochemical industry, and aviation industry.		
Well-known or related commercial or existing use cases (optional)		

Keywords for classification For example, system integration, performance evaluation, information exchange, IT security, and AI application.

A.2.5 Scope of use case (bullet points)

Scope of use case
Include but not limited to following items: • Describe xxxx in xxx scenario; • Describe xxx among xxx systems; • Describe digital twin system architecture in xxx scenario; • Describe requirements about xxx in xxx area or scenario

A.2.6 Objectives of use case (bullet points)

Objectives of use case
• Objective 1: to obtain, realize, minimize or satisfy xxx • Objective 2: xxx • …

A.2.7 Narrative of use case

Narrative of use case
Short description – max. 3 sentences
Complete description

A.2.8 Entities which need to be modelled as digital entities in use case

Entity name For example, robot, sensor, building, person, and car.	**Data**	**Model type**	**Requirements or constraints on the models**

NOTE

(1) Data: can include asset data, operational data, context data, metadata, operational history, maintenance history, and knowledge.

(2) Model type: can include physical model, chemical model, statistical model, AI model, engineering model, and metamodel.

(3) The types of requirements or constraints on the models: can involve performance requirements of the models, input and output requirements of the models, and important constraints. Constraints: can include legal contracts, legal regulations, and others (including regional regulations).

A.2.9 Actors: people, organizations or systems

Actor name For example, $Actor_n$: xxx	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
	☐ system actor ☐ business actor: role: ______		
	☐ system actor ☐ business actor: role: ______		
	☐ system actor ☐ business actor: role: ______		
	☐ system actor ☐ business actor: role: ______		
	☐ system actor ☐ business actor: role: ______		

	☐ system actor ☐ business actor: role: ______		

NOTE 1 According to IEC 62559-2:

(1) Actor refers to people, organizations or systems that communicates and interacts, such as, consumer, customer energy management system, distribution management system, distribution system operator, meter operator, and system operator.

NOTE 2 These actors can include people, software applications, systems, databases, and even the power system itself.

The entities in A.2.8 refer to the objects that will be modelled as digital models in the digital space. The actors in A.2.9 refer to the people, organizations or systems that will trigger or have influences on the digital twin system. The business actor refers to the people, organizations that can apply, trigger or have influences on the digital twin systems.

(2) Actor type is divided into system actors and business actors.

- System actors are covering functions or devices. For example, in the energy system area, system actors are defined in the interface reference model (IEC 61968-1).
- A business actor specifies in fact a "role"; roles can be taken by diverse entities.

Typical examples for actors or roles in the energy system:

- "Meter operator" is a role that can be taken either by a specific company or by a distribution system operator (DSO) company;
- "Aggregator" is a role that could be taken by many entities like a DSO company, an energy service company (ESCO) or an energy supplier.

(3) Examples of actors given in IEC 62559-2:2015, Table A.1 are as follows:

Consumer refers to end user of electricity, gas, water or heat.

NOTE 3 As the consumer can also generate energy using a distributed energy resource, the consumer is sometimes called the "prosumer".

Customer energy management system refers to energy management system for energy customers to optimize the utilization of energy according to supply contracts or other economic targets. Customer energy management system is responsible for gathering flexibilities within the customer premises and providing them to an aggregator, and therefore does not directly participate in flexibility markets.

A.2.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☐ deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

A.2.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
		For Objective x, xxxx.

NOTE Some qualitative indicators, such as synchronization, reliability, verification, robustness, traceability, reconfigurability and some quantitative indicators can be taken into consideration. The description of some qualitative indicators is given in Table A.1 and defined in Clause 3.

Table A.1 – Description of some qualitative indicators

Name	Description
conformity	process of analysis to determine whether a digital twin meets the specified requirements and to form a judgement as to whether the digital entity is fit for its corresponding physical entity
synchronization	action of making the states of target and digital entity synchronized, using network for real time system NOTE Synchronization is the measurement of or process by which the correspondence between a DTw and its target is measured or achieved.
reliability	ability of an item to perform a required function under given conditions for a given time interval
verification	confirmation, through the provision of objective evidence, that specified requirements have been fulfilled
validation	confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled
robustness	degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions
fidelity	ability to accurately describe the relevant aspects of the physical counterpart within a well-defined set of conditions by its digital model
traceability	ability to trace the history, application or location of an object
reconfigurability	ability of an artefact to be changed through configuration changes rather than having to modify its underlying structure or its code or both

A.2.12 Digital infrastructures

Name	Description	Impact on use case

NOTE Digital infrastructures of a digital twin refer to the infrastructure that will exchange the information with the digital twin system in the use case, such as Computing devices, Sensors, Artificial intelligence, Situation- or Context-Awareness, Localization and Tracking, Actuators, Controls, Energy Consumption, Time Synchronization, Management Functions or Risk management, Unique Identification, Database, Networking, IT Security, Data Privacy, and Simulations.

A.2.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

A.2.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

A.2.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

A.2.16 General remarks (optional)

General remarks

A.2.17 Challenges and issues (optional)

Challenges and issues

A.2.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications and systems
Privacy requirements and implications for applications and systems
Trustworthiness requirements and implications for applications and systems

A.2.19 User requirements and interactions with other actors (optional)

User requirements and interactions

A.3 Drawings or diagrams depicting the use case

A.3.1 Drawing of use case

Drawing or diagram of use case – for example, graphic depiction of use scenarios, or "use case diagram"

A.3.2 Data flow diagram of use case (optional)

Data flow diagram of use case

NOTE Entities in A.3.2 can be aligned with entities listed in A.2.8.

A.3.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

NOTE In addition to a high-level sequence diagram, it can be helpful to split out critical interactions to provide additional details on actors involved at such stages (for example providing information on handling of fault conditions).

A.3.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

A.3.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)

Annex B
(informative)

Collected use cases

B.1 Smart building – Smart building operation based on digital twins

B.1.1 Description of use case

B.1.1.1 Name of use case

ID	Name of use case
001	Smart building – Smart building operation based on digital twins – CN

B.1.1.2 Digital twin application area or context of use

Application area or context of use
• Smart building NOTE Donghe Center Building H in China has the total construction area of about 86 000 m^2, with 23 stories above ground and a height of 101,5 m. Its digital twin building system could reflect the whole life cycle process of the corresponding physical building, by applying physical architecture model and a variety of sensors to simulate the process and complete the mapping in the virtual space. The digital twin building system has four characteristics: accurate mapping, virtual–real interaction, software definition, and intelligent intervention.

B.1.1.3 Version management

Changes or version	Date	Name Author(s) or committee	Approval status (optional)
V 1.0	2021-07-11	Jiangf	draft
V 2.0	2021-09-15	Jiangf	draft

B.1.1.4 Basic information to use case

Source(s) or literature (optional)	Link (optional)	Conditions (limitations) of use (optional)
/	/	/
Maturity of use case		
☑ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
CHINA		
Vertical application area		
Intelligent building		
Well-known or related commercial or existing use cases (optional)		
Keywords for classification		
system integration; information exchange		

B.1.1.5 Scope of use case

Scope of use case
• Describe operation management and maintenance of the building based on digital twins and related systems; • Describe the intelligent building management system architecture in this scenario

B.1.1.6 Objectives of use case

Objectives of use case
• Objective 1: to realize intelligent property management and intelligent energy management of the building; • Objective 2: to achieve energy conservation, environmental protection and lower the operational cost; • Objective 3: to reduce the cost of management personnel, reduce building energy consumption cost, and optimize the qualification management strategy.

B.1.1.7 Narrative of use case

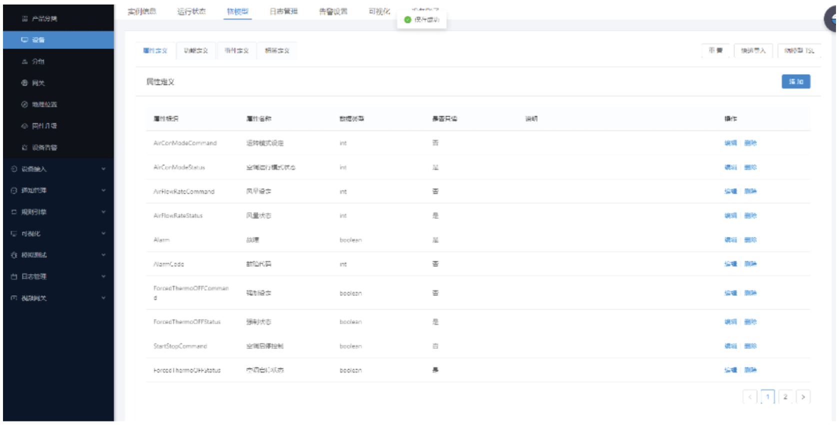
Narrative of use case
Short description
This use case establishes the mapping among physical entities and their corresponding virtual models based on data collection and integration, including key device parameters and logical strategy of operation and management. The use case establishes the precipitation algorithm based on experience and knowledge. At the same time, the use case achieves analysis of operation optimization strategies through real-time condition monitoring of devices and facilities as well as data acquisition, storage, analysis, visualization and use.
Complete description
The intelligent building management system in the use case includes the subsystems related to building automation, energy management, intelligent lighting, fire control, security and environmental monitoring. At the same time, the system integrates the various subsystems together organically to complete both the mapping among the physical environment and digital virtual reality space and the bilateral control. The system provides the building the ability of self-diagnosis, self-analysis, and some degree of self-decision. The system manages more than 30 000 dynamic data (such as data from environmental monitoring, intelligent lighting, energy management, equipment management, photovoltaic power generation, light-current system, HVAC system, water supply and drainage system, industrial control systems) and additional static data (static data such as 3D model, drawings, and technical documents.). The system covers the whole life cycle of the building, including the design, construction, and operations of the building. It achieves 3D virtual monitoring, equipment maintenance, energy management, property management, and further achieves the purpose of safety, stability, green, and intelligence. The system also includes energy saving and optimization control logistics and strategies to save energy and improve management effect in building public areas without any switch panel. Presently, the lighting energy saving rate reaches 70 %, and air conditioning energy saving rate reaches 17 % by statistics of more than a year of operation data. For special conditions (such as maintenance and reception), only simple configuration operation can realize the control of all the devices quickly to avoid manually changing the building equipment operation state and mode. System description: The whole system through BIM forward design, operation and maintenance model into a large number of designer languages, and the construction of a perfect coding system to achieve the model and drawings, equipment systems, systems between the virtual mapping and configuration association. The architecture of self-perception, self-decision, self-diagnosis and self-execution in the digital twin system is fully dependent on the developed digital graphics platform and industrial Internet platform. It realizes multi-source data fusion through the integration of end, edge and cloud equipment. In addition, lighting, air conditioning, fresh air, fan are all intelligently controlled in the public area of the building without any switch panel. Building operation and maintenance only need a property engineer.

IEC

(1) Digital entity establishment: Because information of the entire life cycle of a project in three dimensions is collected, uses can directly view any drawings, any equipment and piping of fast positioning, and any component of the query, including design attributes (such as size, the working set, system and specifications), procurement information (such as brand, manufacturer, date of production) as well as the running data, alarm and maintenance logs. It greatly improves the operational efficiency.

IEC

(2) Object model building: According to business requirements, the object models, the realization of attribute definition, feature identification, function definition, and event definition are established based on the virtual models. In addition, the abstract mapping between the virtual model and the real device is completed. At present, the system supports the object model construction of common air conditioning, lighting, water pump and other general equipment, and establishes the object model and review process. It can support user customization to edit, add, or modify the object model. Finally, the system is released through a variety of communication protocols to complete docking with the real side of the data and system correlation.

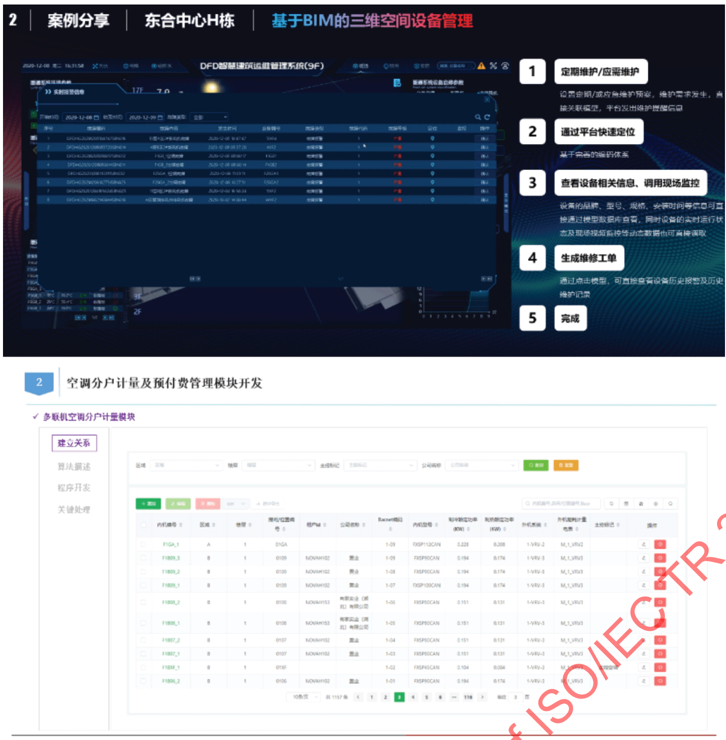


IEC

(3) Establishment of strategy optimization model: Similarly, the use case puts a large number of energy saving and optimized control logic strategies into the system, so that the building does not need a switch panel, and the energy saving and management effect is remarkable. Based on operation data statistics of more than a year, the lighting energy saving rate has reached 70 %, the air conditioning energy saving rate has reached 17 %. In terms of special conditions (such as maintenance, reception), only a simple configuration operation is needed to realize the control of all the devices quickly while manually changing the building equipment operation state and mode. The labour cost of building operation and maintenance was greatly reduced.

IEC

(4) Business system application: The system is completely in the three-dimensional process of equipment management. In terms of the biggest difference with traditional operations, the use case doesn’t apply the concept of various systems and implements a unified platform containing a lot of equipment diagnosis logics (including regular maintenance or emergency fault maintenance). Through the platform, the use case can directly locate the point of failure and retrieve the design parameters, drawings, historical maintenance records, and on-site video surveillance of the equipment to assist maintenance decisions. Finally, it can generate maintenance work orders. The whole process is fast, accurate and effective.



IEC

B.1.1.8 Entities that need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Building	Geometric information, parameter information, material information, procurement information	physical model	Performance requirements: consistency, accuracy and fineness
Electromechanical equipment	Geometry information, parameter information, material information, procurement information, maintenance information, energy consumption information, sensor data, operation information	physical model	Performance requirements: consistency, accuracy and fineness
Environment	Temperature, humidity, illumination, CO_2 concentration, human flow	physical model	Performance requirements: consistency, accuracy and fineness

Entity name	Data	Model type	Requirements or constraints on the models
Predictive analysis rules and algorithms	Equipment operation data, operation time data, tenant management data	artificial intelligence model	Performance requirements: accuracy rate, recall rate; Input and output requirements: interface
Fault diagnosis rules and algorithms	Equipment operation data, alarm failure data, sensor data, scheme execution data	artificial intelligence model	Performance requirements: accuracy rate, recall rate; Input and output requirements: interfaces
Process or rule	Business management process data, user role data, rights management data	knowledge model	Performance requirements: accuracy rate, recall rate; Input and output requirements: interfaces
Energy consumption optimization rules and algorithms	Equipment energy consumption data, time data, historical data	artificial intelligence model	Performance requirements: accuracy rate, recall rate; Input and output requirements: interfaces
Operation and maintenance knowledge	Maintenance orders, drawings, technical documents	knowledge model	Performance requirements: accuracy rate, recall rate; Input and output requirements: interfaces

B.1.1.9 Actors: people, organizations or systems

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
System manager	☐ system actor ☑ business actor: role: user	System users, who view the running status of the building, data statistics, control and manage the system.	
System operation and maintenance personnel	☐ system actor ☑ business actor: role: user	System operation and maintenance personnel, who are responsible for rights management, system configuration, upgrade and optimization.	
Decision user	☐ system actor ☑ business actor: role: user	System decision level users, who are responsible for data report view, data analysis and statistical use, construction management decisions.	
Project manager	☐ system actor ☑ business actor: role: service provider	Project manager, who is responsible for system requirements, and development, operation and maintenance management of the system.	
Developer	☐ system actor ☑ business actor: role: service provider	System coding developers, who are responsible for data development, background development, front-end development, 3D component development.	
Modellers	☐ system actor ☑ business actor: role: service provider	Modellers can be divided into system modeller, 3D modeller, parametric modeller, knowledge modeller, artificial intelligence modeller, rule modeller.	
Field implementer	☐ system actor ☑ business actor: role: service provider	System field implementation personnel, who are responsible for installation, deployment, debugging and testing of the system.	

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
Database engineer	☐ system actor ☑ business actor: role: service provider	Data collection personnel, who are responsible for report input, database strategy, data model establishment.	
Designer	☐ system actor ☑ business actor: role: service provider	Designer, who is responsible for architectural design, system design, model design, business process design.	
Civil construction staff	☐ system actor ☑ business actor: role: service provider	Civil construction staff, who is responsible for construction and maintenance of civil and structural works	
Equipment procuremen t staff	☐ system actor ☑ business actor: role: service provider	Equipment procurement staff, who are responsible for the purchase and installation of important equipment and facilities	
Mechanical and electrical installation staff	☐ system actor ☑ business actor: role: service provider	Mechanical and electrical installation staff, who are responsible for electromechanical equipment, cable wiring, network weak current, sensor deployment and installation	

B.1.1.10 Life cycle of use case

Life cycle of use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☑ deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.1.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Consistency	Agreement or logical coherence among the digital entities and the corresponding physical entities, in other words, the specified requirements.	For Objective 3, optimize the qualification management strategy through high-accuracy behaviours of digital entities.
Energy saving	Lighting energy saving rate	70 %
	Air conditioning energy saving rate	17 %
Cost	Reduction of property management personnel	30 %
	Reduction of equipment losses and maintenance costs	20 %

B.1.1.12 Digital infrastructures

Name	Description	Impact on use case
Sensors	All kinds of complete equipment PLC or DDC sensors, energy meters, IoT terminals, files and other communication terminals	Such devices access the edge layer of the platform through various IO links (such as LAN, WIFI, RTU, ZigBee, HTTP, TCP or IP, and MQTT.) or directly connect with the private cloud service providers.
Data storage devices	The real-time collected data are stored. According to the characteristics of large data volume and high frequency of architectural group data, a database cluster is built to satisfy the persistence of a large number of highly concurrent real-time data.	For the storage design of massive historical data of architectural complex, the data are partitioned and stored in pieces through the design of database partition and sub-database to meet the requirements of the upper application for data re-application.

B.1.1.13 Challenges and issues

Issue	Impact of issue on use case	Reference
Real-time data problems	Data from different sources have different time cycle, which can result in the analysis errors and accuracy reduction.	

B.1.1.14 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.1.1.15 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.1.1.16 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.1.1.17 General remarks (optional)

General remarks

B.1.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications, systems
The use case deploys the VPN (Virtual Private Network) system. It can access certification management system, mobile security management system and firewall system to provide the functions of remote access and data encryption transmission for remote operation and maintenance users.
Privacy requirements and implications for applications, systems
Trustworthiness requirements and implications for applications, systems

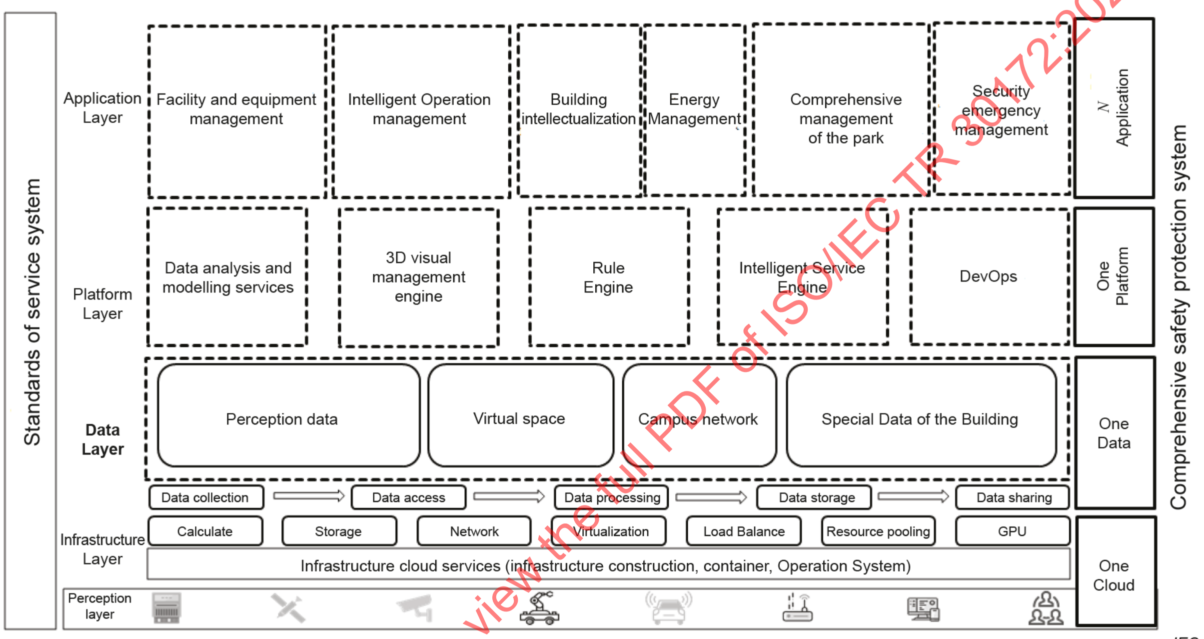
B.1.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.1.2 Drawings or diagrams depicting the use case

B.1.2.1 Drawing of use case

Drawing or diagram of use case



IEC

The use case adopts the design of micro service architecture based on internet data collection technologies, big data management and analysis technologies, the whole process of encoding technology, BIM technologies, and 3D visualization technologies to build wisdom park or building integrated control platform. The platform realizes the resource flexibility management, modular application development, rapid response to business demands and ubiquitous connection of edge layers.

The architecture includes perception layer, infrastructure layer, data layer, platform layer and application layer. The details are shown as follows:

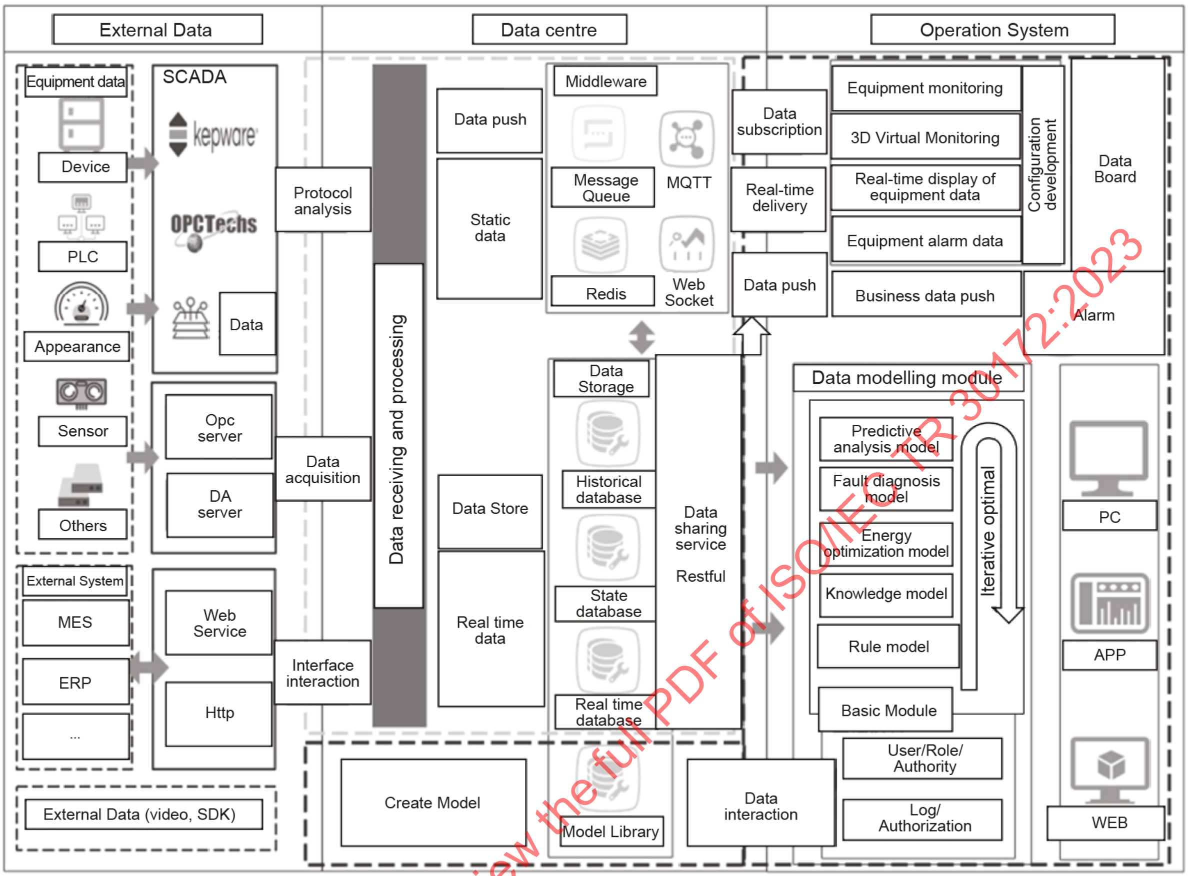
Perception layer includes building automation, weak-current control subsystem and other subsystems. Infrastructure layer includes industrial cloud.

Data layer is used for data storage, processing and sharing.

Platform layer is mainly to complete data collection, storage, processing, analysis, data interaction, intelligent computing, diagnosis and decision.

Application layer is mainly to complete the interaction with users, such as operation module, intelligent energy management module, wisdom property management module, intelligent building, personnel management, and vehicle intelligent security management. The client can access and display each system of the platform through a PC browser or a mobile device application or large-screen display.

B.1.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case


IEC

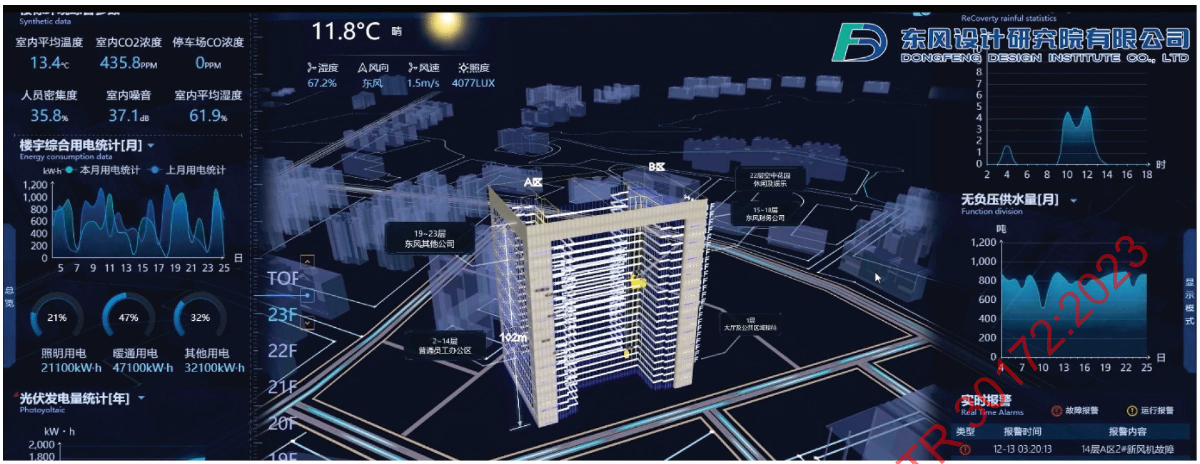
B.1.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.1.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.1.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)
 IEC

B.2 Industrial smart park – Digital twin based industrial smart park design and construction

B.2.1 Description of use case

B.2.1.1 Name of use case

ID	Name of use case
002	Smart park – Digital twin based industrial smart park design and construction - CN

B.2.1.2 Digital twin application area or context of use

Application area or context of use
City management

B.2.1.3 Version management

Changes or version	Date	Name Author(s) or committee	Approval status (optional)
V1.0	2021-10-21	Tencent Cloud	draft

B.2.1.4 Basic information to use case

Source(s) or literature (optional)	**Link (optional)**	**Conditions (limitations) of use (optional)**
Maturity of use case		
☑ in business operation ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
CHINA		
Vertical application area		
industrial smart park		
Well-known or related commercial or existing use cases (optional)		
Keywords for classification		
AI, cloud computing, IoT, IT security		

B.2.1.5 Scope of use case

Scope of use case
Include but not limited to following items: • Address the spatial design, landscape planning, transportation planning, municipal planning and other schemes for industrial smart park by utilization of digital twin; • Describe the real-time construction progress status of the industrial smart park; • Give system architecture for this industrial smart park scenario.

B.2.1.6 Objectives of use case

Objectives of use case
• Objective 1: to realize effective and precise spatial design, landscape planning, transportation planning, municipal planning and other schemes of the industrial smart park; • Objective 2: to achieve precise visualization of the construction progress status of the industrial smart park with auxiliary capability of overall decision-making. • Objective 3: to reduce the economic and time cost of data acquisition, and to lower the safety risks of the technical personnel.

B.2.1.7 Narrative of use case

Narrative of use case
Short description
This use case explores the digital pre-construction, pre-judgment, and visualization for the planning and construction of the industrial smart park via two digital twin platforms. On one side, the planning and design platform achieves spatial design, landscape planning, transportation planning, municipal planning and others for the industrial smart park based on the high-precision rendering effect as well as various operabilities. On the other hand, the construction visualization platform shows the real-time construction progress status of the industrial smart park by integrating the industry-leading lightweight data technology, 3D as well as GIS (Geographic Information System) visualization technology, simple and easy-to-use functional operation.
Complete description
• Planning and design of the industrial smart park The planning and design platform is based on the high-quality and high-precision rendering effect, as well as operation of UE4 (Unreal Engine version 4) engine. It closely focuses on the overall planning and design business of the Shenzhen Bay super headquarter base, such as area overview, spatial design, landscape planning, traffic planning and municipal planning. It uses a high-quality three-dimensional visualization technology to realize the precise display of the concept and highlights of the industrial smart park planning via a variety of human–computer interaction methods and interaction effects. Further, through JS-SDK (a cloud game development kit), the planning and design platform adopts the cloud rendering technology. It can browse and display on the web, which breaks the limitations of the traditional C or S architecture and greatly alleviates the requirements of hardware configuration on the client. • Real-time construction progress visualization of the industrial smart park The construction of the visualization platform applies the three-dimensional measurement function, so that important information such as site area, volume and length can be collected without technicians on the site. Furthermore, it can ensure personnel safety and improve the work efficiency.

In addition, it displays the three-dimensional inclined model in time series, which is used to show the project progress and understand the construction progress and construction effect in different time periods. It is helpful for the engineering department to intuitively control the overall progress of the project, as well as to arrange the construction plan and process interleaving for each milestone in a reasonable manner. More importantly, it reduces the economic and time cost of data acquisition of the three-dimensional model and restores the real appearance of the industrial smart park more intuitively and effectively than the BIM model.

IEC

- Interconnections of the two platforms

  The planning and design platform can integrate the Client or Server and Browser or Server architecture with the construction visualization platform, which can be browsed on the web. Moreover, through RESTFUL protocol, the user information of the two platforms is integrated into the same database to uniformly manage the user permissions. Only one authentication is required to realize the mutual switching between the two platforms.

IEC

B.2.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Building	geometric, parameter, material, procurement	physical model	consistency, accuracy and fineness
Park	planned plot information, earthwork survey, area measurement	AI model	consistency, accuracy and fineness
Environment	sky, atmosphere, clouds and other natural environment and light	AI model	consistency, accuracy and fineness
Landscape	arrangement of flowers and plants, pavement of the ground, placement of public facilities such as seats	AI model	consistency, accuracy and fineness
Moving car	geometric, material, velocity	AI model	consistency, accuracy and fineness
Pedestrian	parameter, velocity	AI model	consistency, accuracy and fineness
Engineering process control	process	Knowledge model	accuracy rate, interface
Fault diagnosis	scheme execution, alarm failure	Knowledge model	accuracy rate, recall rate

B.2.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	Actor interactions
Project manager	☐ system actor ☑ business actor: role: user	Project manager, who is responsible for system requirements, development, operation and maintenance management	
Decision maker	☐ system actor ☑ business actor: role: user	System decision level user, who is responsible for data report view, data analysis and statistical use, construction management decisions	

Actor name	Actor type	Actor description	Actor interactions
Designer	☐ system actor ☑ business actor: role: service provider	Designer, who is responsible for architectural design, system design, model design, business process design.	
Modeller	☐ system actor ☑ business actor: role: service provider	Modellers can be divided into system modeller, 3D modeller, parametric modeller, knowledge modeller, artificial intelligence modeller, rule modeller	
Developer	☐ system actor ☑ business actor: role: service provider	Developer, who is responsible for system coding developers, data development, background development, front-end development, 3D component development	
Industrial smart park construction staff	☐ system actor ☑ business actor: role: service provider	Industrial smart park construction staff, who are responsible for construction and maintenance of the industrial smart park	

B.2.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☑ deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.2.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Security	Provide security access, data encryption, secure storage and other policies for platform services	
Synchronization	Display the equipment position and status in the building model. When something happens, users can immediately click the camera to view the real-time picture.	
Reliability	Focus on the on-site real scene model and information collection, comprehensively show the progress status of the project, pay attention to the decision-making, overall planning and visual assistance ability, and realize the visual business function of regional project information.	

B.2.1.12 Digital infrastructures

Name	Description	Impact on use case

B.2.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.2.1.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.2.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.2.1.16 General remarks (optional)

General remarks

B.2.1.17 Challenges and issues (optional)

Challenges and issues

B.2.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications, systems
Privacy requirements and implications for applications, systems
Trustworthiness requirements and implications for applications, systems

B.2.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.2.2 Drawings or diagrams depicting the use case

B.2.2.1 Drawing of use case

Drawing or diagram of use case

B.2.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.2.2.3 Sequence diagram(s) of use case (optional)

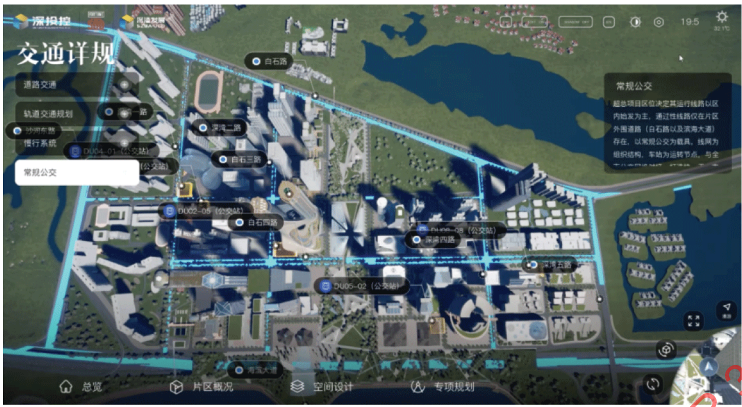
Sequence diagram(s) of use case

B.2.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.2.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)



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B.3 Smart city – Digital twin based smart city management system

B.3.1 Description of use case

B.3.1.1 Name of use case

ID	Name of use case
003	Smart city – Digital twin based smart city management system (CN)

B.3.1.2 Digital twin application area or context of use

Application area or context of use
Smart city

B.3.1.3 Version management

Changes or version	Date	Name Author(s) or committee	Approval status (optional)
V1.0	2021-10-21	Tencent Cloud	draft

B.3.1.4 Basic information to use case

Source(s) or literature (optional)	**Link (optional)**	**Conditions (limitations) of use (optional)**
	https://www.sohu.com/a/434518600_212034	
Maturity of use case		
☑ in business operation ☑ realized in demonstration project ☐ realized in R&D ☐ in preparation ☑ visionary		
Generic, regional or national relation		
Shanghai, China		
Vertical application area For example, Automotive industry, petrochemical industry, aviation industry.		
industrial smart park, smart building		
Well-known or related commercial or existing use cases (optional)		
Keywords for classification		
system integration, big data, AI		

B.3.1.5 Scope of use case

Scope of use case
Include but not limited to following items: – Address digital twin-based AI park platform that realizes "one map and one system for one park". – Give system architecture for this industrial smart park scenario.

B.3.1.6 Objectives of use case

Objectives of use case
– Ubiquitous interconnection: break down the barriers between heterogeneous systems and realize interconnection – Refined management and control: refined management of safety, energy and assets – Autonomous disposal: automatic identification, liberating part of the mechanical manpower work – Pre-judgment: proactively prevent and predict, and discover deep-seated risks – Precise service: provide personalized and precise service – Industry park integration: solution output and AI park development

B.3.1.7 Narrative of use case

Narrative of use case
Short description
This use case explores the construction of a digital twin based AI park, which establishes a unified standardized digital base for the industrial smart park. By combing real-time state data of GIS, BIM and IoT as well as applying comprehensive ability of digital entity mapping, the platform provides smart applications including digital twin operation and maintenance, digital intelligence meeting, digital intelligence firefighting, and digital intelligence parking. This AI park is reproducible and has been gradually promoted in Shanghai.

Complete description
The construction of this AI park covers the Lingang Taopu Zhichuang Industrial City in Shanghai, and takes the AI park platform and AI+ application construction of the Digital Intelligence Park as the starting point. The use case establishes a digital model based on digital twin technology, and uses artificial intelligence, cloud computing and big data. The application of emerging technologies, based on the intelligent buildings, creates an innovative and in-depth adaptation of intelligent building scenarios in the digital intelligence park platform-AI park platform. It provides important functions such as system access, equipment management, application development, data services, intelligent analysis, and interconnection with third-party systems. It also opens up the underlying intelligent facilities, equipment and the existing group business management system to make a breakthrough in the machine learning to apply to the daily operation and maintenance management of the park. Furthermore, it realizes the linkage of the park security management, asset management, customer management, energy management, centralized management and control, office environment optimization and other systems. It continuously enriches the modules of the AI interactive system to meet the diverse uses of the park intelligence demand in the scene, including: • Digital Twin Operation and Maintenance Center The digital twin operation and maintenance management center is to form a three-dimensional virtual park based on GIS+BIM from the industrial data, personnel data, enterprise data, supporting data, construction data, land data and other physical space data of each park. The digital backplane system of the park realizes the centralized management and control of multiple parks with the technical means of data visualization. • Digital Intelligence Energy Management Based on the software integration framework, operation support environment, and development tool components, the middleware of the Internet of Things, visualization, and data centralized display are used as the technical support of the Internet of Things. The feedback adjustment strategy is re-optimized and the feed-forward optimization control is used to control the energy system. The behaviour prediction and optimal control of equipment operation realize the refined management of the energy system and the intelligent optimization control of AI, and further optimize the energy management method and improve the efficiency of energy management. At the same time, it uses the "cloud-side-end" technology, and applies the design standard of AI optimization control hardware system for equipment in energy facilities with the concept of human–machine–object perception as the core. Furthermore, it realizes the high-speed docking of intelligent optimization algorithms and intelligent equipment control. • Digital Intelligence Security Based on the organic combination of many computer vision algorithms such as the improved background modelling motion detection algorithm and the deep learning attribute recognition algorithm, as well as the development of human target detection related technologies, the innovation of park security management is focused on video surveillance targets on the screen. Semi-automatic data annotation is used to improve the performance of deep learning algorithms with rich data, upgrade passive management to active prevention and prediction, improve post-event tracing efficiency, discover deep-level risks, and reduce security personnel costs.

- Digital Intelligence Meeting

  To improve the service level of the conference room, the system integrates audio and video conferencing, wireless screen projection, face recognition, voice recognition, environmental adjustment, equipment cloud fault monitoring and maintenance. The system strives to create effectiveness of intelligence, perception, interconnection, and sharing. Safe and modern intelligent conference system, through the application of AI technologies, provides the efficiency of park meeting rooms, improves the work efficiency of park employees, and helps customers solve the issues of finding meeting rooms and the difficulty of manual sign-in statistics.

- Digital Intelligence Firefighting system

  This system mainly realizes the comprehensive docking of the platform with fire water system and electrical system data. It not only digitally presents fire-related point equipment through the visualization system, but also connects the video monitoring system to display the scene in real time when there is a smoke alarm. At the same time, a pressure sensor is installed at the end of the test fire hydrant, which can monitor water pressure data in real time. The entire system can realize unified management, scheduling and emergency treatment, reduce personnel costs, improve efficiency, and link with superior firefighting units to truly achieve alarm prevention in advance.

- Digital Intelligence Elevator

  Lingang Taopu Smart Park Elevator System is a smart elevator control system that supports face-sweeping and code-scanning authentication. The door-passing system is linked to intelligently allocate the elevator that reaches the destination floor as soon as possible. It reduces the energy consumption of the elevator while reducing waiting time of people. In addition, through the visualized digital floor, the user can view the elevator running status, real-time running data, fault data statistics, real-time monitoring in the car. Furthermore, managers and operators can have an intuitive display of the system running status.

- Digital Intelligence Lighting system

  The platform of the Lingang Taopu industrial smart park is equipped with front-end IoT sensors and intelligent dimming systems to realize intelligent lighting control in public areas. The brightness is 10 % when there is no one, and the brightness is restored to 100 % when people walk by. The intelligent scene of "lights on and people walking and lights off" greatly saves lighting energy consumption. Combining with the visual digital baseboard, it can view the lighting loop failure status and the regional lighting turn-on status in real time. Through combining with real-time work order alarm information, it improves Operational management level.

- Digital Intelligence Parking

  The Lingang Taopu industrial smart park platform digital intelligent parking system can not only visualize the occupancy of each parking space in the parking lot, but also reserve parking spaces online. There are instructions all the way into the park. By matching forward guidance and real-time parking space allocation algorithms, users can enter the parking in real time. When the reserved parking space is reached, the lock is automatically released and the parking space is entered, which truly realizes the synchronous reservation of visitors and vehicles and the navigation function of the reserved parking space.

- Digital Intelligence Visitor System
- For enterprise employees in the park, through the face detection algorithm, the main functions of face intelligent analysis are realized to satisfy the park's attendance and safety management, such as face capture, face identity verification, face control alarm, face retrieval, and face database management. To achieve "one-face access" for different needs, the permission information of the respondent in the park can be shared synchronously through the mini terminal or visitor system to make an appointment to visit or be invited, and a two-dimensional report can be generated in real time. One-dimensional code identification, through this two-dimensional code, can realize "one-code access" in the park, such as entrance and exit prohibition, elevator dispatch, parking, conference sign-in, and dining.
- Data Interoperability and Linkage

  Based on the digital intelligence park platform, the use case improves the self-contained system of traditional information platform systems, and realizes access control, ladder control, environment and energy through the application of computer vision, deep learning, biometric recognition and other technologies, and executes predetermined business logic. System interconnection, innovative AI + access management, AI + office environment management, AI + conference and other linkage scenarios, and AI empower a new park experience.
- Digital Intelligence Operation system

  This system is mainly divided into two parts: property repair service and asset management. Through data interconnection and business connection with the property company management platform, the real-time automatic alarm information of the equipment will be sent to the property management operation and maintenance personnel in the form of automatically generated work orders. The asset management system is based on the AI park platform, combined with the latest BIM+FM+GIS technology. It integrates professional knowledge and provides users with a one-stop property service, asset service and knowledge service which is integrated into the asset management system.

B.3.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Buildings, equipment, personnel, sensors	Asset data, equipment data, spatial data, fault data, operation data, maintenance history, operation manuals.	Building model Equipment operating mechanism model BIM model Predictive model	Constraints: boundary constraints, terminal environment, equipment safety, laws and regulations

B.3.1.9 Actors: people, organizations or systems

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
Project manager	☑ system actor ☐ business actor: role: user	Project manager, who is responsible for system requirements, development, operation and maintenance management	
Decision maker	☐ system actor ☑ business actor: role: user	System decision level user, who is responsible for data report view, data analysis and statistical use, construction management decisions	
Designer	☐ system actor ☑ business actor: role: service provider	Designer, who is responsible for architectural design, system design, model design, business process design.	
Modeller	☐ system actor ☑ business actor: role: service provider	Modellers can be divided into system modeller, 3D modeller, parametric modeller, knowledge modeller, artificial intelligence modeller, rule modeller	
Developer	☐ system actor ☑ business actor: role: service provider	Developer, who is responsible for system coding developers, data development, background development, front-end development, 3D component development	
Implementor	☐ system actor ☑ business actor: role: service provider	Implementor, who is responsible for implementation of the platform, construction and maintenance of the industrial smart park	

B.3.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☑ deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.3.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Safety	Administrator functions, unauthorized restrictions, other user restrictions, management logs, unauthorized logs, data logs, password policies, password display, storage, transmission, data backup, storage restrictions	Industry Park Integration; Ubiquitous interconnection
Reliability	Fault tolerance, stability, important data verification, error prompt, operation prompt, data validity check, backup and recovery function	Refined management and control
Easy to use	Easy to operate, easy to read information, interface settings, user manual, online help function, user interface	Pre-judgment
Portability	Adaptability, software installation, coexistence, easy replacement	Precise service
Low carbon	Through feedback adjustment strategy re-optimization, feed-forward optimization control, based on energy data collection, platform optimization algorithm and machine learning, the energy consumption analysis, behaviour prediction and control optimization of building energy system and equipment operation are realized, thereby optimizing energy management methods, improving the efficiency of energy management, and achieving a comprehensive energy saving of about 20 %.	Industry park integration

B.3.1.12 Digital infrastructures

Name	Description	Impact on use case
Environmental monitoring system	Real-time monitoring of indoor and outdoor environmental changes, providing data support for energy system optimization	Intelligent application scenarios
AI energy efficiency system	Refined building energy management, implementation of optimization of energy system operation strategy, through connection with environmental data and personnel data, construction of equipment operating mechanism models, implementation of optimized operating parameters, and reduction of skills	Intelligent application scenarios
Video surveillance system	Through AI algorithm analysis, the security of the park is made intelligent, after the incident tracking is changed to active defence, and the operation efficiency is improved	Intelligent application scenarios

Name	Description	Impact on use case
Parking management system	Digitalization of the physical space of the main parking lot, including parking space guidance, remaining parking space display, capability of real-time display of parking space occupancy status and parking space vehicle information in the digital space	Intelligent application scenarios
Intelligent lighting system	Mainly include lighting circuit and circuit control status, lighting fault information, which can be three-dimensional visualization in the digital twin.	Intelligent application scenarios
Conference system	Including the conference room audio and video system, central control system, electric curtains, connect the conference room reservation platform with the hardware equipment, and link the air conditioning, lighting, curtains to be automatically turned on some time before the meeting starting time	Intelligent application scenarios
Elevator system	It is connected with the access control system and basic information system to realize functions such as automatic dispatch of elevators.	Intelligent application scenarios
Access control system	Open up with the fire protection system, attendance system, and face recognition system to realize the contactless passage of people in the park, and realize the on-off control of the gates in combination with different scenarios	Intelligent application scenarios
Firefighting system	Intelligent upgrade of the fire protection system, predict fire failures in advance, and provide emergency command drill simulation environment and emergency evacuation route guidance	Intelligent application scenarios

B.3.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.3.1.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.3.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.3.1.16 General remarks (optional)

General remarks

B.3.1.17 Challenges and issues (optional)

Challenges and issues

B.3.1.18 Data security, privacy and trustworthiness (optional)

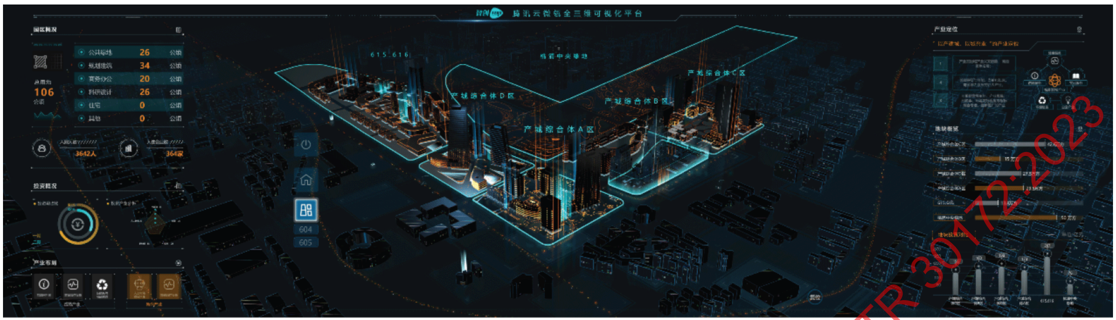
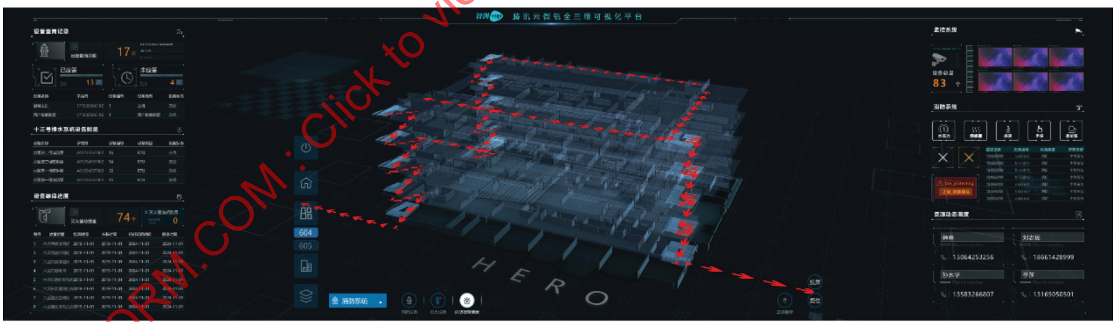
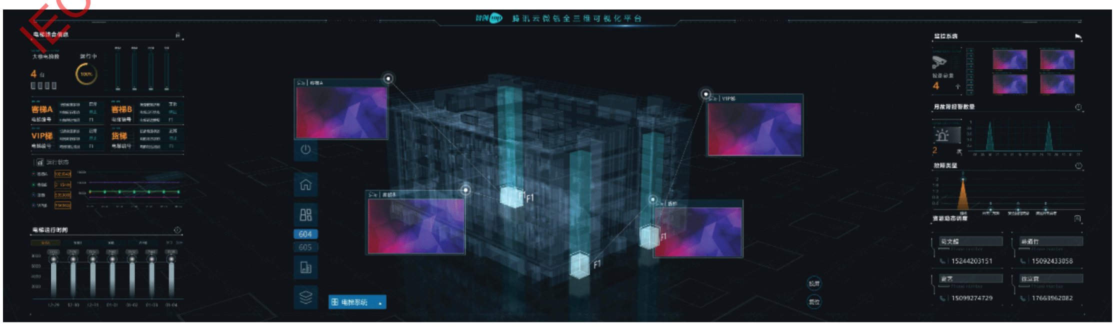
Data security requirements and implications for applications and systems
Privacy requirements and implications for applications and systems
Trustworthiness requirements and implications for applications and systems

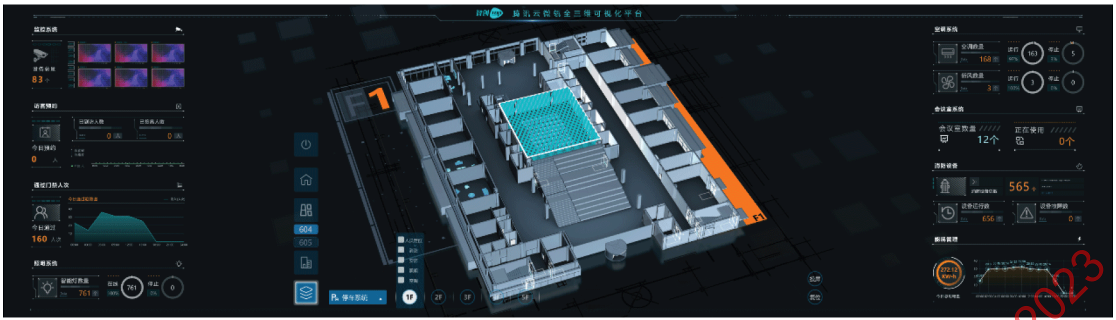
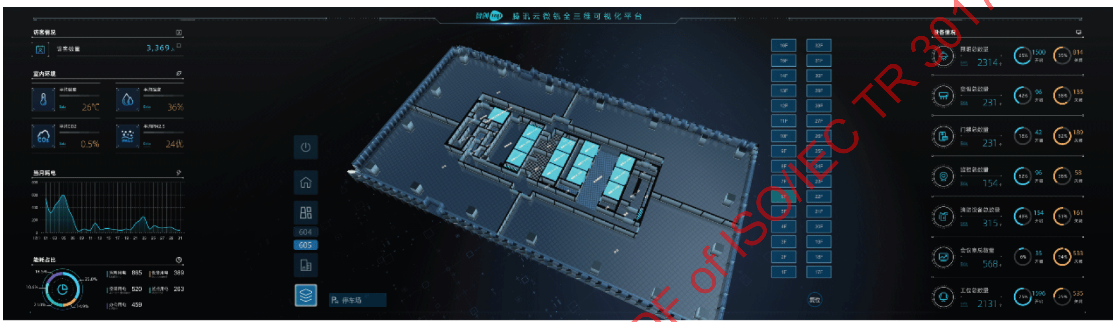
B.3.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.3.2 Drawings or diagrams depicting the use case

B.3.2.1 Drawing of use case

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"
 IEC  IEC  IEC  IEC

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"
 IEC  IEC

B.3.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.3.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.3.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.3.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)

B.4 Smart energy – Construction and application of digital twins for a large oil and gas processing facility

B.4.1 Description of use case

B.4.1.1 Name of use case

ID	Name of use case
004	Smart energy – Construction and application of digital twins for a large oil and gas processing facility – CN

B.4.1.2 Digital twin application area or context of use

Application area or context of use
Digital factories, intelligent oil fields

B.4.1.3 Version management

Changes or version	Date	Name Author(s) or committee	Approval status (optional)
V 1.0	2021-11-13		draft

B.4.1.4 Basic information to use case

Source(s) or literature (optional)	Link (optional)	Conditions (limitations) of use (optional)
/	/	/
Maturity of use case		
☑ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
CHINA		
Vertical application area		
Intelligent energy		

Well-known or related commercial or existing use cases (optional)
Keywords for classification
system integration; information exchange

B.4.1.5 Scope of use case

Scope of use case
• Describe construction and application of large oil and gas processing facility based on digital twin

B.4.1.6 Objectives of use case

Objectives of use case
• Objective 1: To achieve professional 3D model design and simulation layout of engineering, seamless docking of multi-format models, real-time and convenient review of design results and improve design efficiency and quality. • Objective 2: To achieve virtual scene real-time dynamic simulation of the whole process of facility construction, integration of construction data to realize visualization of real-time control of project progress, quality and safety, promote on-site resource allocation optimization, and maximize construction benefits. • Objective 3: To realize the application of facility virtual inspection, simulation training, equipment early warning and intelligent diagnosis. • Objective 4: To save operation and maintenance costs, ensure personnel safety and improve facility maintenance efficiency.

B.4.1.7 Narrative of use case

Narrative of use case
Short description
Based on the digital twin technology, the designer in the initial design stage can simulate the layout through virtual 3D scene, reduce "mistakes, defects and defects", and improve the design efficiency and quality. During construction, through the dynamic simulation of the construction process and combined with the Internet of Things equipment, the facility and yard structure and equipment attributes are continuously simulated and adjusted to promote the optimization of resource allocation. Finally, the use case can complete the overall modelling of the facility and library, and lay a foundation for production operation and maintenance. Through the integration of the IoT technology, knowledge base, artificial intelligence and other technologies, the use case achieves schedule management, virtual inspection, simulation training, supervision of the construction process, intelligent operation and maintenance of equipment and other functions. This can improve the safety, quality and efficiency of construction for a large oil and gas processing facility.

Complete description
Xinjiang oil field explored a practical route of using digital twin technology to build digital twin of a surface engineering oil and gas processing facility, which provided a new idea for the establishment of a large intelligent oil and gas surface engineering facility and an intelligent construction site. The main processes, practices and outcomes are shown as follows: 1) Design stage: Based on the cross-platform lightweight display model analysis technology, the 2D and 3D visual collaborative design review platform was established to realize the 3D design of the whole professional ground engineering. To realize the full professional 3D design of the ground engineering, a platform for online collaborative design review of 2D and 3D visualization is established based on cross-platform lightweight analytical technology and BIM or PIM model storage technology. The platform provides a convenient and unified 3D design mode and breaks the restriction of point-to-point use of professional design software. It also provides corresponding parsing rules for 23 model formats commonly used in the industry. In the same part of the compression model, only one copy of the same data is kept for reuse to achieve the compression effect. The lightweight rate can reach 50 % to 95 %. It realized the seamless connection of models with different formats, changed the traditional offline joint review mode. At the same time, it eliminated the constraints of design review in location environment, system hardware and software authorization quantity, realized the multiple participants in design review in advance, and made online comments at the same time, and saved 30 % of the time to find problems compared with the traditional offline review process. Design problems can be directly transformed into rectification tasks and pushed to designers to deal with, which reduces 80 % construction rework problems caused by design changes, shorts the closed-loop cycle of design problems and greatly improves design quality. 2) Construction phase: The use case establishes the working mode of collaborative data collection at each stage of the project and visual management of the whole asset life cycle, and realizes the acquisition of business data line, dynamic simulation of project construction and real-time control of project progress. The working mode of collaborative data collection at each stage of the use case is established. Through workflow engine technology, the use case can issue the unified dispatching commands automatically and realize the full cycle project digital conversion of the business. It achieves the effect of collection and centralized storage on the business data line. In addition, the use case constructs the visual management mode of asset life cycle. Through fusion of the construction data and the construction plan, the use case developed the linkage technology of the model and the progress control. The use case can present the appearance colour of the facility according to the progress of the feedback. The use case integrates entrance guard, live video, long-distance built multi-source monitoring, can virtually monitor the personnel, machines, materials, vehicles. The use case can check in real time the 3D coordinates, construction, inspection attributes and document information. It comprehensively realizes the visual management and control of the facility progress, quality, safety and resources. Further, it changes the tradition of on-site tracking feedback, and creates a new 4D visualization construction mode of the ground engineering. By comparing with the traditional way of management, the facility management cost can be reduced by more than 3 %, the construction period can be shortened by 30 %, and the facility digital twin ensures the construction accuracy higher than 99 %.

3) Operation and maintenance stage: The use case establishes the intelligent operation and maintenance mode of the facility, realizes the safe operation and resource optimization of the whole life cycle of the production of oil and gas fields, further achieves cost reduction and efficiency increase, and improves the production benefit.

Based on the static basic data collected during the construction of the facility, the intelligent operation and maintenance system of the equipment was established to realize the intelligent management of the whole life cycle of equipment from procurement, installation, failure, treatment and maintenance to inventory. The system combines with the real-time data in Distributed Control System or Program Logic Control and other control systems during the production and operation. The use case establishes the integrity monitoring system of the treatment facility, strengthens the ability to predict and evaluate the corrosion and risk of the project, and ensures the safe and reliable operation of the project. The facility-based digital twin can dynamically monitor the safe operation of the factory equipment, and apply machine vision, intelligent analysis and other algorithms to realize abnormal alarm location. Further, the system can quickly locate the fault point, shorten the maintenance time of equipment, and greatly reduce the risk of safety accidents. At the same time, if a worker cannot arrive at the scene of the danger zone, the user can apply a virtual remote simulation inspection facility based on internal inspection line. When the virtual inspection personnel are near to the equipment, the system can automatically push the related equipment operation parameters, to find potential safety hazard in time and ensure the safety of personnel. In order to further improve the skills of operating personnel and simulate the fewer abnormal drills during accident conditions, collaborative simulation training of people based on digital twin is developed by adopting the combination of map operation and guide method. It can improve convenience of human–computer interaction, realize the emergency drill, auxiliary personnel training, save operation, maintenance, and training costs, and comprehensively improve the emergency handling capacity of the facility.

B.4.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Three-dimensional model of oil and gas processing facility in large surface engineering	Engineering model data: mechanical, HVAC, process, general drawing, structure, pipeline layout, corrosion prevention, electrical, instrument and 23 other kinds of professional 3D modelling and various related attribute data. Entity model data of various devices including entity bit number, shape structure, attribute parameters, regional unit, type classification, professional name, and Product Breakdown Structure (PBS) structure tree, to build a complete model data architecture.	engineering model	1) Redundant points, lines and planes are not allowed in the 3D model, and two planes whose vertical distance is less than or equal to 5 cm in the same building model are not allowed; 2) There are no gaps at the internal edges of the model to ensure that the spatial topological relations of the intersection points are strictly coincident; 3) The 3D monomer model is complete and cannot contain any links to other models. The merged 3D model is complete and not repeated;

Entity name	Data	Model type	Requirements or constraints on the models
	Structural solid model data including all kinds of building structures, roads, bridges and other solid model data.		4) All professional models can adopt unified origin and coordinate system modelling. Coordinate, unit, orientation and proportion can be unified, and the modelling can be based on 1:1 ratio; 5) The 3D model object can attach engineering design attribute information and other related engineering data information; 6) The 3D model is consistent with the engineering data information in the 2D drawings. 7) All 3D engineering objects and related documents can be associated with the factory decomposition structure.
Logging sheet and spare part	The asset data model mainly includes: 1) Design data: mainly including basic attributes, design parameters, relative coordinates and other data, mainly from design documents, to provide guidance for procurement and construction, and applied to mechanical settings or maintenance in the operation and maintenance stage. 2) Procurement data: mainly equipment procurement attributes, product reliability, stability and other data. Its main source is the supplier's procurement documents, procurement data can provide the basis for equipment, machinery maintenance and replacement and factory expansion.	data model	1) Requirements for engineering object class library property table (structured data): It is necessary to ensure the integrity, consistency, accuracy and relevance of engineering model object attributes. The basic attribute requires that the uniqueness of the object can be expressed accurately. 2) Requirements for file data (unstructured data) at each stage of the project: The document number can be unique and continuous according to the standard coding requirements, and no special characters can be used. Electronic documents can have integrity under the same document and cannot contain any links to other documents. Electronic documents can be safe and reliable and free from computer viruses and Trojan horses. All uploaded files in the system can be in PDF format or other unmodifiable files.

Entity name	Data	Model type	Requirements or constraints on the models
	3) Construction data: mainly including all kinds of construction record data, inspection batch acceptance record and so on, such as the process in the facility, gathering and conveying pipeline, electrical installation, and automatic control. Mainly from construction units, supervision units and testing units. Fully record traceable and queryable data in the construction process through form flow control. 4) Equipment asset data: mainly includes equipment ledger data, equipment information maintenance data, equipment attribute data, equipment status data, equipment change data and electronic archives.		3) All documents to be associated with engineering model objects can provide association relation tables.

B.4.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
Digital Delivery Service provider	☐ system actor ☑ business actor: role: user	(1) Responsible for collecting and integrating the data and 3D models of the design, procurement, construction and trial operation of the construction period, and constructing the facility digital twin. (2) Participate in the preparation of unified technical provisions for digital delivery, cooperate with all parties to discuss and confirm the unification of data standards, and be responsible for the compilation of data dictionary. (3) Participate in the formulation of digital delivery plan, and organize all participants to discuss and review digital delivery plan, implementation process and document template. (4) Responsible for the configuration, deployment, standard specification built-in and maintenance of the digital delivery platform in the early stage of the project. (5) Responsible for training and supporting the standardized implementation of digital cooperative operation and data collection of all participants.	
construction unit	☐ system actor ☑ business actor: role: user	(1) Responsible for determining the scope of digital delivery and putting forward specific requirements for all kinds of data within the scope of delivery. (2) Responsible for the preparation of digital delivery plans and unified technical regulations for digital delivery. (3) Responsible for checking and supervising the integrity and compliance of relevant data delivered by each party, and responsible for generating quality report and informing each party of rectification in a timely manner. (4) Responsible for the final acceptance of the construction results of digital twin-based facility.	

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
general contractor	☐ system actor ☑ business actor: role: user	(1) Responsible for coordinating and organizing the digital delivery team to meet the owner's digital delivery requirements. Manage digital delivery. (2) Be responsible for guiding, supervising, checking and accepting the work of the digital delivery team, and provide timely feedback of the problems to the digital contractor for handling. (3) Responsible for organizing and coordinating the design party, the purchaser, the construction party and the supervisor to complete data collection, sorting and integration.	
supplier	☐ system actor ☑ business actor: role: service provider	(1) Responsible for cooperating with the digital delivery team in the data collection, sorting and integration of products; (2) Submit digital data of purchased goods accurately, effectively, completely, and in a timely manner, including equipment models, drawings, product descriptions, calculations and other data. (3) Responsible for collecting equipment installation process quality report, single test report, system test report and inspection materials. (4) Responsible for verifying the validity and integrity of the product data; (5) Responsible for collecting the re-inspection report of valves, instruments and other equipment requiring secondary calibration.	

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
construction unit	☐ system actor ☑ business actor: role: service provider	(1) The construction party can be responsible for providing digital delivery data of project construction and materials purchased; provide accurate, timely, effective and complete construction data and supplier data within the scope of work. (2) Responsible for the management and inspection of construction-related documents such as change sheets and contact sheets, which can be recorded into the platform in real time by the company according to the delivery list of documents in the construction stage. (3) Collect, sort out and integrate all kinds of inspection and testing data in the construction process. Browse models, take on-site photos and upload data through mobile application.	
design unit	☐ system actor ☑ business actor: role: service provider	(1) Responsible for 3D model design, intelligent P&ID design. (2) Responsible for providing design schedule, including detailed drawing plan such as drawing catalogue list. (3) Responsible for complying with data delivery specifications and providing engineering design data within the scope of work accurately, in a timely manner, effectively and completely. (4) Cooperate with the review of the accuracy of 3D models and drawings, and complete the rectification according to the review opinions. (5) Responsible for the collection, sorting and integration of response and coordination design data.	
supervising unit	☐ system actor ☑ business actor: role: service provider	(1) Responsible for providing digital delivery data related to project supervision. (2) Provide engineering project supervision data within the scope of work accurately, effectively, completely, and in a timely manner.	

Actor name	Actor type	Actor description	**Actor interactions** (Transactions between Actors) (optional)
testing unit	☐ system actor ☑ business actor: role: service provider	(1) Responsible for providing digital delivery data such as engineering testing data and documents. (2) Accurately, timely, effectively and completely provide engineering project testing data within the scope of work.	

B.4.1.10 Life cycle of use case

Life cycle of use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☑ deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.4.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Consistency, fidelity	Based on the BIM or PIM model storage technology, and through data acquisition and device control, the similarity between 3D model and physical entity in appearance, geometric structure and texture is guaranteed, and the digital twin following changes in the changing physical world is realized, forming a digital twin-based facility with construction accuracy higher than 99 %.	Achieve Objective 1 and Objective 2. Achieve the full professional 3D model design and simulation layout of the project, virtual scene real-time dynamic simulation of the whole construction process of the facility, integration of construction data to achieve the visualization of the real-time control of the project progress, quality and safety, promote on-site optimal resource allocation, and maximize the construction benefit.

Name	Description	Reference to mentioned use case objectives
Reconfigurability	Using Extract-Transform-Load technology and hotspot technology, the scattered engineering objects and related attribute data are cleaned and integrated into the data warehouse, and the 3D spatial data are automatically classified, and 55 % to 95 % of lightweight compression and monomer processing are carried out without losing the original model graphics, materials and attributes.	Achieve Objective 2. Good data reconstruction, can support the digital twin agile, visual display of the actual construction process, to achieve real-time control of the project progress, quality, reasonable optimization of construction resources.
Expandability	Based on standardized interfaces and services, it has the ability to integrate, add or replace 3D digital models, and can flexibly add entity extension structures anywhere and anytime using PC or mobile terminals according to design processes and specifications.	Achieve Objective 1, 2 and 3. 3D model with good scalability, supporting the layout design stage simulation of agile delivery, efficient review, design results for entities facility construction, the dynamic changes of the operational phase of equipment layout can be reflected in a timely manner into the digital twin-based facility to display, combined with machine vision technology, such as realization of intelligent operation maintenance.

B.4.1.12 Digital infrastructures

Name	Description	Impact on use case
Database server	Run Oracle and MongoDB databases	Provide database foundation for the relevant system of this case, save structured and unstructured data.
Documentation Server	Run the FTP file service.	Provide file saving services for this case, and provide files to related applications upon request.
Backburner Server	Run the 3D model rendering engine to quickly transfer the 3D model to the client through efficient rendering.	It provides 3D model rendering services for the relevant systems in this case, which minimizes the requirements on client performance and supports smooth roaming of 3D models on ordinary computers and mobile terminals.

Name	Description	Impact on use case
Application Server	It runs the online collaborative design review system of 2D and 3D visualization, digital handover system and 3D visualization large screen.	It provides a running environment for the relevant system in this case.

B.4.1.13 Challenges and issues

Issue	Impact of issue on use case	Reference
The granularity of 3D engineering object partition.	The precision of digital twinning, the depth of application and reusability of data will be affected by the requirement of division of different precision of the physical facility.	Technical regulations for digital delivery of oil and gas field surface engineering (Trial)

B.4.1.14 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.4.1.15 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.4.1.16 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.4.1.17 General remarks (optional)

General remarks

B.4.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications and systems
1) According to the scale of ground engineering construction, it is required to establish data classification, classification and isolation measures and authorized access mechanism, and establish a list of important data protection. 2) Data collection and data interaction services from different sources are required to adopt industry-standard data interface specifications and unify communication protocols. 3) Cloud data storage service and data security analysis and evaluation service are required to avoid problems such as data storage security and file sharing privacy protection. 4) Users are required to authenticate their real names through the combination of account password, SMS and mobile phone token during system login.
Privacy requirements and implications for applications and systems
Trustworthiness requirements and implications for applications and systems

B.4.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.4.2 Drawings or diagrams depicting the use case

B.4.2.1 Drawing of use case

Drawing or diagram of use case

B.4.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.4.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.4.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.4.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)

B.5 Smart building – Monitoring of water

B.5.1 Description of use case

B.5.1.1 Name of use case

ID	**Name of use case**
005	Smart building – Monitoring of water

B.5.1.2 Digital twin application area or context of use

Application area or context of use
Residential buildings. Implement hot water temperature monitoring in order to detect and avoid proliferation of legionella bacteria

B.5.1.3 Version management

Changes or version	**Date**	**Name Author(s) or committee**	**Approval status (optional)**
V1.0	2022-02-22	Clotilde Cochinaire	draft

B.5.1.4 Basic information to use case

Source(s) or literature (optional)	**Link (optional)**	**Conditions (limitations) of use (optional)**
Maturity of use case		
☑ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
Europe – France		
Vertical application area		
Smart building for Residential and Industry		
Well-known or related commercial or existing use cases (optional)		
Energy monitoring in smart building		
Keywords for classification		
System integration		

B.5.1.5 Scope of use case

Scope of use case
Include but not limited to following items: • Describe setup, operation, and maintenance of hot water temperature based upon digital twin and related systems; • Describe monitoring and intelligent building related cases based upon the same architecture.

B.5.1.6 Objectives of use case

Objectives of use case
• Objective 1: detect any issue to prevent and avoid legionella bacteria with measurement of hot temperature for human consumption, in residential or industrial use • Objective 2: be compliant to regulation: obligations of public health (CSP) (articles L.1321-1, R.1321-1 and following, quoted R.1321-49 and R.1321-53) • Objective 3: improve digital management of operations • Objective 4: reduce cost of energy, reduce cost of operations

B.5.1.7 Narrative of use case

Narrative of use case
Short description
This use case establishes the mapping between real and virtual water networks inside the building. It allows digital management and monitoring of actions related to thresholds of temperature detection, in order to prevent legionella bacteria. It enhances a digitalization of operations linked to energy and water topics. This use case is one of the digital twin applications using distributed and hybrid edge or cloud architecture. It reinforces the fusion of both energy networks and IT networks on one unique network. This use case belongs to larger scope smart and intelligent building Scope of use cases, based upon a full bidirectional, real time and 3D digital twin.

Complete description
• French regulation committed to reinforcing compliance of monitoring of temperature of hot water, in residential and industrial buildings. The associated regulation is detailed in obligations of public health (CSP) (articles L.1321-1, R.1321-1 and following, quoted R.1321-49 and R.1321-53). • This use case is one of the sub use cases and applications of smart and intelligent building. Intelligent building aims at providing – reduction of operational costs, – reduction of energy costs, expenses, – reductions of carbon footprint of the building, – digitalization of operations. • The digital twin of the building aims at answering to those 4 challenges and moreover in this example with some applicable specificities such as monitoring of hot water temperature through probes in different selected metering points in the building. • The complete system manages multiple probes for hot water temperature measurement. It will include different steps. – Step 1: Virtualization - Preparation of setup through the digital twin: identification of metering points. Creation of virtual entities: metering points, networks, building – Step 2: Object model mapping with virtual model realization - deployment of entities, networks, devices after complete process digitalized through the digital twin – Step 3: Operations - activation of the digital entity through the physical entity in a bidirectional way – Step 4: Improvement of models through data gathered and analysed, as well as the auto managed services – Step 5: Injection of data analysis in process management to generate return-on-investment and compliance reports

B.5.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Building	• Physical data: plans, mapping • Material information (type, height, date, history) • Procurement info • Legal information • parameters	physical model	Performance requirements: consistency, accuracy and fineness

Entity name	Data	Model type	Requirements or constraints on the models
IT network	• Type of network • Equipment • Architecture • Systems	Physical model Virtual model	consistency, accuracy, interface, performance, IT network management, QoS, Data rate, Interface
Environment	• CO_2, O_2, humidity, temperature, fine particles, NO_2	Physical model Digital model	Consistency, Accuracy, Precision
Water network	• Design of the network, • history, • structure • equipment	Physical model Virtual model	Consistency, Accuracy, Precision
Sensors	• Type of devices • Numbers • Connectivity • Data gathered • Device management	Physical model Virtual model	Performance, Environment, Consistency, Accuracy, Precision
Algorithms	• Equipment operation data, • System data • sensor data, • execution data	AI model	Legal regulations, Consistency, Accuracy, Precision, Inputs or outputs
Fault Diagnostics	• Equipment operation data, • Alarm data • System data • Sensor data • Execution data	AI model	Legal regulations, Consistency, Accuracy, Precision, Inputs or outputs
Process	• Process data • User role data • Rights management data • Process algorithm data • Environment data	Enterprise knowledge or industry knowledge model	Legal regulations, Inputs or outputs, Interface, Accuracy, Consistency

B.5.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	Actor interactions
System Architect	☑ system actor ☐ business actor: role: ______	Creates the architecture of the digital twin, enhances its bidirectional view, reinforces its capability to integrate full subsystems and applications,	Interact with software coding team (analytics, developers)
Integrator (SVI or HVI)	☐ system actor ☑ business actor: role: ______	Operates and maintains the system with rights management, system configuration, upgrade and optimization	Interacts with IT manager, decision end user, operations support manager
Operations, support manager	☐ system actor ☑ business actor: role: ______	Operates the building and the system, identify and trigger processes on cases of operation issue, maintenance	Interact with technician, installer, IT manager, integrator
Decision End user	☐ system actor ☑ business actor: role: ______	Based upon data report view, data analysis and statistical use, decisions can be taken	Interact with integrator, system architect
Analytics engineer	☐ system actor ☑ business actor: role: ______	AI engineer, process understanding, analytics systems expertise, algorithms focus	Interact with developer, and system architect
developer	☐ system actor ☑ business actor: role: ______	Frontend, Backend developer, system coding developer, 3D developer, 3D modelling	Interact with analytics engineer and system architect
Technician, installer	☐ system actor ☑ business actor: role: ______	On field: install sensors according to processes, wires, deploy energy or water networks	Interact with Operations, support manager
IT manager	☐ system actor ☑ business actor: role: ______	Manage the evolution, operations on IT network	Interact with system integrator and operation manager

B.5.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ requirements phase ☐ development phase ☐ test phase ☑ integration phase ☑ installation phase ☐ modification phase

B.5.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Temperature	In the threshold defined by regulation Accuracy of the measurement	
Cost saving	Property management personnel 20 %	Analyses gains provided thanks to digital twin
Energy metrics	Energy gains 40 %	Analyses gains provided thanks to digital twin

B.5.1.12 Digital infrastructures

Name	Description	Impact on use case
sensors	Energy meters, IoT terminals	Gather and transmit data through IoT connectivity to the digital twin through BOS
edge gateway	Edge gateway with BOS integrated	Gathers and models data on edge
network	WLAN network with IoT connectivity integrated	Provides connectivity
digital twin platform	Bidirectional, real time and 3D visualization platform	Manages the whole use case

B.5.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.5.1.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.5.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship
Energy management		Shares the same network infrastructure

B.5.1.16 General remarks (optional)

General remarks

B.5.1.17 Challenges and issues (optional)

Challenges and issues
• Main challenge is the digitalization of operations and synchronization of all systems in one digital platform • The second challenge is the fusion of IT and energy networks in one unique network

B.5.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications and systems
The digital twin uses security management system, including firewall and security rules.
Privacy requirements and implications for applications and systems
Trustworthiness requirements and implications for applications and systems

B.5.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.5.2 Drawings or diagrams depicting the use case

B.5.2.1 Drawing of use case

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"
The use case respects a Ready2Services architecture based upon 3 levels within a BOS in B.5.1.12 that integrates • Connectivity • Infrastructure • Services 1) Connectivity layer includes building automation subsystems, probes, devices, meters, connectivity network. 2) Infrastructure layer is used for data storage, processing and sharing, IT resources deployed on edge. 3) Services layer englobes both: • Cloud platform capabilities (digital twin) with data collection, storage, processing, analytics, modelling, diagnosis, decision capabilities, and • applications to interact with the dedicated use case such as water management, building operations, intelligent energy management, property management, intelligent building, security management and more applications.

B.6 Smart Power Grid – Smart grid operation based on a digital twin

B.6.1 Description of use case

B.6.1.1 Name of use case

ID	**Name of use case**
006	Smart Power Grid – Smart grid operation based on a digital twin – CN

B.6.1.2 Digital twin application area or context of use

Application area or context of use
• Smart Power Grid The power grid digital twin construction consists of simulation modelling, state mapping, self-operation and actuation.

B.6.1.3 Version management

Changes or version	Date	Name Author(s) or committee	Approval status (optional)
V 1.0	2022-02-11	Li J.S.	

B.6.1.4 Basic information to use case

Source(s) or literature (optional)	Link (optional)	Conditions (limitations) of use (optional)
/	/	/
Maturity of use case		
☑ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
CHINA		
Vertical application area		
Smart energy, Intelligent power grid		
Well-known or related commercial or existing use cases (optional)		
Keywords for classification		
cloud computing; big data; IoT; AI; simulation		

B.6.1.5 Scope of use case

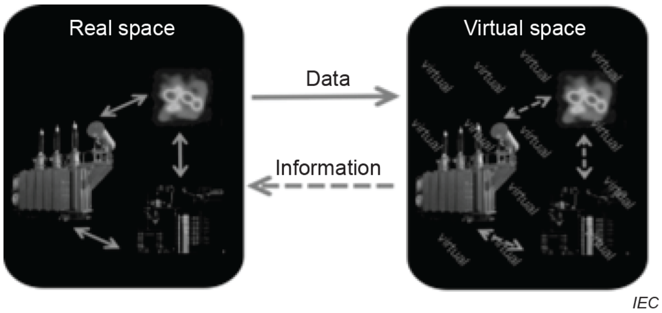
Scope of use case
• Describe the construction process and application scenarios of smart power grid based on a digital twin; • Describe the architecture and data content in this scenario

B.6.1.6 Objectives of use case

Objectives of use case
• Objective 1: to achieve panoramic vision of power grid substation and electrical equipment, and identify power grid operation risks; • Objective 2: to diagnose, assess and warn of risks of electrical equipment of different types; • Objective 3: to conduct virtual service commissioning of electrical equipment based on business processes and maintenance policies;

B.6.1.7 Narrative of use case

Narrative of use case
Short description
This use case introduces the whole process of power grid digital twin construction and describes the use case scenario. The process consists of simulation modelling, state mapping, self-operation and actuation. Simulation modelling and state mapping realize the construction "from real to virtual state", self-operation ensures the dynamic operation of the digital entity, and actuation realizes the impact of the running results on the real world to complete the "virtual-to-real" closed loop.
Complete description
A digital twin constructs a digital mirror symmetrical to the real world, so as to dynamically present and effectively manage the past and current behaviours of a physical entity, and accordingly predict its future behaviours. The information interaction is the basic guarantee for communicating with different domains and realizing the digital twin. The power grid digital twin construction not only realizes the deep integration of cloud computing, big data, IoT and other digital technologies with production business, but also changes the traditional substation operation mode. Meanwhile, data of different kinds, time scales and parts are collected for the information integration with time and space dimensions. The digital twin entity realizes visual display, analysis, automatic alarm of abnormal state and equipment fault judgment. The business of equipment maintenance has changed from unitary to comprehensive mode, and the management structure has changed from hierarchical to flat, which leads to the reform of business model.



In power grid, the digital twin technology realizes the integration of "physical power grid" and "virtual power grid". Electric power employees use digital technology to understand and optimize physical grid, form a mechanism for the integration of physical device, control system and information system, and implement real-time control of power grid operation and management. It completes a closed loop of grid state awareness, real-time analysis, intelligent prediction and accurate execution. While promoting the digitization, networking and internalization of traditional power grid, this improvement supports the industrial upgrading.

At present, the digital twin grid realizes panoramic vision of substation and electrical equipment, risk diagnosis and warning for electrical equipment, business debugging with virtual entities.

1) Simulation modelling: the digital grid entity copies the physical entity digitally and simulates the status and behaviour of the substation in the real environment. The model can be used to carry out virtual simulation, sand table calculation as well as strategy verification for the design, construction, operation and maintenance process of the substation, and to understand the status of the substation and respond to changes. Generally speaking, it covers physical models, power system models, energy field models, and their relationships.

2) State mapping: According to the flow, fusion, control and inter-operation chain of "data-information-knowledge", the state and business process in the operation of power grid is reflected. State mapping can be divided into process mapping and data mapping. Mapping methods consist of data connection, service requirements, process design and development, and multi-source heterogeneous data fusion.

3) Self-operation: the digital twin power grid realizes self-operation according to external data changes and internal policy updates. Virtual entities and physical entities are updated synchronously to generate judgment conclusions or operation guidelines with the application value. The self-running process relies on one or more information systems or electronic modules. According to the different degree of self-operation, it can be divided into primary and advanced levels.

   Primary level: Record. The virtual model at this level can import dynamic data and dynamic flow to realize dynamic update of substation operation process. Meanwhile, the model connects with physical entity through data, status, process changes and support for operation monitoring and fault analysis.

   Advanced level: Thinking. The model at this level not only records the historical state, but also calculates the abnormal conditions of the substation with the help of intelligent algorithms and empirical models.

4) Actuation: When the equipment is damaged and updated, or has technological transformation, the traditional substation can only be updated through manual intervention. The power grid digital twin realizes iterative optimization through the two-way cooperation between the virtual and real entities so as to achieve the effect of reverse actuation. The common reverse actuation measures include simulation, monitoring, diagnosis, prediction and control.

B.6.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Substation entity (including equipment)	Space information, appearance information, state information, attribute information	physical model	Performance requirements: consistency, accuracy and fineness
energy fields	Electric field information, magnetic field information, heat field information, force field information, light field information, sound field information, fluid field information, insulation field information	physical model	Performance requirements: Consistency, accuracy
power system	Dynamic equivalence information, power load information, section parameter, characteristic variable, topological information, energy consumption information, interference information, metrical information, excitation parameters	physical model	Performance requirements: Consistency, accuracy
Diagnose and assess rule and algorithms	Equipment operation data, defect data, operation time data, sensor data, scheme execution information	knowledge or artificial intelligence model	Performance requirements: accuracy rate, accuracy rate, recall rate; Input and output requirements: interface
Operation and maintenance Process or rule	Operation and maintenance data, process drawings, role information	knowledge model	Performance requirements: accuracy rate, accuracy rate, recall rate; Input and output requirements: interface

B.6.1.9 Actors: people, organizations or systems

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
Power business professionals	☐ system actor ☑ business actor: role: user	Inspection engineer, duty officer, maintenance engineer, operation and maintenance engineer, debugging engineer	
Decision user	☐ system actor ☑ business actor: role: user	Risk assessment engineer, data analyst, failure analyst, risk early warning analyst	
Information professionals	☑ system actor ☐ business actor: role: user	System Development Engineer, system operation and maintenance personnel, rights management, system configuration, upgrade and optimization	

B.6.1.10 Life cycle of use case

Life cycle of use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☑ deployment phase ☑ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.6.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
conformity	Agreement or logical coherence among the digital entities and the corresponding physical entities	Objective 1: to achieve panoramic vision of power grid substation and electrical equipment
accuracy	Physical model	Objective 1: to achieve panoramic vision of power grid substation and electrical equipment
	Power system models	
	Energy models	
synchronizati on	Status of digital entities in the digital twin can be synchronized with the status of the real-world entities, or vice versa, using timely-manner networking	Objective 2: to diagnose, assess and warn risks of electrical equipment of different types

B.6.1.12 Digital infrastructures

Name	Description	Impact on use case
Logical level: unified grid model	Data topology that covers all types of equipment, including power transmission, generation, transformation, distribution and consumption	Fundamentals of use case modelling, mapping and interaction
Equipment level: data centre	Unified carrier for data acquisition, storage and calculation	Fundamentals of use case running, interaction

B.6.1.13 Challenges and issues

Issue	Impact of issue on use case	Reference
Data acquisition	Collection performance of terminal equipment is inconsistent with model integrity	
Data quality	Data accuracy and integrity need to be continuously improved	
Standard specifications	Digital twin construction process specifications missing or inconsistent	

B.6.1.14 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.6.1.15 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.6.1.16 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.6.1.17 General remarks (optional)

General remarks

B.6.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications and systems
The network security technology involved in this case covers three aspects: system, network, and information. The application of these technologies not only avoids loss or destruction of data during storage, processing and transmission, but also ensures optimal security for the grid digital twin construction within specified performance, time and cost ranges.
Privacy requirements and implications for applications and systems
Trustworthiness requirements and implications for applications and systems

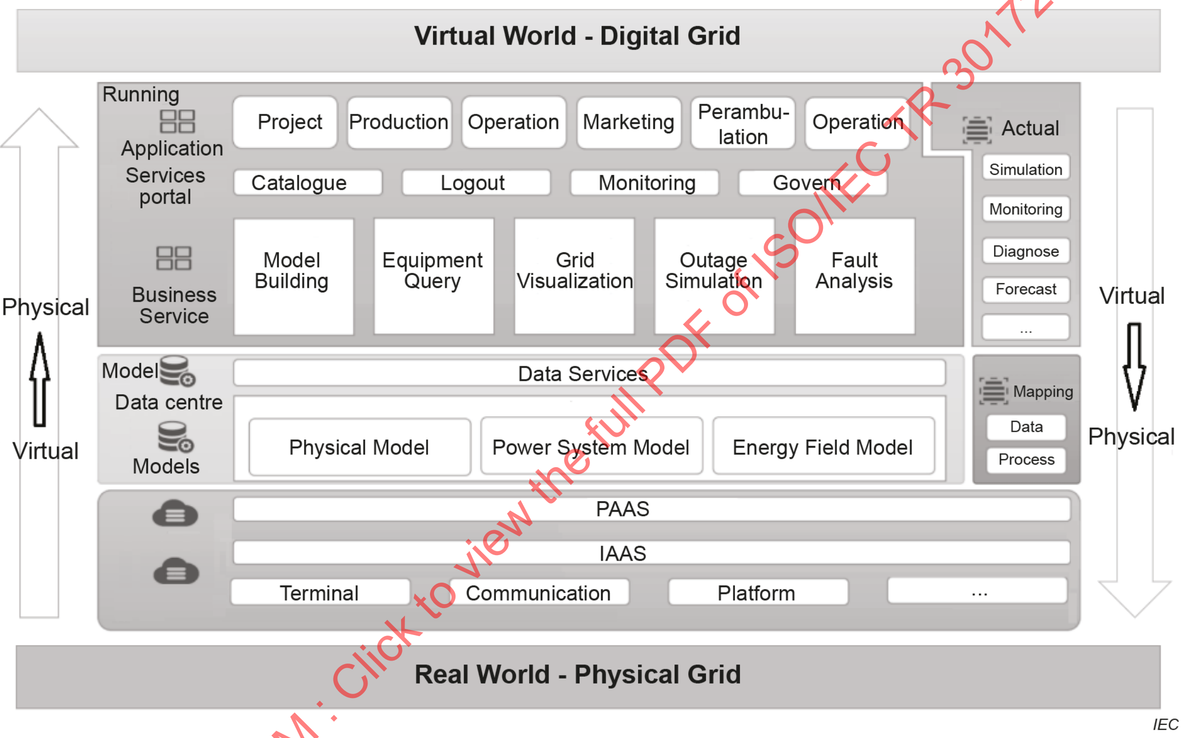
B.6.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions
Power professionals and Decision user make requests for business, Information professionals develop and update on these grounds.

B.6.2 Drawings or diagrams depicting the use case

B.6.2.1 Drawing of use case

Drawing or diagram of use case



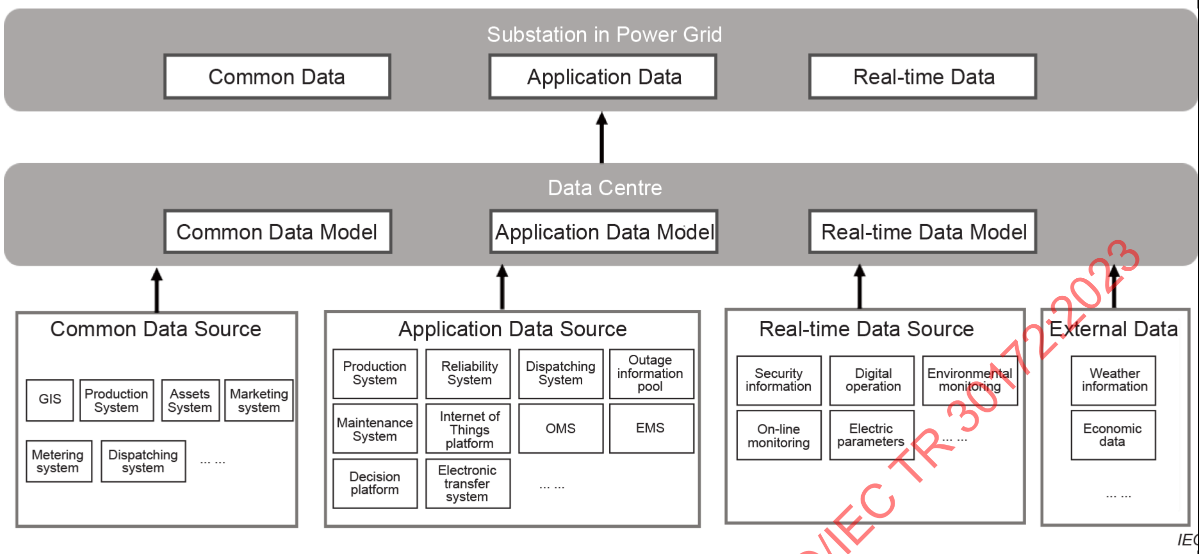
From bottom to top, the reference architecture of this use case consists of the following parts. The underlying data collection part mainly collects all kinds of power grid operation data through intelligent devices and the Internet of Things, which realizes data aggregation and storage by using cloud computing technology and cloud platform.

Then, data storage, gathering, cleaning and integration will be done in the data centre, combined with grid physical entity model, power system model, energy field model and data mapping. It will be the business services that are responsible for the operation of digital entity, and the digital construction for substation from real to virtual levels is thus completed.

The results of digital substation products affect the actual power grid simulation, monitoring, diagnosis and prediction. The substation operation in the physical world will be guided through the actual interaction, and new data are used for digital substation functioning. In this way, the complete full digital-twin closed loop between the virtual and real worlds is established.

B.6.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case



B.6.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.6.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.6.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)

B.7 Smart construction life cycle – Construction-phase digital twin model

B.7.1 Description of use case

B.7.1.1 Name of use case

ID	Name of use case
007	Smart construction life cycle – Construction-phase digital twin model – ES

B.7.1.2 Digital twin application area or context of use

Application area or context of use
AEC (Architecture, Engineering, and Construction), entire construction life cycle

B.7.1.3 Version management

Changes or version	Date	Name Author(s) or committee	Approval status (optional)
V1.0	2022-03-08	COGITO EU project	draft

B.7.1.4 Basic information to use case

Source(s) or literature (optional)	Link (optional)	Conditions (limitations) of use (optional)
-	https://cogito-project.eu/	-
Maturity of use case		
☐ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☑ in preparation ☐ visionary		
Generic, regional or national relation		
European Union		
Vertical application area		
AEC (Architecture, Engineering, and Construction)		
Well-known or related commercial or existing use cases (optional)		
Keywords for classification		
AI application, system integration, information exchange, construction, project management		

B.7.1.5 Scope of use case

Scope of use case

Describe a real-time digital representation (twin) of a construction project to monitor real construction projects from their design to implementation stages that fuses:

- as-designed multidimensional Building Information Model (nDBIM) information, with
- as-is BIM information,
- live IoT and visual data, and
- the (machine or human) project management decisions taken using that data.

B.7.1.6 Objectives of use case

Objectives of use case

- Objective 1: To guide, monitor, and optimize the physical construction workflows, improving schedule and cost predictability while ensuring technical requirements and zero accident objectives.
- Objective 2: To enable systematic, rapid, and highly automated visual and geometric quality control of executed construction works, leading to faster and cheaper certification, objective production control, and accelerated risk assessment.
- Objective 3: To reduce construction accidents through continuous monitoring and effective communication of hazards and planning of collective and personal protective equipment requirements throughout construction projects. Also to provide contextualized health and safety training. This will lead to effectively predicting and reducing construction site accidents and improving worker competencies.

B.7.1.7 Narrative of use case

Narrative of use case

Short description

A construction company needs to guide, monitor, and optimize a construction project from three perspectives: time, cost, and quality; to these, "health and safety" is often added. To do so requires managing and integrating the virtual representations of all the entities involved in the construction project, from the as-designed data (including the Building Information Model and the process data) to the as-built data (including real-time IoT and visual data) related to the physical components making up the project as well as the resources (For example workers, equipment) involved in its delivery.

Complete description

One of the main objectives when developing a digital twin in the field of construction is to monitor all aspects related to the development of construction projects. The constant digital monitoring supported by simulation gives the possibility to prevent any contingency that can occur in the production process of the construction site. Specifically, the digital twin model for construction projects must consider the following aspects:

- Life cycle: The digital twin model encompasses part or the entire life cycle of the construction project with the primary objective of optimizing time, cost, quality, and workers’ safety.

- Monitoring: The digital twin model is connected to the physical environment through an underlying sensor network, selecting and filtering the data required for daily operational management. These data are fed into decision-making by humans or artificial intelligence techniques.
- Simulation: The digital twin model supports simulating all the interactions among the different elements and actors of the construction site in a digital environment. Therefore, before on-site implementation, the digital twin is the virtual test bench for any construction process.
- Prediction: The digital twin model captures events from the physical construction site and enables an intelligent and adaptive construction process, predicting and issuing alerts related to the different physical assets.
- Optimization: The digital twin model provides a holistic approach to all the construction project parameters and identifies the actions or decisions to achieve the best possible project outcomes.

Therefore, developing a digital twin in the construction domain helps streamline project delivery and achieve optimal control and intelligent management.

In this context, a bundle of novel services can facilitate: (i) timely detection of health and safety hazards to humans, (ii) timely identification of quality defects, and (iii) providing means for real-time on-site workflow management.

Work must be done in different phases of the construction project life cycle to mitigate health and safety related issues at construction sites. In the planning phase, potential construction site hazards and necessary protective equipment must be identified considering the Building Information Model and its 3D geometric elements by defining appropriate construction spatial zones in the 3D BIM model, shown in Figure B.1.

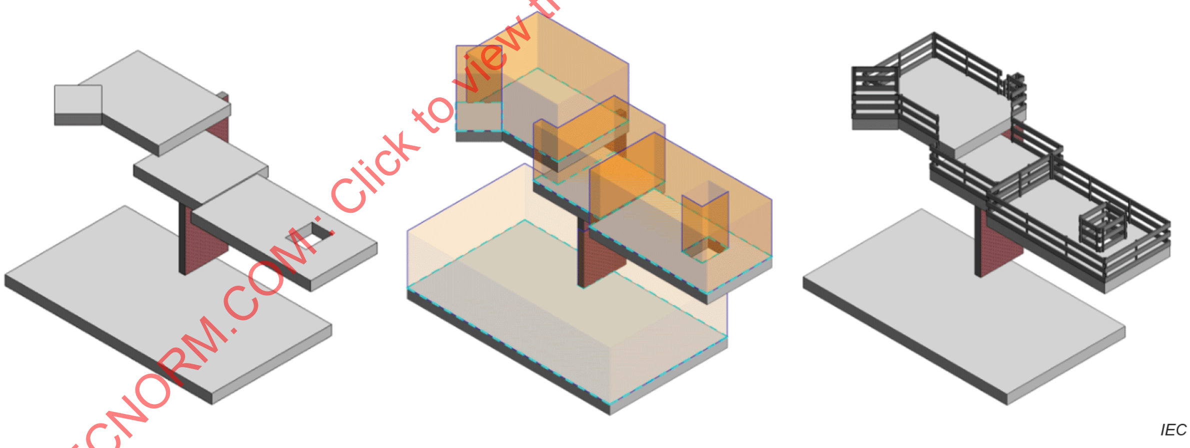
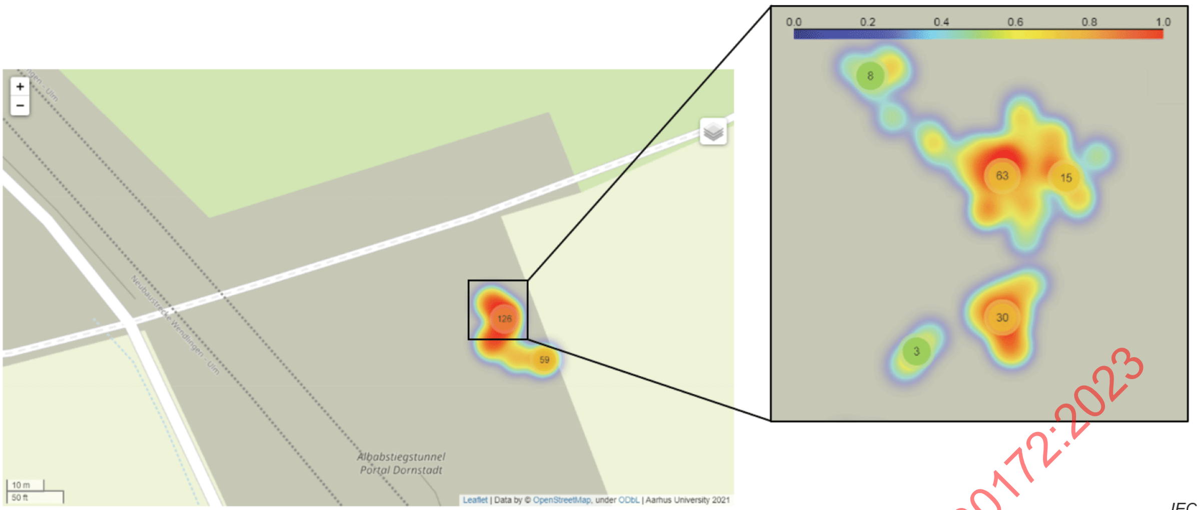


Figure B.1 – Geometric analysis of safety prevention

It is essential to detect rapidly unfolding risks on the construction site during the construction execution phase, using location tracking data to prevent potentially hazardous situations, shown in Figure B.2. This allows to predict potentially dangerous activities and issue personalized alerts.



IEC

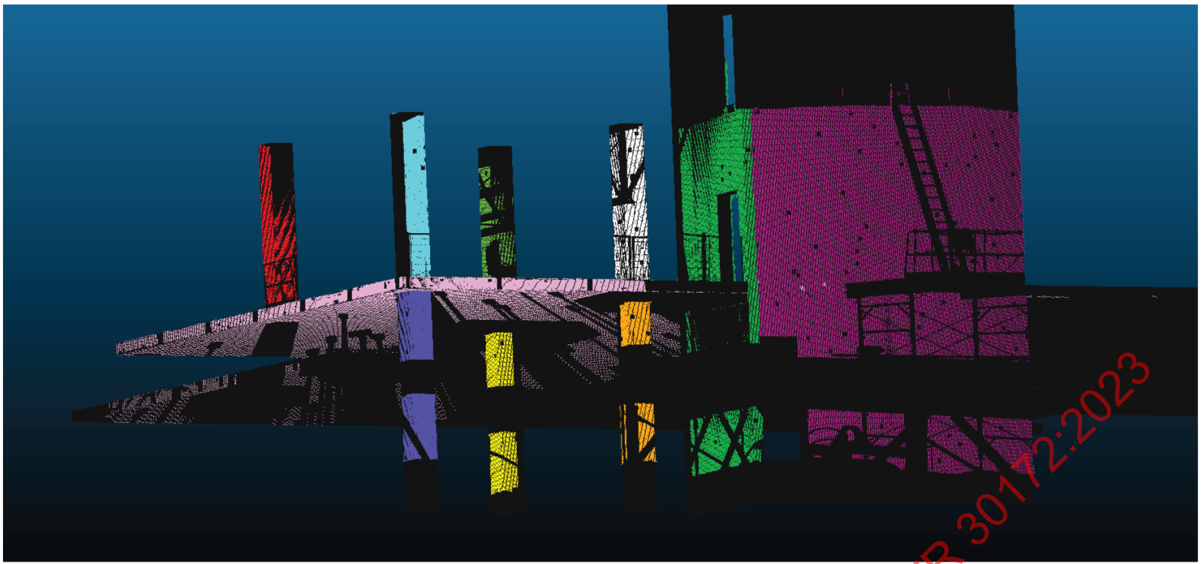
Figure B.2 – Identification of close proximity events between heavy machinery

Furthermore, during the whole life cycle, it is of interest to provide visual and interactive training materials (For example using virtual reality), taking into consideration worker-specific aspects and, if possible, the real construction environment, shown in Figure B.3.

IEC

Figure B.3 – Safety training scenario

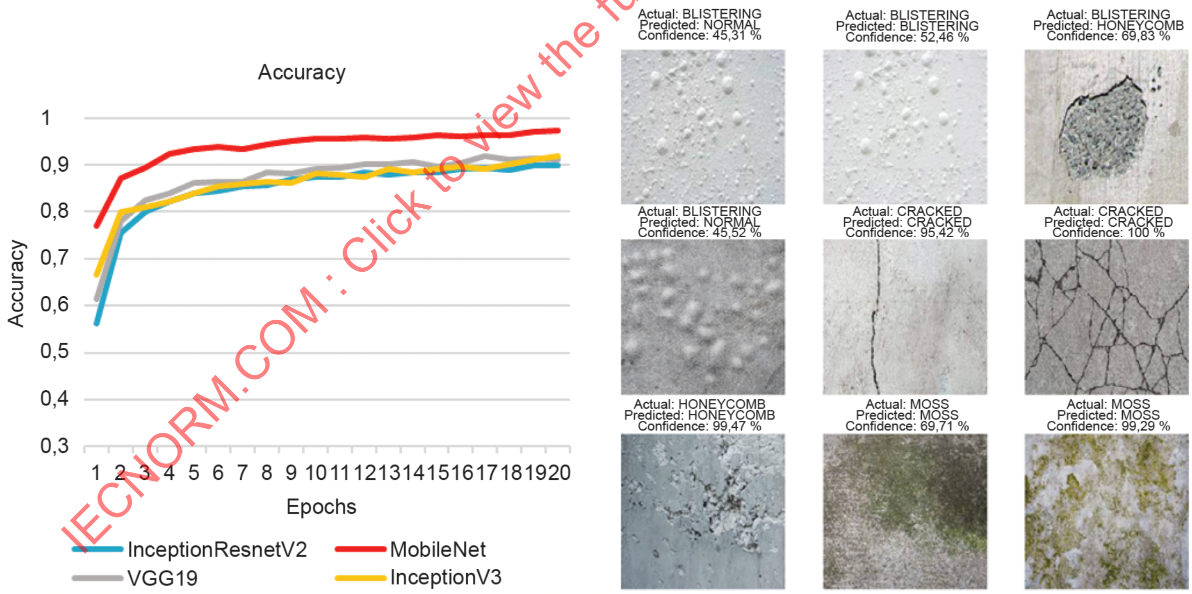
Quality control in construction sites can be approached from different perspectives. One of them is to ensure that geometric specifications are met during the construction process. To do so requires defining during the planning stage where geometric specifications apply in the project (by analysing the BIM model). Then, during construction execution, 3D data captured from the construction site are analysed and compared to information contained in the digital twin (more specifically the BIM model) to recognize the BIM components and then assess whether their attached geometric specifications are met, shown in Figure B.4.



IEC

Figure B.4 – Segmented construction components after voxel space point matching

Another perspective is automatically detecting and classifying common visual construction defects in 2D images acquired on site (either manually by a worker or periodically). Artificial intelligence techniques (For example deep learning) can automate detection with minimal need to manually confirm the detected defects, shown in Figure B.5. All this visual quality information is included in the digital twin to support other tasks in the construction process.



IEC

Figure B.5 – Sample defect predictions

On-site visual data capturing based on Augmented Reality enables the live visualization of the geometric, visual, and safety issues. The relevant stakeholders will be able to visualize the detected issues to confirm them and propose remedial tasks in the workflow, shown in Figure B.6.

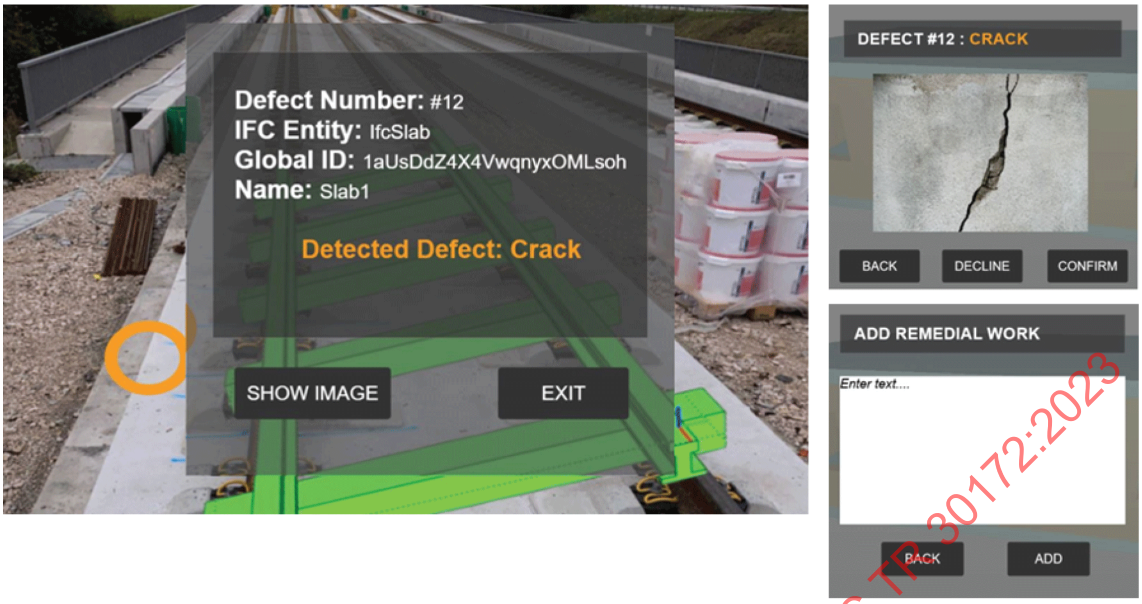


Figure B.6 – On-site defect visualization, defect confirmation, and addition of remedial work

Finally, It is important to define an environment where the construction process and workflow can be modelled and incrementally refined through simulation and optimization mechanisms, over-scheduled data and resource allocation.

Such an environment will allow managers or forepersons to keep track of the entire process and adapt the workflow in case of planned or unforeseen changes during the construction. In addition, it will provide on-site assistance to workers by providing them with the necessary information and instructions of the process, reporting work progress and issues, and receiving updates from the construction manager or foreperson.

B.7.1.8 Entities which need to be modelled as digital entities in use case

Entity name	**Data**	**Model type**	**Requirements or constraints on the models**
Construction site	Geometric and spatial information, facility information, process information, resource information	Physical and knowledge model	Performance requirements: consistency and accuracy Input and output requirements: interface
Construction process	Process information, task information, work order information, resource information	Knowledge model	Performance requirements: consistency and accuracy Input and output requirements: interface
Construction element	Geometric and spatial information, task information, quality information	Physical model	Performance requirements: consistency and accuracy
Construction equipment	Spatial information, work order information	Physical model	Performance requirements: consistency and accuracy
Worker	Spatial information, work order information	Physical model	Performance requirements: consistency and accuracy Input and output requirements: interface Regulation: EU General Data Protection Regulation

B.7.1.9 Actors: people, organizations or systems

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
Project manager	☐ system actor ☑ business actor: role: user	Monitors and controls all aspects of the project and ensures that the people involved achieve the objectives in time and cost, performance, and quality. Also coordinates the design team, ensuring that the project can be effectively executed with the appropriate information and understanding.	
Site manager	☐ system actor ☑ business actor: role: user	Oversees site operations on a day-to-day basis and ensures that work is done safely, on time, within budget and to the right quality standards. Has in-depth knowledge of construction methods.	
Quantity surveyor	☐ system actor ☑ business actor: role: user	Works closely with and helps project managers deliver the project on time, within scope, and on budget. Provides guidelines, estimates, and forecasts of labour, material, and overhead costs, supervises the monitoring of progress on site and consequent estimation of the value of work completed.	
Foreperson	☐ system actor ☑ business actor: role: user	Is responsible for a group of workers forming a construction crew. Is usually a senior worker.	
Worker	☐ system actor ☑ business actor: role: user	Is a tradesperson, labourer, or professional employed in the physical construction of the building or infrastructure asset.	
Quality manager	☐ system actor ☑ business actor: role: user	Is in charge of planning the collection of and reviewing the quality control reports to verify if each element of the project complies with standards and regulations, is safe, and does not present any risk to the project. It is possible to also go on-site and conduct inspections, and through such process collect additional data (For example photographs).	

Actor name	Actor type	Actor description	**Actor interactions** (Transactions between Actors) (optional)
Surveyor	☐ system actor ☑ business actor: role: user	Is in charge of acquiring the data from surveys of sites using tools like total stations, levels, laser scanners, or cameras. Will also likely conduct the computations required from the data to infer whether works are conducted according to specifications and compile quality control reports.	
Heath, Safety, Environment (HSE) Manager	☐ system actor ☑ business actor: role: user	Is in charge of the compliance of all health and safety legislations. Also assists in the creation and management of health and safety monitoring systems and policies in the workplace.	
Health, Safety, Environment Supervisor	☐ system actor ☑ business actor: role: user	Is responsible for monitoring health and safety risks at the workplace and advising employees on avoiding them. Also manages emergency procedures.	
Health, Safety, Environment Trainer	☐ system actor ☑ business actor: role: user	Is responsible for training construction site employees to improve health and safety standards in the workplace and to comply with health and safety regulations.	

B.7.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ requirements phase ☑ development phase ☐ test phase ☐ integration phase ☐ installation phase ☐ modification phase

B.7.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Consistency	Logical coherence among the digital entities and the corresponding physical entities and among the digital entities themselves.	For Objective 1, to ensure that decisions are taken on a reliable replica of the construction site.
Conformity	Determination of whether the digital representation of the construction site meets the specified requirements.	For Objectives 2 and 3, to ensure that specifications and regulations are met with respect to geometric and visual quality control and health and safety quality control.
Synchronization	The status of the digital entities in the digital twin can be synchronized with the status of the physical entities, or vice versa, using timely-manner networks.	For Objectives 1, 2, and 3, to ensure that the digital representations of all the construction elements and resources (equipment and workers) in the construction site are up to date.
Traceability	Ability to trace the history, allocation, or location of equipment and workers.	For Objectives 1, 2 and 3, to enable the construction site's monitoring, simulation, and prediction.
Productivity	Ability to be efficient while obtaining long-term resilience and meeting short-term financial goals.	For Objectives 1, 2, and 3, reduce costs, improve predictability, and minimize risks and maintenance.
Safety	Knowledge and understanding of health and safety aspects is key to reducing costs and keeping staff productive by predicting any prior contingencies using the digital twin model.	For Objective 3, to reduce construction site accidents and to improve worker competencies.

B.7.1.12 Digital infrastructures

Name	Description	Impact on use case
2D photographic and 3D scanning (and photogrammetry)	This equipment is used to capture the visual (2D) and geometric (3D) states of the construction site.	These data are used for visual and geometric quality control assessment and health and safety control.
Localization and tracking	This equipment is used to track the different moving resources on the construction site.	There is the need to know the location of workers and equipment in order to support them in performing their tasks and to enable real-time health and safety control.

Name	Description	Impact on use case
End-user devices	Users use this portable equipment to send and receive different types of information.	End users have digital devices that allow them to know the current work orders of their location and warn them of any danger that is occurring or can occur on the construction site.
Artificial intelligence	A collection of artificial intelligence techniques supports different aspects of the digital twin.	Workflow optimization, visual quality control, and health and safety assessment tasks require different artificial intelligence techniques. Furthermore, knowledge representation is necessary to enable semantic interoperability with the digital twin platform.

B.7.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.7.1.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.7.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.7.1.16 General remarks (optional)

General remarks

B.7.1.17 Challenges and issues (optional)

Challenges and issues

B.7.1.18 Data security, privacy and trustworthiness (optional)

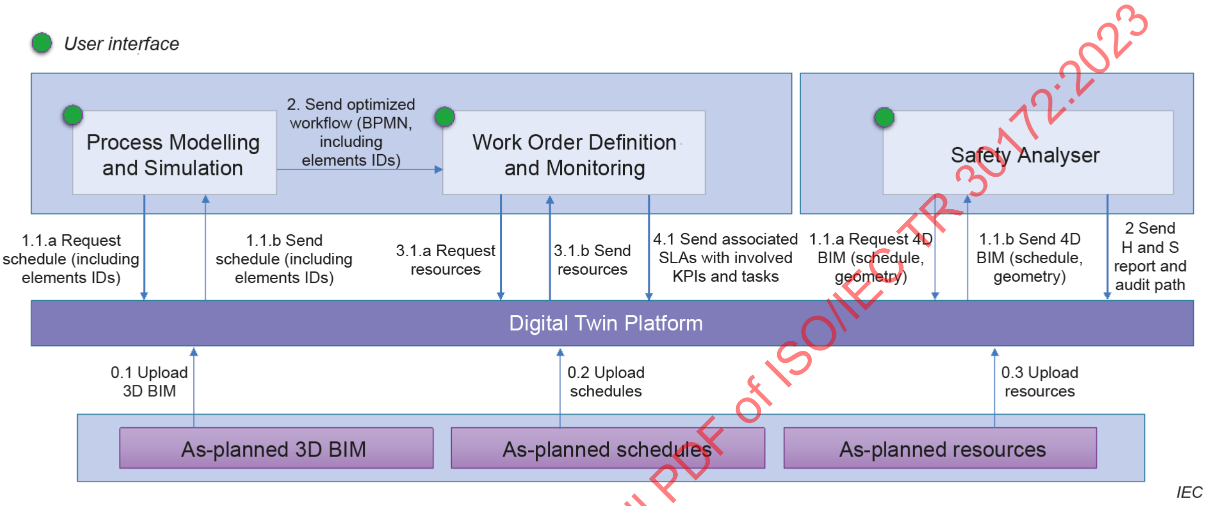
Data security requirements and implications for applications and systems
Privacy requirements and implications for applications and systems
Trustworthiness requirements and implications for applications and systems

B.7.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.7.2 Drawings or diagrams depicting the use case

B.7.2.1 Drawing of use case

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"
The use case diagram is split into two to reflect the information flow on the use case and improve its readability. The first diagram depicts the use case diagram relevant for the planning phase before the actual construction works start. In contrast, the second diagram represents the information flow during the construction phase.  **Figure B.7 – Use case diagram: before construction starts** As-planned data include the 3D BIM model, scheduling data that could be the fourth dimension of the BIM model, resources (workers and their roles and heavy machinery), and cost data that can be considered the fifth dimension of the BIM model. Before construction works on a project start, the as-planned project data are uploaded to the Digital Twin Platform. Then, the information flows as follows: 1) The Process Modelling and Simulation component requests and receives a subset of the 4D BIM data (as-planned schedule including construction element identifiers) from the Digital Twin Platform. It generates an optimized business process and workflow model that is sent to the Work Order Definition and Monitoring component. In parallel, the Safety Analyser component requests and receives (a) the 4D BIM data from the Digital Twin Platform and (b) formalized safety code rules from its local database to enrich the 4D BIM data with health and safety information. The enriched 4D BIM model is sent to the Digital Twin Platform. 2) The Work Order Definition and Monitoring component requests and receives: (a) the as-planned resources data from the Digital Twin Platform and (b) the service level agreement templates for work orders, and after the user defines the work orders and their assignments to personnel, it sends the associated service level agreements along with involved personnel and tasks to the Digital Twin Platform.

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"

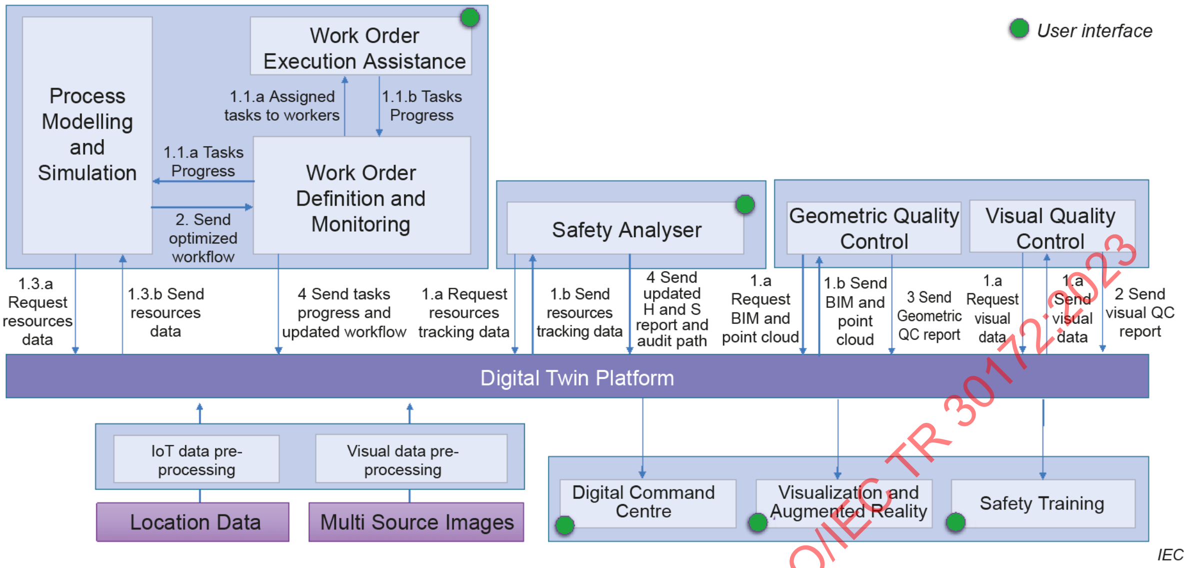


Figure B.8 – Use case diagram: during construction

In the construction phase, groups of components are collaborating to provide support for the workflow, quality control, and health and safety management:

1) The IoT and Visual Data Pre-processing components feed the Digital Twin Platform with the as-built data acquired on-site.
2) Regarding workflow management, the Work Order Definition and Monitoring component sends notifications to workers about tasks assigned to them through the Work Order Execution Assistance application. Workers also use this application to report their progress. The Process Modelling and Simulation component requests and receives resource tracking data from the Digital Twin platform. It combines it with the reported tasks progress data, runs scenario simulation and optimization, and updates the process and workflow model. The updated model is received by the Work Order Definition and Monitoring component, which in turn sends that task's progress and the updated work orders (workflow) to the Digital Twin Platform.
3) Concerning the prevention of construction on-site accidents, the Safety Analyser component receives the resource tracking data from the Digital Twin platform and processes them in combination with the 4D BIM model enhanced with health and safety information to generate alarms for health and safety risks that are sent as notifications to the Work Order Execution Assistance application. The Safety Analyser also updates its health and safety parameters and rules.
4) For quality control checking, the Geometric Quality Control component requests and receives the 4D BIM model and point cloud data from the Digital Twin Platform to produce the geometric quality control results that are forwarded to the Digital Twin Platform. Similarly, the Visual Quality Control component requests and receives the 4D BIM model and visual (imagery) data from the Digital Twin platform to produce the visual quality control results that are forwarded to the Digital Twin Platform.
5) The Digital Command Centre and Visualization and Augmented Reality components are used mainly for visualization purposes; the Safety Training component is used for workers' training.

B.7.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.7.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.7.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.7.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)

B.8 Smart building – Residential explicit demand response – Consumer behavioural digital twin for energy demand prediction

B.8.1 Description of use case

B.8.1.1 Name of use case

ID	Name of use case
008	Residential explicit demand response – Consumer behavioural digital twin for energy demand prediction – EU

B.8.1.2 Digital twin application area or context of use

Application area or context of use
In the context of continuously increasing, highly distributed renewable generation, grid operators require more flexibility from the grid, to balance the increase of uncontrollable Renewable Energy Sources (RES) production. As major loads in the grid, and sometimes also as producers, consumers are at the core of the energy system and thus at the centre of developing Demand Response (DR) services. These services are expected to massively increase the efficiency and hosting capacity of distribution networks in the mid-term. This will allow for the utilization of flexibility in the distribution grid, which will serve to improve frequency stability and congestion management. The Consumer Digital Twin will be part of a larger system of next generation of energy service applications for demand response, home automation and home convenience, which considers that consumers or prosumers are at the heart of the energy market by engaging them directly in a co-creation process with other actors from the energy domain during the design, development, and utilization of pro-active demand-response mechanisms. These mechanisms will be paired with cross-sectoral, value-adding services that will be defined according to consumer or prosumer preferences. The Consumer Digital Twin and the use case were developed within the context of the European Union's Horizon 2020 research and innovation programme in the SENDER (Sustainable Consumer Engagement and Demand Response) project under grant agreement No 957755.

B.8.1.3 Version management

Changes or version	**Date**	**Name Author(s) or committee**	**Approval status (optional)**
V1.0	2022-02-25	Jason TSAHALIS	draft
V2.0	2022-03-07	Christian KUNZE	draft
V3.0	2022-04-13	Jason TSAHALIS	for review
V4.0	2022-05-30	Christian KUNZE	Adjusted review after input from SENDER project consortium meeting

B.8.1.4 Basic information to use case

Source(s) or literature (optional)	**Link (optional)**	**Conditions (limitations) of use (optional)**
/	/	/
Maturity of use case		
☐ in business operation, ☑ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		

Generic, regional or national relation
European Union
Vertical application area
Smart buildings for electricity grid flexibility
Well-known or related commercial or existing use cases (optional)
\
Keywords for classification
Energy grid; smart home; smart building; flexibility; load forecasting; consumer engagement; consumer behaviour

B.8.1.5 Scope of use case

Scope of use case
• Participation of consumers through smart home or buildings in demand response.

B.8.1.6 Objectives of use case

Objectives of use case
• Objective 1: to propose or offer Smart Home or Building flexibility to market actors through the form of flexibility forecasts. • Objective 2: to adapt the behaviour of the Smart Home or Building following the reception of flexibility activation demands.

B.8.1.7 Narrative of use case

Narrative of use case
Short description
This use case describes how the SENDER solution will extract flexibility from four different assets of a Smart Home (HVAC system, lighting system, hot water tank and Electric Vehicles) to propose them to a flexibility market. The digital twin developed describes the occupant or consumer behaviour in the Smart Home.

Complete description
In a context of decentralization of energy generation, grid operators (Transmission System Operator – TSO and Distribution System Operator – DSO) are facing new challenges: frequency deviation, voltage drop, congestion, etc. Occupants of a Smart Home or Building can contribute to grid stabilization by taking part in Explicit Demand Response. Demand Response (DR) refers to a reduction or a shift of the electricity usage of a consumer in response to supply constraints. This use case describes: • How Smart Home or Building, equipped with the SENDER solution, takes part in Demand Response by proposing or offering flexibility extracted from Heating Ventilating Air-Conditioning (HVAC) systems, lighting systems, Hot Water Tanks or Electric Vehicles (EVs) to an aggregator. The aggregator can, in return, provide multiple services (frequency management, voltage control, congestion management, etc.) to grid operators (DSO or TSO). It is important to mention here that the SENDER solution will ensure that occupants' comfort is not violated (For example house temperature is always within comfort boundaries, vehicle is charged at its departure time, etc.) • How Smart Home or Building, equipped with the SENDER solution, responds to flexibility activation demands by automatically adapting the loads of the aforementioned assets according to the flexibility activation demand • How the occupant of the Smart Home or Building will be notified about automatic responses and DR requests and can opt-out of a planned or ongoing automatic response after receiving a notification. In that case, the Smart Home will apply a new strategy that matches the consumer's instructions. Note that this opt-out option needs further discussion between partners and in co-creation and that we might limit this option for the project demonstration activities This use case is composed of the following functions: • Evaluate flexibility that can be extracted from HVAC systems, lighting systems, hot water tanks and EVs • Send flexibility offers or forecasts to an aggregator • Upon receipt of a flexibility activation demand, define and carry out the proper remote controls for load dispatching • At the end of the flexibility period: define and carry out the corrective controls for switching loads back on if need be • Opt-out – give the possibility to consumers to not take part in any Demand Response for a defined period of time

This use case relies on the following principles:

- P1. This use case considers flexibility to apply on a period basis.
- P2. This use case considers flexibility intended for:
  - A reduction or termination of loads or electricity generation
  - A rise in loads or electricity production.
- P3. Flexibility is usually composed of two elements:
  - A flexibility forecast, sent by the SENDER solution to an aggregator, indicating the start of the period, the involved capacity or energy and period duration
  - A flexibility activation demand, sent by the aggregator to the SENDER solution, indicating the validation of a previously sent offer or forecast and detailing the start of the period, the capacity or energy to activate or deactivate and its duration.
- P4. This use case assumes that the SENDER solution sends the flexibility forecasts from several buildings to the aggregator, who, in return, selects the most proper ones and creates the flexibility activation demands depending on the needs of the system operator.
- P5. Appliances taking part in the DR scheme are:
  - Heating, Ventilating and Air-Conditioning (HVAC) system
  - Lighting system
  - Hot Water Tanks (HWT)
  - Electric Vehicles (EV)
- P6. The consumer can opt out of the flexibility scheme if no flexibility activation demand is ongoing.
- P7. This use case assumes that the household is equipped with an Internet connection.

This use case is composed of the following scenarios:

1) Flexibility from HVAC and lighting systems: the SENDER solution evaluates the flexibility that can be proposed by HVAC and lighting systems, sends flexibility forecasts to an aggregator, executes the proper control actions on the related appliances upon flexibility activation demand from the aggregator and informs the Occupant if necessary
2) Flexibility from hot water tanks: the SENDER solution evaluates the flexibility that can be proposed by hot water tank, sends flexibility forecasts to an aggregator, executes the proper control actions on the water tank upon flexibility activation demand from the aggregator and informs the Occupant if necessary
3) Flexibility from Electric Vehicles: the SENDER solution evaluates the flexibility that can be proposed by plugged Electric Vehicles, sends flexibility forecasts to an aggregator, adapts the EV charging process upon flexibility activation demand from the aggregator and informs the Occupant if necessary
4) Consumer customizations and possible opt-outs (if no flexibility activation demand is ongoing)

The main innovation of this use case stands in the co-simulation performed by the Load and DER forecast tool and the Consumer Digital Twin, which operate in tandem. The load and DER forecasting system developed in the project addresses the problem in an innovative way by realizing a probabilistic forecast of loads and generation of the PV systems at the single house and installation level. The loads of individual houses show a very high level of variability, which makes accurate deterministic forecasting extremely difficult, not allowing the use of techniques traditionally applied for load forecasting at grid level, for example in power dispatching. Modern machine learning techniques are necessary, and above all, a probabilistic forecast is required that is not limited to giving an indication about the expected value for consumption, but that provides an estimate of the probability distribution of the achievement of a certain load level for each instant of the time frame of interest. The models used are based on the elaboration of features of environmental type (in other words the external temperature), of calendar type (in other words the time of day, the day of the week, the holidays), and features that take into account the activity of the users (in other words the occupation of the house). These last ones are important because they can determine relevant load increments (in other words switching on of an oven) and are of particular interest from the point of view of a Demand Response programme. In SENDER, user characterization is implemented via a Digital Twin based on the IEA EBC Annex 66, further augmented by the inclusion of artificial intelligence for enhanced adaptation to the Consumer trends or habits and for better and more accurate co-simulation predictions of the energy consumption.

B.8.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
Consumer	Parameter information for buildings, occupants, behaviours, calendar.	AI, data mining, statistical, stochastic, meta.	Requirements: accuracy Constraints: GDPR
Smart Home or Building	Sensors, HVAC, lighting, HV charger	Physical model	Requirements: accuracy Constraints: GDPR
Weather or Environment	Temperature, humidity, illumination, CO_2 concentration, human flow, etc	Physical model	Requirements: accuracy

B.8.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	**Actor interactions** (Transactions between Actors) (optional)
Consumer	Business Actor	A party that consumes electricity	

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
Smart Home	Logical Actor	House or apartment equipped with a communicating (electricity, telecoms) and structured home area network (HAN)	
Heating Ventilation Air-Conditioning (HVAC) systems	Logical Actor	System providing heating and cooling to residential and commercial buildings. HVAC systems provide thermal comfort for occupants accompanied with indoor air quality. Primary HVAC equipment includes heating equipment, ventilation equipment and cooling or air-conditioning equipment.	
Lighting systems	Logical Actor	System providing lighting to residential and commercial buildings	
Hot Water Tank	Logical Actor	Water heating is a heat transfer process that uses an energy source to heat water above its initial temperature	
Electric Vehicle (EV)	Logical Actor	Automobile which is powered completely or in part by electricity and whose battery can be charged from an EVSE	
Electric Vehicle Supply Equipment (EVSE)	Logical Actor	Electric Vehicle charger	
SENDER solution	Logical Actor	The solution developed in the SENDER project and which supports this use case	
Aggregator	Business Actor	A party which aggregates flexibilities for its customers	

B.8.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ requirements phase ☑ development phase ☑ test phase ☑ integration phase ☑ installation phase ☐ modification phase

B.8.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Increase profitability for DSOs	Increase profitability for DSOs by increasing the number of potential DR clients in the next 5 years. Target: 20 %	For Objective 2.
Number of DR services considered	Target: > 3	For Objective 2.
Percentage of power subscription	Percentage of power subscription that can be mobilized for flexibility per household. Target: up to 20 %	For Objectives 1 and 2.
Percentage of energy consumption	Percentage of energy consumption that will be mobilized for flexibility per household in the project. Target: 5 % to 10 %	For Objectives 1 and 2.

B.8.1.12 Digital infrastructures

Name	Description	Impact on use case
Load and DER forecast tool	A system for the forecast of electrical loads of domestic users and distributed generation from renewable sources, typically photovoltaic systems. Also links directly to weather forecasting models.	Uses the Consumer digital twin to simulate the occupant behaviours in the smart homes or buildings to forecast the load and DER.
Comfort profile engine	The purpose of comfort profiling is to identify the occupants' comfort boundaries on indoor ambient conditions relying on sensing and monitoring collected data.	Feeds into the Consumer digital twin the thermal comfort profiles extracted from the sensed and monitored data.

Name	Description	Impact on use case
SENDER database	Cloud-based central database that retains all sensor, monitoring, and control data of the smart homes or buildings.	Provides the training data for the AI component of the Consumer digital twin.

B.8.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard

B.8.1.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links

B.8.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship
\	\	\

B.8.1.16 General remarks (optional)

General remarks

B.8.1.17 Challenges and issues (optional)

Challenges and issues

B.8.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications and systems
The digital twin (DTw) that is the basis for this document was developed within the context of the European Union's Horizon 2020 research and innovation programme in the SENDER (Sustainable Consumer Engagement and Demand Response) project under grant agreement No 957755. Therefore, the aspects of Data security, privacy and trustworthiness become mainly analysed from an EU law perspective. The set-up of a digital twin in the electricity domain requires the collection and processing of personal data of involved household consumers. Therefore, the compliance with EU and national regulations on data protection must be guaranteed (see following section on data privacy) and it is proposed to sign a specific consent form with all involved, data-providing parties. Furthermore, the security and privacy practice must be based on relevant reference architectures, ISO standards, NIST guidelines for smart grid cyber-security (NISTIR 7628) and EC recommendations on cybersecurity in the energy sector. In terms of data security requirements, it is important that the following processes and measures are taken into consideration: 1) Files and folders A common repository for documentation of the DTw is established. It hosts technical material and documentation generated on the DTw; different access rights must be given to each user from read only to all type of modifications. The access to the repository is controlled by a central, trustworthy instance (data repository owner). 2) Backup and recovery The site repository keeps a frequent backup procedure to not lose any information, so in case of an incident, the data can be recovered according to the procedures of the data repository owner.

3) Data security risks

The main data security risks and mitigation actions are presented in the following table:

Risk	Mitigation measure
Accidental data loss due to software or hardware failure	A backup copy of the data is available. The backup copy is not in the same physical location as the original one.
Data access by unauthorized third party	Access to the data repository is allowed only for authorized users and requires secure authentication mechanisms. The access is restricted by rights to each user, depending on its activity and required repository modification right requirements.
Data breach	Access to data is restricted to pre-defined users. When a data breach is suspected to happen, a procedure of communication and mitigation measures is put in place. The repository owner gathers the information with the responsible users and notifies the National Data Protection Authority (DPA) within 72 hours, detailing the subjects that are affected with the breach and notifying them on the concrete violations of their data.

Due to the collection and processing of many different data sets for the set-up of the DTws, a PIA (Privacy Impact Assessment) is mandatory. A specific Security and Privacy Plan (SPP) for each pilot in the project will be defined in which the PIA will be scheduled and performed. In the Data registry, all these reports will be gathered for possible audits and for the improvement of the data procedures and management.

4) Anonymization

Anonymization is mandatory to unlink data collected from users. This will be applied for the recruitment of the users and the collection of their data for identifying patterns.

5) Encryption

All special categories of data as defined by Art. 9 of GDPR, especially sensible data, must be encrypted to provide confidentiality, integrity, and authenticity of the data.

Privacy requirements and implications for applications, systems, etc.

The legal basis for privacy requirements in terms of the digital twin development is the EU General Data Protection Regulation complemented by the International Human Rights Instruments.[2] Public and private organizations adapt their processing of data accordingly. In this way the protection of personal data by this legal instrument strengthens the role of human rights that could be affected by new technology.

When processing personal data for the purpose of a digital twin development, activities must comply with the lawful basis and principles stated in Article 5.

2 The General Data Protection Regulation (EU) 2016/679 (GDPR) is a regulation in EU law on data protection and privacy in the European Union (EU) and the European Economic Area (EEA). The GDPR is an important component of EU privacy law and of human rights law, in particular Article 8(1) of the Charter of Fundamental Rights of the European Union.

From an operational point of view, different forms of meetings by involved parties are recommended to align interests and expectations in terms of digital twin utilization and to guarantee the compliance with relevant legislation:

1) Context meetings to explain the background and basis of the security, safety and privacy practice defined, together with an understanding of the pilot architecture and use cases. (ISO/IEC 27005 for security risk, ISO/IEC 29134 for privacy impact assessment).
2) Based on the finalized definition of procedures, roles, implications and methodologies to follow, a risk and privacy analysis meeting, using established methods such as STRIDE or NIST security framework (for security) and LINDDUN, CNIL method, NIST Privacy Framework or ISO/IEC 29134 (for privacy) is conducted.
3) Finally, policy framework analysis meetings serve to debrief on the policy framework from the perspectives of
   a) Trust analysis
   b) Engagement analysis
   c) Security and privacy analysis

It is important that Fundamental rights aspects of DTw implementations are analysed by answering the following questions:

– Does the AI system potentially negatively discriminate against people on the basis of any of the following grounds (non-exhaustively): sex, race, colour, ethnic or social origin, genetic features, language, religion or belief, political or any other opinion, membership of a national minority, property, birth, disability, age or sexual orientation?
– Does the AI system respect the rights of the child, for example with respect to child protection and taking the child's best interests into account?
– Does the AI system protect personal data relating to individuals in line with GDPR?
– Does the AI system respect the freedom of expression and information or freedom of assembly and association?[3]

This will serve to ensure on the one hand Fundamental Rights compliance of DTw implementations as well as on the other hand consumer acceptance of the applied solutions.

Trustworthiness requirements and implications for applications, systems, etc.

The analysis of trustworthiness aspects of artificial intelligence solutions requires to define the AI term. In this context, the AI definition of the high-level expert group AI that was set-up by the European Commission is used.

For an AI System, and digital twins, to be considered trustworthy, seven requirements are fulfilled: Human agency and oversight, Technical Robustness and Safety, Privacy and Data Governance, Transparency, Diversity, Non-discrimination and Fairness, Societal and environmental well-being, Accountability. These requirements are covered by any assessment of an AI System during the life cycle of its development.[4]

3 Independent High-Level Expert Group on Artificial Intelligence (2020): The Assessment List for Trustworthy Artificial Intelligence (ALTAI), Brussels July 2020, pp.6; available at: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=68342

4 The "Ethics Guidelines for Trustworthy AI" in addition to existing practices and assessment tools provide a list for assessment, but it makes clear that compliance with the assessment list does not equal legal compliance with applicable laws.

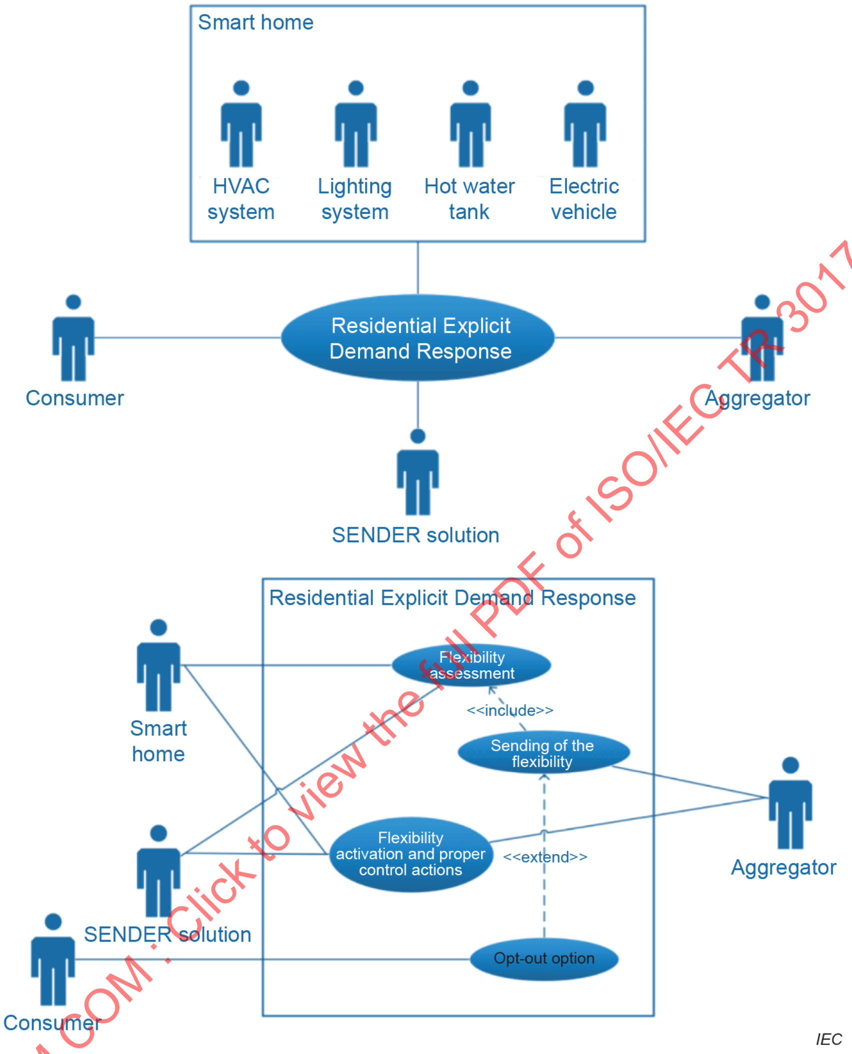
With reference to the seven points of the Assessment List for Trustworthy AI (ALTAI), the following approaches serve as good practice to create trustworthiness: 1) Human Agency and Oversight: users must be able to choose to accept results with or without the inclusion of the AI module in the DTw, implementing a human-in-command (HIC) approach. 2) Technical Robustness and Safety: the included AI of a digital twin is strictly limited in data access rights and have bare minimum code execution rights for its own internal running. The digital twin and AI themselves operate under specific limits of potential results, therefore the effects of any potential malicious attacks will be severely limited and minimal. Regular inspections must be planned, and automatic alerts be implemented. Any issues can be immediately dealt with via restoration to previous working version. No physical harm can come from the AI module. 3) Privacy and Data Governance: all private data must be masked at the source prior to submitting to the digital twin and its AI module. All communications must follow latest https encryptions protocols. It is important that any local databases are properly encrypted (at least 256-bit) and will not be accessible via internet. Access to data will be only for designated developers and logs will be kept for access tracking. It is important that a supervisor is designated to oversee the process and carry out checks. 4) Transparency: the AI algorithm must be fully traceable with comprehensive explanation of each part and step. Labelling of the system must be exactly defined from the beginning and provided along with results from alternative methodologies for continuous comparison. 5) Diversity, non-discrimination, and fairness: a continuous comparison with alternative methodologies is to be implemented. It is important that the AI model is reliant on inclusivity. 6) Societal and environmental well-being: AI modules address the need to design for better human comfort and well-being. Interaction with humans is not to be foreseen and there must be no pathway to affect their behaviour. 7) Accountability: all relevant information is published and presented in scientific journals and conferences and be openly available. The HIC approach implemented ensures a hard stop on potential negative impacts, with no negative trade-offs on the system. Redress must be possible at any time.

B.8.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.8.2 Drawings or diagrams depicting the use case

B.8.2.1 Drawing of use case

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"


B.8.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.8.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

NOTE In addition to a high level sequence diagram it can be helpful to split out critical interactions to provide additional detail on actors involved at such stages (for example, providing information on handling of fault conditions).

B.8.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.8.2.5 Others (optional)

If possible, provide a graphical image or a video of the demonstration model (optional)

B.9 Smart city - Greater Hobart Digital Twin

B.9.1 Description of use case

B.9.1.1 Name of use case

ID	**Name of use case**
009	Greater Hobart Digital Twin - Australia

B.9.1.2 Digital twin application area or context of use

Application area or context of use
The Greater Hobart Digital Twin provides the interface with which local government authorities, the community, and commercial investors will interact with the key government services data in a single joint environment.

B.9.1.3 Version management

Changes or version	**Date**	**Name Author(s) or committee**	**Approval status(optional)**
V1	23/09/2021	Gavin Cotterill (Standards Australia IT-042)	DRAFT

B.9.1.4 Basic information to use case

Source(s) or literature(optional)	Link(optional)	Conditions (limitations) of use (optional)
Maturity of use case		
☐ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☐ in preparation ☑ visionary		
Generic, regional or national relation		
Greater Hobart, Tasmania Australia		
Vertical application area		
Cities and Built Environment		
Well-known or related commercial or existing use cases (optional)		
Singapore, Barcelona, London, Stockholm, Helsinki		
Keywords for classification		
BIM, GIS, geospatial, IoT, system integration, data visualization, data analysis, simulation		

B.9.1.5 Scope of use case (bullet point)

Scope of use case
Include but not limited to following items: Digital Reform There is a need to embrace digital sharing as a means of overcoming competing local governments' challenges. The current lack of digital service integration across the Local Government Authorities (LGAs) is a key non-structural impediment to joint, cross-boundary service opportunities. Strategic planning and joint investment opportunities are constrained as a result. Multi-modal Visualization There is a need to create a more liveable region, where quality of life is achievable through equitable housing and mobility options, attractive open spaces, high environmental quality and personal safety. Without a tangible operational model to combine cross-sector data and information—for example, home building, commercial and industrial developments and transport planning—holistic cross-boundary precinct planning remains constrained. Economic Investment Friction There is a need to encourage economic growth by attracting investors from all sectors; an approach inclusive of, but agnostic to the strategic imperatives of individual local authorities. To undertake such decisions, investors, both foreign and domestic, require access to a broad range of data currently not visible to them. As a result, this lack of easily available, visual and clear to interpret data will add friction to decision making and create significant barriers to future investment.

B.9.1.6 Objectives of use case

Objectives of use case
• Supporting the City Deal mission of making Greater Hobart a smart, liveable and investment-ready city. • Enabling a high degree of collaboration and digital collaboration across the four Greater Hobart LGAs. • Unlocking delivery efficiencies and economic development through the availability of trusted information and data. • Increasing concurrent development planning by combining data and information from different modes or industry sectors. • Accelerating and digitizing the process for statutory planning applications and approvals. • Providing transparency and driving certainty that we will deliver against our commitments. • Attracting and de-risking investments by making data easily available and visible to potential investors and stakeholders…

B.9.1.7 Narrative of use case

Narrative of use case
Short description
The digital twin will provide the Greater Hobart public, private investors and local government authorities with new insights beyond what is currently seen with existing infrastructure models and can be used as a tool to aid decision making.
Complete description
The Digital Twin will provide the Greater Hobart public, private investors and local government authorities with new insights beyond what is currently seen with existing infrastructure models. In short, it will transform ways in which the region can sense and respond to, and predict and act on, strategic and operational activities to dramatically improve decision-making capabilities. **Local government and government business stakeholders** will be able to access, on a sophisticated and secure permissions basis, all archived and real-time data shared by the State Government and the four local government authorities within a single environment, opening-up access to that data and giving insight across all key services. **Private investors** including manufacturing and tourism developers will be able to rapidly understand and make quicker investment decisions by having the data made easily available to them. **The Greater Hobart public** will be able to interface with the Digital Twin by accessing data from a range of services, including the proposed digital bus shelters to search for bus routes, find sights to see in the area, optimize their route planning and receive live service updates on key government services.

B.9.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models
land parcel and property	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
transport	operational and context	knowledge	legal, permission based, openness, restricted
imagery	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
elevation and depth	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness

Entity name	Data	Model type	Requirements or constraints on the models
Waste and energy	operational and context	knowledge	legal, permission based, openness, restricted
place names	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
positioning	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
access system	operational and context	knowledge	legal, permission based, openness, restricted
monitoring	operational and context	knowledge	artificial intelligence, big data, synchronization
Asset management	operational and context	knowledge	legal, permission based, openness, restricted
Tourism	operational and context	knowledge	legal, permission based, openness, restricted
Emergency Management	operational and context	knowledge	legal, permission based, openness, restricted
Planning	operational and context	knowledge	legal, permission based, openness, restricted
Commercial	operational and context	knowledge	legal, permission based, openness, restricted

B.9.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
service delivery	☐ system actor ☑ business actor: role: service provider	data delivery mechanism for persistent data feeds to external users	

Actor name	**Actor type**	**Actor description**	**Actor interactions** (Transactions between Actors) (optional)
systems administrator	☐ system actor ☑ business actor: role: system operator	system operation and maintenance personnel, rights management, system configuration, upgrade and optimization	
project manager	☐ system actor ☑ business actor: role: service management	manage process and deliverables, system requirements, change process, project sprints	
data custodian	☐ system actor ☑ business actor: role: data or asset producer	data collection personnel, report input, database strategy, data model establishment	
database manager	☐ system actor ☑ business actor: role: system operator	database development, operation and maintenance management	
public	☐ system actor ☑ business actor: role: role: user	external data user who views the data but has limited physical data usage purposes	
industry	☐ system actor ☑ business actor: role: role: user	external data user with ability to analyse and aggregate data, build new products with data or insights	
government	☐ system actor ☑ business actor: role: role: user	internal and external data user with ability to analyse and aggregate data, build new products with data or insights	
academia	☐ system actor ☑ business actor: role: role: user	external data user with ability to analyse and aggregate data, build new products with data or insights	

B.9.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ inception phase ☑ design and development phase ☐ verification and validation phase ☐ integration and deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.9.1.11 Key performance indicators (KPIs)

Name	Description	Reference to mentioned use case objectives
reliability	ability of an item to perform a required function under given conditions for a given time interval	Supporting the City Deal mission of making Greater Hobart a smart, liveable and investment-ready city
fidelity	ability to accurately describe the relevant aspects of the physical counterpart within a well-defined set of conditions by its digital model	Enabling a high degree of collaboration and digital collaboration across the four Greater Hobart LGAs
conformity	process of analysis to determine whether Digital Twin meets the specified requirements and to form a judgement as to whether the digital entity is fit for its corresponding physical entity	Unlocking delivery efficiencies and economic development through the availability of trusted information and data.
validation	process of evaluating a system or component to ensure compliance with the functional, performance and interface requirements	Increasing concurrent development planning by combining data and information from different modes or industry sectors.
verification	confirmation by examination (testing) with evidence that specified requirements have been met	Providing transparency and driving certainty that we will deliver against our commitments.

B.9.1.12 Digital infrastructures

Name	Description	Impact on use case
Data storage	Database system that stores data on premises	Houses and stores the primary of delivery asset of spatial digital twin (DTw)
Cloud system	Cloud storage that stores, maintains and delivers data is in the cloud	Aggregates and stores the multiple datasets to be called or pushed to visualization ecosystem service or users on premises or cloud systems
Repository	Federation system that gathers data and feeds to digital twin (DTw) system	Hosts and stores spatial data entities for delivery
Visualization platform	System that calls datasets and displays in cloud system with dynamic control, display and rendering capabilities	Single view platform that pulls and displays spatial data objects in an exploratory visualization environment for 3D objects and time-based manipulation
Connection and Integration	Capability that enable multiple data sources or platforms to be connected and integrated so that data can be presented in one environment	Single view platform that pulls and displays multiple data sets
Authentication	System that authenticates permission-based access to data	Controls open and secured datasets

B.9.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard
ISO Building Information Modelling	ISO 19XXX family of standards	Published and drafts
ISO/IEC JTC 1/SC 41 Internet of things and digital twin	ISO/IEC TR 30172: Digital twin – Use cases, ISO/IEC 30173: Digital twin – Concepts and terminology	draft
ISO/TC 268	ISO 37XXX family of standards	Published and drafts

Relevant standardization committees	Standards relevant to the use case	Status of standard
IEC SyC Smart Cites	WG 1 Terminology, WG 2 Market Relationship, WG 3 Reference Architecture	drafts
ISO/TC 211: Geographic information or Geomatics	ISO 19XXX family of standards	Published and drafts

B.9.1.14 Referenced papers or patent(optional)

References	Type	Impact on use case	Links

B.9.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	Source	Relationship

B.9.1.16 General remarks(optional)

General remarks

B.9.1.17 Challenges and issues (optional)

Challenges and issues

B.9.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications, systems, etc.

Privacy requirements and implications for applications, systems, etc.

Trustworthiness requirements and implications for applications, systems, etc.

B.9.1.19 User requirements and interactions with other actors(optional)

User requirements and interactions

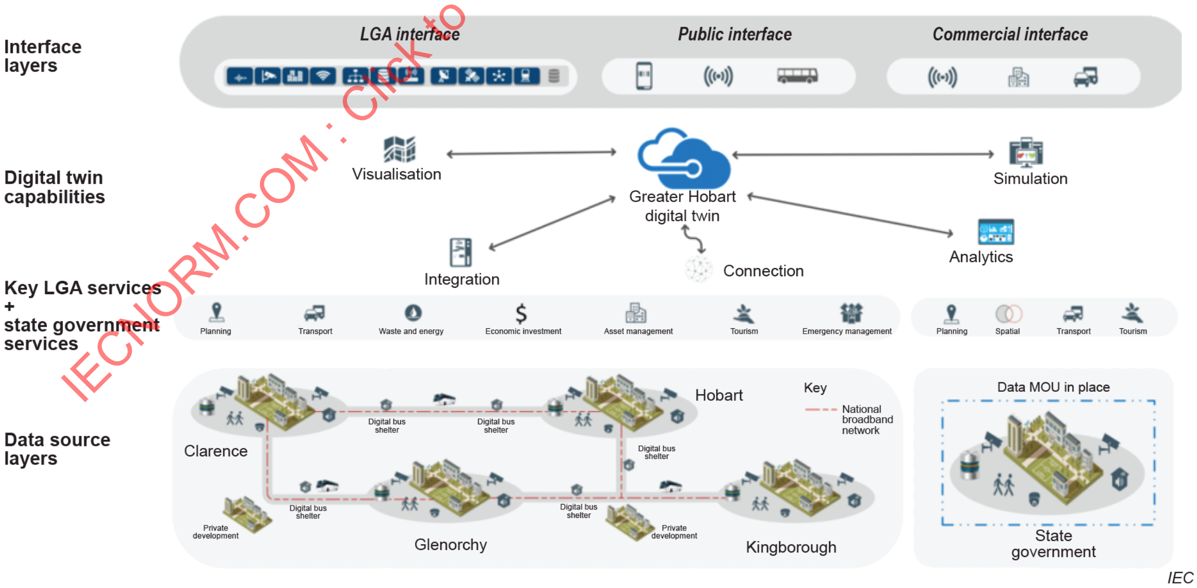
B.9.2 Drawings or diagrams depicting the use case

B.9.2.1 Drawing of use case

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"

The architecture of Greater Hobart Digital Twin is one of multiple layers, creating a digital ecosystem made up from data sets from each Greater Hobart council and selected data from State Government.

This architecture will enable the public, local government, commercial stakeholders to access key Greater Hobart data.



B.9.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.9.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.9.2.4 Deployment diagram(s) of use case (optional)

Deployment diagram(s) of use case

B.10 Smart city - NSW Spatial Digital Twin

B.10.1 Description of use case

B.10.1.1 Name of use case

ID	**Name of use case**
010	Smart city - NSW Spatial Digital Twin - Australia

B.10.1.2 Digital twin application area or context of use

Application area or context of use
Geospatial datasets associated to themes: land parcel and property, transport, administrative boundaries, geocoded address, imagery, elevation and depth, water, land cover, place names and positioning.

B.10.1.3 Version management

Changes or version	**Date**	**Name Author(s) or committee**	**Approval status(optional)**
v.1	31/08/2021	Prudence Lawrence (Standards Australia IT-042)	draft

B.10.1.4 Basic information to use case

Source(s) or literature(optional)	**Link (optional)**	**Conditions (limitations) of use (optional)**

Maturity of use case		
☐ in business operation, ☑ realized in demonstration project ☐ realized in R&D ☐ in preparation ☐ visionary		
Generic, regional or national relation		
New South Wales, Australia		
Vertical application area		
Planning, infrastructure, real estate, transport, health, education, utilities, construction, emergency services, logistics		
Well-known or related commercial or existing use cases (optional)		
Virtual Singapore, Fisherman's Bend Victoria, Helsinki 3D City		
Keywords for classification		
GIS, geospatial, land administration, land parcel and property, transport, administrative boundaries, geocoded address, imagery, elevation and depth, water, land cover, place names, positioning		

B.10.1.5 Scope of use case

Scope of use case
Include but not limited to following items: • Describe geospatial data in spatial digital twin scenario. • Describe geospatial data among digital twin systems. • Describe digital twin system architecture in spatial digital twin scenario. • Describe requirements about location-based data in digital twin area or scenario.

B.10.1.6 Objectives of use case

Objectives of use case

• Objective 1: delivery of foundational geospatial data as temporal • Objective 2: delivery of foundational geospatial data as 3 dimensional • Objective 3: federate multiple geospatial data sources and delivery in a single view visualization environment • Objective 4: Support government, academia and industry through delivering foundational spatial data products • Objective 5: Support government, academia and industry though modernized geospatial visualization and data delivery services

B.10.1.7 Narrative of use case

Narrative of use case
Short description
To deliver 4D (3D + time) foundational geospatial data to support, enable and enhance smart decision making, analysis, analytics and insight creation across government, academia and industry across New South Wales.
Complete description
The NSW Spatial Digital Twin is upgrading the existing two-dimensional spatial data to 3D or 4D in order to create a digital real-world model of our cities and communities which will facilitate better planning, design and modelling for NSW's future needs. The platform also integrates Digital Engineering assets, Building Information Models, and live API feeds for public transport, air quality, and energy production. The platform is also designed to integrate with the NSW Spatial Collaboration Portal that provides a central point to search, discover and share spatial information. While primarily focused on supporting infrastructure planning and delivery, this platform has benefits at national, state and local government levels, for industry and for the community. Its benefits are also broad, spanning all sectors – infrastructure planning and delivery, planning, service delivery, environmental management, natural resource management, as well as emergency management and counterterrorism.

B.10.1.8 Entities which need to be modelled as digital entities in use case

Entity name	**Data**	**Model type**	**Requirements or constraints on the models**
land parcel and property	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
transport	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness

Entity name	Data	Model type	Requirements or constraints on the models
administrative boundaries	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
geocoded address	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
imagery	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
elevation and depth	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
water	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
land cover	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
place names	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
positioning	geometry, feature information, metadata	physical	performance requirements: consistency, accuracy and fineness
access system	operational and context	knowledge	legal, permission based, openness, restricted
monitoring	operational and context	knowledge	artificial intelligence, big data, synchronization
process or rule	Business management process data, user role data, rights management data	knowledge	Performance requirements: accuracy rate, accuracy rate, recall rate; Input and output requirements: interface

B.10.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
service delivery	☐ system actor ☑ business actor: role: service provider	data delivery mechanism for persistent data feeds to external users	
systems administrator	☐ system actor ☑ business actor: role: system operator	system operation and maintenance personnel, rights management, system configuration, upgrade and optimization	
project manager	☐ system actor ☑ business actor: role: service management	manage process and deliverables, system requirements, change process, project sprints	
data custodian	☐ system actor ☑ business actor: role: data or entity or asset producer	data collection personnel, report input, database strategy, data model establishment	
database manager	☐ system actor ☑ business actor: role: system operator	database development, operation and maintenance management	
public	☐ system actor ☑ business actor: role: role: user	external data user who views the data but has limited physical data usage purposes	
industry	☐ system actor ☑ business actor: role: role: user	external data user with ability to analyse and aggregate data, build new products with data or insights	
government	☐ system actor ☑ business actor: role: role: user	internal and external data user with ability to analyse and aggregate data, build new products with data or insights	
academia	☐ system actor ☑ business actor: role: role: user	external data user with ability to analyse and aggregate data, build new products with data or insights	

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
interface platform developer	☐ system actor ☑ business actor: role: role: distribution system operator	platform visualization and data behaviour provider, coder, development, operation and maintenance of cloud system delivery	
spatial database infrastructure	☑ system actor ☐ business actor: role:	data storage and maintainer system	
repository of spatial data	☑ system actor ☐ business actor: role:	cloud system of data collection, storage and delivery mechanisms	
web services	☑ system actor ☐ business actor: role:	data delivery, cloud system	

B.10.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☐ inception phase ☐ design and development phase ☐ verification and validation phase ☑ integration and deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.10.1.11 Key performance indicators (KPIs)

Name	Description	Reference to mentioned use case objectives
replication	how closely does the data mirror a real ground truth object, in other words building, tree, river, etc.	Objective 2: delivery foundational geospatial data as 3 dimensional Objective 3: federate multiple geospatial data sources and delivery in a single view visualization environment
data currency	temporal accuracy of the data in relation to current state real world object	Objective 1: delivery foundational geospatial data as temporal

data consistency	repeatable physical and conceptual data supply and updates	Objective 4: Support government, academia and industry through accurate foundational products
metadata	data about data that explains the origins, transformation, resources, contacts, usage and limitations	Objective 5: Support government, academia and industry though modernized geospatial visualization and delivery services

B.10.1.12 Digital infrastructures

Name	Description	Impact on use case
Data storage	Database system that stores data on premises	Houses and stores the primary of delivery asset of spatial digital twin (DTw)
Cloud system	Cloud storage that stores, maintains and delivers data is in the cloud	Aggregates and stores the multiple datasets to be called or pushed to visualization ecosystem service or users on premises or cloud systems
Repository	Federation system that gathers data and feeds to digital twin (DTw) system	Hosts and stores spatial data entities for delivery
Visualization platform	System that calls datasets and displays in cloud system with dynamic control, display and rendering capabilities	Single view platform that pulls and displays spatial data objects in an exploratory visualization environment for 3D objects and time-based manipulation
Authentication	System that authenticates permission-based access to data	Controls open and secured datasets

B.10.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard
ISO/TC 211: Geographic information or Geomatics	ISO 19XXX family of standards	Published and drafts
ISO/IEC JTC 1/SC 41 Internet of things and digital twin	ISO/IEC TR 30172, Digital twin – Use cases, ISO/IEC 30173, Digital twin – Concepts and terminology	draft
ISO/TC 268	ISO 37XXX family of standards	Published and drafts

IEC SyC Smart Cites	WG 1 Terminology, WG 2 Market Relationship, WG 3 Reference Architecture	drafts

B.10.1.14 Referenced papers or patent(optional)

References	**Type**	**Impact on use case**	**Links**

B.10.1.15 Relation with other known use cases, for example common requirements (optional)

Known use case	**Source**	**Relationship**
Virtual Singapore		Land administration modernization in stratified buildings
Fisherman’s Bend Victoria		Australian city based digital twin
Helsinki 3D City		3D building LoD 1 models and reality mesh features

B.10.1.16 General remarks (optional)

General remarks

B.10.1.17 Challenges and issues (optional)

Challenges and issues

B.10.1.18 Data security, privacy and trustworthiness (optional)

Data security requirements and implications for applications, systems, etc.
Privacy requirements and implications for applications, systems, etc.

Trustworthiness requirements and implications for applications, systems, etc.

B.10.1.19 User requirements and interactions with other actors (optional)

User requirements and interactions

B.10.2 Drawings or diagrams depicting the use case

B.10.2.1 Drawing of use case

Drawing or diagram of use case – For example graphic depiction of use scenarios, or "use case diagram"

B.10.2.2 Data flow diagram of use case (optional)

Data flow diagram of use case

B.10.2.3 Sequence diagram(s) of use case (optional)

Sequence diagram(s) of use case

B.10.2.4 Deployment diagram(s) of use case(optional)

Deployment diagram(s) of use case

B.11 Transport - Sydney Trains Engineering and Maintenance Digital Twin

B.11.1 Description of use case

B.11.1.1 Name of use case

ID	Name of use case
011	Transport - Sydney Trains Engineering and Maintenance Digital Twin - Australia

B.11.1.2 Digital twin application area or context of use

Application area or context of use
Transport- Sydney Trains – Engineering and Maintenance

B.11.1.3 Version management

Changes or version	**Date**	**Name Author(s) or committee**	**Approval status(optional)**

B.11.1.4 Basic information to use case

Source(s) or literature(optional)	**Link(optional)**	**Conditions (limitations) of use (optional)**
Maturity of use case		
☐ in business operation, ☐ realized in demonstration project ☐ realized in R&D ☑ in preparation ☐ visionary		
Generic, regional or national relation		
Sydney - Australia		
Vertical application area		
Well-known or related commercial or existing use cases (optional)		
Keywords for classification		

B.11.1.5 Scope of use case

Scope of use case
The POC will utilise LiDAR Point Cloud data as the basis of the Enterprise Digital Twin. Other data set layers or connections to be included are: • NSW Spatial Digital Twin • Front of Train Imagery • Drone based photogrammetry • Asset data for linear and non-linear assets • Fault Notifications and work orders • Major Works Projects and Possession Worksites • Asset Lifecycle Optimization data • Digital Engineering or BIM data • GIS data

B.11.1.6 Objectives of use case

Objectives of use case
To provide asset managers, planners, engineers and infrastructure workers with a holistic, self-selecting, filterable view of all elements of planning and executing work in the rail corridor to reduce safety risks and to optimize their maintenance planning activities. The POC will determine the technical feasibility of • Using a LiDAR point cloud of the Railway Corridor as the foundation of the Digital Twin for • Overlaying multiple types of data sets from disparate data sources and multiple referencing systems in a singular visual platform

B.11.1.7 Narrative of use case

Narrative of use case
Short description
LiDAR Point Cloud data can be used as the foundation for a dashboard view with other images and enterprise data in a spatially accurate three dimensional view of the railway. This will allow asset managers, planners and maintainers to have a holistic, filterable view of all elements of planning and executing work in the rail corridor.
Complete description
Sydney Trains Engineering and Maintenance operate and maintain 1 600 km of track and associated assets across signals, corridor, civil facilities, rolling stock and track disciplines. They collect large amounts of visual and condition data on their assets every single day and this will continue to increase as Industry 4.0 revolutionizes our current work practices.

The Sydney Trains Engineering and Maintenance Digital Twin is a visual tool that will leverage all data from our condition monitoring, operational technology, and enterprise systems to inform decision making required to optimize whole of asset life costs and performance and to reduce risks for our staff and the network. It will enable staff with the appropriate access and permissions to locate and visualize data layers from condition monitoring devices, OT systems, operational systems, and enterprise applications in a single platform that is a spatially accurate digital representation of the real world. The Sydney Trains Engineering and Maintenance Digital Twin will be designed to integrate with other TfNSW Digital Twins to support planning and maintenance activities across the entire cluster. The POC is focused on the technical feasibility of the solution and primarily uses data extracts rather than integration or live feeds.

B.11.1.8 Entities which need to be modelled as digital entities in use case

Entity name	Data	Model type	Requirements or constraints on the models

B.11.1.9 Actors: people, organizations or systems

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
Engineering and Maintenance staff	☐ system actor ☑ business actor: role: ______		
Other Sydney Trains departments	☐ system actor ☑ business actor: role: ______		
TfNSW Cluster Agencies	☐ system actor ☑ business actor: role: ______		
Other NSW Government Agencies	☐ system actor ☑ business actor: role: ______		
	☐ system actor ☐ business actor: role: ______		

Actor name	Actor type	Actor description	Actor interactions (Transactions between Actors) (optional)
	☐ system actor ☐ business actor: role: ______		

B.11.1.10 Life cycle of digital twin system in use case

Life cycle of digital twin system in use case
☑ inception phase ☐ design and development phase ☐ verification and validation phase ☐ deployment phase ☐ operation and monitoring phase ☐ re-evaluate phase ☐ retirement phase

B.11.1.11 Key performance indicators (KPIs) of use case

Name	Description	Reference to mentioned use case objectives
Reduction in Red Zone Hours	Number of hours of current maintenance and inspection activities performed in the physical corridor that can be performed digitally.	
Visual Planning	Improved efficiencies and new capabilities in short-term and long-term planning activities	
New Insights	Number of disparate data sources that can be layered on the same visualization platform	
Timeline of Change	Visually compare changes over time side by side	
Foundations for the Future	Provide a digital solution which will support future adoption of AI, Machine Learning and 3D Augmented Capabilities	

B.11.1.12 Digital infrastructures

Name	Description	Impact on use case
Data Extracts from Small World		
Equip		
AWS Bentley Systems Digital Infrastructure		

B.11.1.13 Referenced standards and standardization committees (optional)

Relevant standardization committees	Standards relevant to the use case	Status of standard
	ISO 19650	
	ISO GIS standards (ISO/TC 211)	
	OGC data standards (https://www.ogc.org/)	
	buildingSMART open data standards (https://www.buildingsmart.org/)	
	TfNSW Digital Engineering Framework (https://www.transport.nsw.gov.au/digital-engineering/digital-engineering-framework-0)	

B.11.1.14 Referenced papers or patent (optional)

References	Type	Impact on use case	Links
Spatial Services - a business unit of Department of Customer Service NSW (2020). Spatial Digital Twin - Spatial Services. [online] NSW.gov.au. Available at: https://www.spatial.nsw.gov.au/what_we_do/projects/digital_twin [Accessed 31 May 2021].	Website	Description information	https://www.spatial.nsw.gov.au/what_we_do/projects/digital_twin