PD CEN/TR 18077:2024



BSI Standards Publication

Building information modelling — Digital twins applied to the built environment — Use cases

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Published by BSI Standards Limited 2024

ISBN 978 0 539 30870 9

ICS 35.240.67; 35.240.67

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This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 September 2024.

Amendments/corrigenda issued since publication

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TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER REPORT

CEN/TR 18077

September 2024

ICS 35.240.67

English Version

Building information modelling - Digital twins applied to the built environment - Use cases

Modélisation des informations de la construction - Jumeaux numériques appliqués à l'environnement bâti - Cas d'usage

Building information modelling - Digitale Zwillinge in der bebauten Umwelt - Anwendungsfälle

This Technical Report was approved by CEN on 14 July 2024. It has been drawn up by the Technical Committee CEN/TC 442.

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European foreword

This document (CEN/TR 18077:2024) has been prepared by Technical Committee CEN/TC 442 “Building Information Modelling (BIM)”, the secretariat of which is held by SN.

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Introduction

Complementary to a building information model, which contains as built and historical data, a digital twin (DT) can be used to assess the current state of the asset and to potentially forecast the future state.

Given the wide range of buildings and infrastructure in the built environment, both in application and in scale, there is currently insufficient information available to make informed decisions about good practice in the development of digital twins. There is a need for clear use cases to inform any such provisions. This document will collect and collate use cases from throughout Europe to show how digital twins are currently being applied, and then to analyse these use cases to identify common characteristics and methods. This analysis could then be used to support future projects of CEN/TC 442/WG 9 “Digital Twins in built environment”.

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1 Scope

This document collates case studies of digital twins applied to the built environment, including infrastructures, in Europe. These case studies have been obtained from CEN experts and related EU research projects.

This document identifies common characteristics to support further standardization work.

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
case study
instance of a use case or, more generally, a record of specific set of actions

Note 1 to entry: A case study could record research relating to an instantiated use case.

Note 2 to entry: Most of the cases presented in this document are case studies.

EXAMPLE A case study could be “Free University of Berlin’s application of AI to improve space utilization”.

3.2
use case
document set of actions performed by one or more actors and by the system itself

EXAMPLE A case could be “predictive maintenance”, with the actions including monitoring performance, and repair/replacement activity prior to failure.

4 Abbreviations

ADT	Assets Digital Twin
AECO	Architectural, Engineering, Construction & Operations
AI	Artificial Intelligence
AODB	Airport Operational Database
API	Application programming interface
AR	Augmented Reality
BACnet	Protocol, Building Automation and Control Networks.
BAS	Building Automation System

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BDT	Building Digital Twin
BDT Manager	Building Digital Twin Manager
BEM	Building Energy Model
BIM	Building Information Modelling
CAFM	Computer-aided facility management
DT	Digital Twin
GIS	Geographical Information System
HTM	Human Thermal Model
HVAC	Heating Ventilation Air Conditioning
ICDD	Information Containers for linked Document Delivery
ICT	Information Communications Technology
IFC	Industry Foundation Classes
IoT	Internet of Things
KNX	Standard. Stands for "Konnex"
KPI	Key Performance Indicator
LD	Linked Data
LoD	Level of Detail
MEP	Mechanical, Electrical and Plumbing engineering
Modbus	A request-response protocol implemented using a master-slave relationship
MPC	Model Predictive Controller
NDT	Non Destructive Testing
OBIX	Open Building Information Exchange
PBS	Product Breakdown Structure
PDF	Portable Document Format
PV	Photovoltaic
R&D	Research and Development
RDF	Resource Description Framework
REST API	Protocol (Application programming interface for REST)
RISA	Commercial brand
SOAP	Simple Object Access Protocol
SPARQL	RDF query language

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TOS	Terminal Operation Systems
UAV	Unmanned Aerial Vehicles
URI	Unique Resource Identifier
VR	Virtual Reality
WebGL	Web Graphics Library

5 Objective

The main objective of this document is to collect a wide range of case studies of Digital Twin (DT) implementations across the built environment, to generate a set of examples ranging across different life cycle phases and different constructive assets.

In addition, the collected case studies include their purpose or purposes. The aggregation of these main or secondary purposes allows to infer new potential use cases of the application of DT in the built environment.

6 Methodology

6.1 Introduction

The use cases were collected using a simple generic template approved by the expert's group. The template was defined in order to gather general information on a use case, its main use, a description, what improvements could be found beyond the state of the art and replication potential (see Annex A).

After that, the completed templates were circulated amongst the group responsible for receiving and reviewing the case studies. The decision to accept a case study was determined by the degree and clarity of information provided.

To enable future compilation of use cases, some iteration with the authors was carried out to facilitate comprehension and benchmarking among the case studies received. Before the agreed deadline, a total number of 37 cases were gathered and 34 were selected (see Annex B for the selected use cases). To ease their aggregation, they were included in a dynamic table. That table included the main uses of the DT as well as other key considerations provided by the experts, such as the types of assets, the phase of their life cycle or the tools used beyond the current state of the art.

This table was also shared between the experts showing the key information collected, as well as their evolution, in case of iteration of each case study. The result, therefore, allows for a more homogeneous comparison and a panoramic view of the contents, hence enabling the conclusions given in Clause 6.

6.2 Table of compiled case studies

As a summary of the dynamic table, Table 1 presents all the case studies collected and accepted. Each line is a case study that was presented.

The first column of the table ("#") is a sequential number that would be the reference number used in other tables. The second column ("Name") gives the name or a short description of the case study. The third column ("General info") contains a short description. In the fourth column ("Main use") is the declared main use of the case study. Column five ("Asset type") contains an asset type for grouping the case studies. Finally, the last column ("Phase") indicates the life cycle phase.

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Table 1 — Summary table, case studies presented

#	Name	General info	Main use	Asset type	Phase
1	D2EPC THESS	Building Residential	Energy Performance	Building Residential	Operation
2	D2EPC NICOSIA	Building School	Energy Performance	Building Tertiary	Operation
3	PLANON DT	Smart Climatized Asset/Space Management	Energy Performance, Control, Events, Space Management	Building Tertiary	Operation
4	SAMBA	Building Office, Coworking	Operation	Building Tertiary	Operation
5	H2 ELECTRO	DT for Technical Marketing	Marketing	Others (Machinery)	Production (Offsite Construction)
6	BRIDGE WEBGL	Bridge INFRA	Maintenance, marketing	Civil Infrastructure (Linear)	Operation
8	CRANE	Building Crane	Planning Construction Operations	Others (Machinery)	Operation
9	KUBIK	Building	Test Lab	Building Industrial	Design
10	BRIDGE ZUBIOTE	Bridge INFRA	test bridge	Civil Infrastructure (Linear)	Design
13	BIM2TWIN	Digital Twin of Construction Execution	Construction Management	Building Tertiary	Execution (Onsite Construction)
14	ENERGY_TWIN	Building Office	Commissioning, Operation	Building Tertiary	Commissioning
15	BRIDGE BASt	Bridge Rail/Road Infra	Operation, Maintenance	Civil Infrastructure (Linear)	Operation
16	ROAD TU	Road Infra	Operation	Civil Infrastructure (Linear)	Operation
17	BRIDGE ROAD INFRA	Bridge Road Infra	Operation, Maintenance	Civil Infrastructure (Linear)	Operation
18	BUILDING OFFICE	Building Office	Construction	Building Tertiary	Construction
19	BRIDGE RAIL INFRA	Bridge Rail Infra	Operation, Maintenance	Civil Infrastructure (Linear)	Operation
20	SNCF	Rail Infra	Knowledge optimization	Civil Infrastructure (Linear)	Operation

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#	Name	General info	Main use	Asset type	Phase
21	ZADAR	Airport Infra	Maintenance	Civil Infrastructure (Punctual)	Operation
22	AVILES PORT	Port Infra	Operation, logistics	Civil Infrastructure (Punctual)	Operation
23	SETEC-StMALO	Port Infra	Heritage	Civil Infrastructure (Punctual)	Reconstruction/preservation
24	LEGENDRE	Building, provisions for openings	Construction Management	Building Tertiary	Execution (Onsite Construction)
25	ETSICCP	Building School	Operation	Building Tertiary	Operation
26	IRRIGATION	Smart Irrigation Management	Operation	Utility network	Operation
27	LLOBREGAT	BUILDING (Council)	Operation	Building Tertiary	Operation
28	HIDROPOWER	Powerplant Rabenstein (AUSTRIA)	Maintenance, optimization, simulation and VR	Energy Infrastructure	Operation
29	NUCLEAR_DECOMM	(Confidential)	Optimization, Simulation, Training	Building Industrial	Dismantling
30	ST_ETIENNE	Building School	Optimization, simulation, operation	Building Tertiary	Operation
31	ECOLE CENTRALE	Building School	Building information model, CMMS and BMS DATA.	Building Tertiary	Operation
32	LILLE	Building Public	Facilities ticketing system interface	Building Tertiary	Operation
33	TNO SPHERE	Building Residential	Energy management	Building Residential	Operation
34	VTT SPHERE	Abloy factory	Energy optimization	Building Tertiary	Operation
35	EGIS	Gironde Estuary, Grand Port Maritime de Bordeaux	Operation and maintenance	Civil Infrastructure (Punctual)	Operation
36	ANDRA	Nuclear waste recycling plant	Waste management	Building industrial	Operation
37	VSB-TUO	Building office	Operation	Building Tertiary	Operation

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7 Conclusions

All of the case studies have been grouped according to their similar characteristics to help extract the potential use cases.

The results show a wide range of use cases (see Table 2). A total of 14 use cases have been identified based on the grouping according to purpose. As can be seen in Annex A, the case studies received present not only a dedicated main use but some secondary uses in some cases. From this can be extracted that a digital twin could add more value through different use cases and their associated benefits.

Regarding the typology of the use cases, the majority of use cases concentrates on improving the operation (see Table 2) through optimization of the decision making.

Table 2 — Group of use cases from case studies presented

	USE CASE	MAIN USE	SECONDARY USE
I	Design Optimization		16, 36
II	Construction Optimization	8, 13, 18, 24	36
III	Commissioning Optimization	14	
IV	Operation Optimization (Energy Performance)	1, 2, 4, 14, 30, 33, 34	3, 4, 27, 31, 37
V	Operation Optimization (Space and Administrative Management)	3, 22, 25, 27, 32	4, 20, 30, 31, 37
VI	Operation Optimization (Logistics)	35	20, 22
VII	Operation Optimization (Waste Management)	36	
VIII	Maintenance Optimization	15, 16, 17, 19, 20, 21, 23, 28, 31	6, 22, 25, 27, 36
IX	Dismantling Optimization	29	16
X	Safety		4, 29
XI	Training		4, 28, 29
XII	Marketing	5,6	
XIII	Test Lab	9, 10, 19, 37	
XIV	Others	26	34, 35

As shown above, the optimization pursued in the collected examples can target the constructive operations (planning and design, construction, commissioning, energy performance, maintenance or dismantling) as well as the dedicated operative of the asset (space management in buildings, logistics in transport infrastructures or heritage administration). A special case of dedicated operative of the asset is research infrastructures. In this case, four case studies have been grouped as “Test Lab” use cases, with the DT being a way to enhance products and services developed in real laboratories. Additional purposes have also been grouped into three main use cases focusing on safety, training and marketing. As in all use cases, specific examples of them can be found in Annex A.

Finally, there is a small heterogeneous group of main and secondary uses which include a main purpose, irrigation operative (26), and several secondary uses such as occupants (employees) wellbeing (34) or climate change resilience estimation (35).

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Based on the description received so far, many of the case studies show a big potential for replication, with the possibility of being converted into a commodity or a massive product.

Beyond use cases, early adoption can also be inferred from the information received using another aggregation based on the typology of the assets. Tertiary buildings and infrastructure (see subclause 6.2, Table 1, column “Asset type”) are the rule from the case studies received. There are 11 cases of tertiary buildings, 5 linear infrastructure and 4 cases of punctual (or spatial) civil infrastructure, in a total of 30.

It is important to note that case studies #5 and #6 (H2ELECTRO and BRIDGE WEBGL) are not representing a real physical asset.

The analysis of the use cases will allow the development of a standardized framework and definitions for digital twins.

The digital twin approach is designed to provide a better understanding of the asset throughout its life cycle. It will facilitate a sustainable future by better management of energy, resources and other requirements in the context of the EU Green Deal.

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Annex A
(informative)

Case study template

Introduction

To develop a TR covering the application of Digital Twins (DT) in Europe, CEN/TC 442/WG 9 is gathering case studies and use cases.

The TR will cover DT of buildings and infrastructures (civil engineering works). Information on other technologies, such as smart cities or GIS, can be included in the DT, but as part of the data of the construction asset (i.e. the TR will not cover a DT of a smart city, only building or relevant infrastructure within a neighbourhood or city).

CEN and/or CENELEC experts, EU funded research projects and other stakeholders are invited to send their use cases or case studies to the Secretariat, Aitor Aragón, before 2023-04-27. Feedback regarding the template itself (new fields to be included, etc.) is also welcome.

Use case: NAME OF THE USE CASE

General information

Typology: (for example, residential, road infrastructure, etc.)

Location:

Asset owner:

Building Digital Twin (BDT) manager:

Main use of the DT

Max. 50 words.

Description of the DT

Max. 50 words. Figures can be included.

Main improvements beyond the state of the art

Max. 200 words. KPIs should be included, if possible.

Replication potential

Max. 200 words. KPIs should be included, if possible.

Relevant links

More information provided in websites, scientific papers, etc.

Contact information

Name, email and telephone of a contact person on behalf of the DT owner and/or the BDT manager. This information will not be included in the final TR, but will be used to ask for further information, if needed.

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Annex B
(informative)

Case studies presented

B.1 Case Study 1: D2EPC THESS. D^2EPC- BIM based DT- nZEB Smarthome DIH

B.1.1 General information

Typology: Mixed-use Building (Residential and Office)

Location: Thessaloniki, Greece

Asset owner: CERTH/ITI

Building Digital Twin (BDT) manager: CERTH/ITI

B.1.2 Main use of the DT

The BIM-based Digital Building Twin Model has been developed as part of the D^2EPC project with the aim of providing a platform for the dynamic assessment of a building's energy performance. The model is designed to incorporate information on the building's design, materials and systems, and to provide a near-real time representation of the building's energy performance. See Figure B.1.

B.1.3 Description of the DT

The model integrates information from the building's BIM file and other documentation sources with dynamic data received from IoT devices, sensors, and meters deployed throughout the building. This results in a highly detailed building model that serves as a common documentation approach for assessing the building's energy performance, operational conditions and indoor environmental quality.

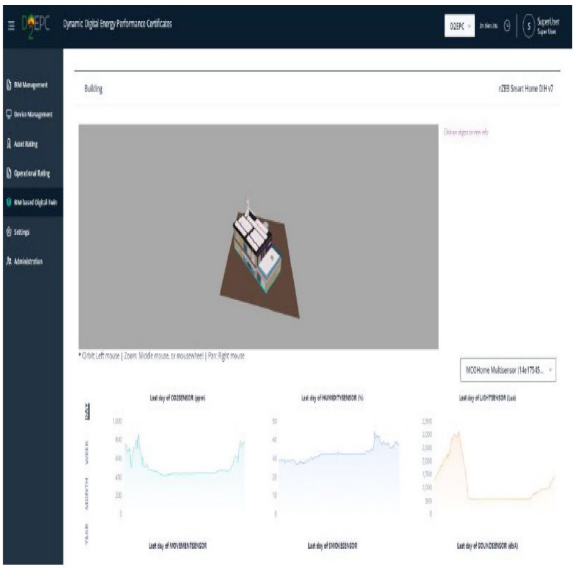


Figure B.1 — D2EPC THESS - BIM-based DT platform

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B.1.4 Main improvements beyond the state of the art

The developed DT application leverages advanced computational capabilities derived from the domains of machine learning and artificial intelligence to offer a range of services aimed at improving a building's energy performance and indoor environmental conditions. Specifically, the model can identify areas of weakness in a building's infrastructure and generate retrofitting recommendations. Additionally, by analysing operational data, the model can identify patterns of behaviour and predict future operational states, enabling end-users to take proactive steps to improve their overall energy efficiency.

B.1.5 Replication potential

As the primary application is focused on EPC issuance, the resulted DT application is intended to be applicable on the majority of the European building stock. At present, the application unit is limited to individual building units and partitioned spaces, such as apartments. However, efforts are underway to expand its application to encompass building complexes and even entire neighbourhoods.

B.1.6 Relevant documents and links

More information about D^2EPC (GA No 892984) can be found on the project's website:

https://www.d2epc.eu/.

The developed tools are available at https://d2epc.iti.gr/.

B.2 Case Study 2: D2EPC NICOSIA. Mixed-use University building, Nicosia, Cyprus

B.2.1 General information

Typology: Mixed-use University building

Location: (Longitude and Latitude 33°22'46.70 "E, 35°10'46.20 "N), in the area of Palouriotissa, Nicosia (Y. Frederickou Str.).

Asset owner: SCHOLAI FREDERICKOU

Building Digital Twin (BDT) manager: D2EPC

B.2.2 Main use of the DT

The digital twin allows us to conduct more effective research with the aim of achieving and maintaining peak efficiency. It also helps us to mirror and monitor the installed equipment in real-time and analyse performance data to understand how individual components (i.e. lighting or HVAC systems) or the entire building are functioning.

B.2.3 Description of the DT

Frederick University's digital twin is a two-story 2 100 m^2 building, its volume is approximately 7 100 m^3 (including the basement floor/parking area), and it was built in 2007. The understudy building does not border with any other building. The building consists of a basement (area of 450 m^2), ground floor (area of 545 m^2), and two floors (area of 545 m^2 each floor). See Figure B.2.

Smart meters installed throughout the building allow for real-time measurement of electricity, as well as of internal conditions, such as temperature, humidity and carbon dioxide. A platform is available for monitoring, downloading and analysing data. See Figure B.3.

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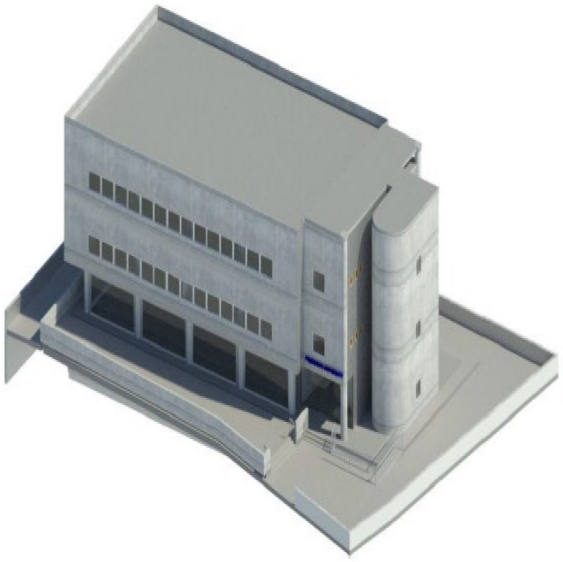


Figure B.2 — BIM model

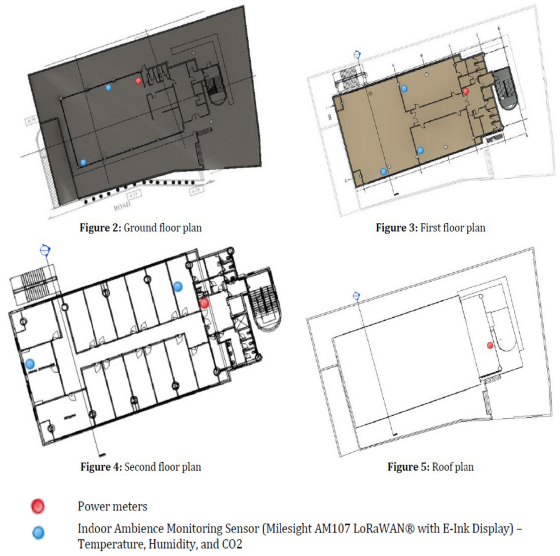


Figure B.3 — Floor plans and location of measuring devices

B.2.4 Main improvements beyond the state of the art

The installed equipment is connected to a system that allows monitoring, control and remote sensing of the actual energy performance of the building, and enables the realization of the dynamic EPC scheme. The 3-Zone monitoring and remote sensing, as well as the power consumption of the building, are implemented with the use of equipment covering the following aspects:

— temperature;

— humidity;

— CO_2;

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— outdoor temperature, wind speed, and direction, rain concentration, solar irradiation (through a roof weather station);

— energy meters for electricity consumption.

KPIs presenting the operational energy performance are relevant to:

— the definition of the drawbacks and discrepancies of the current EPC scheme, as well as the update of EU standards on the classification requirements of buildings;

— increasing partners' absorptive capacity;

— improving partners' market knowledge;

— contribution to standards.

B.2.5 Replication potential

The implementation of digital twin technology is part of the Next-generation Dynamic Digital EPCs for enhanced quality and user awareness – D^2EPC project (GA No 892984), capable of being replicated in other mixed-use infrastructures, presenting a scalable approach towards enhancing building sustainability and efficiency.

KPIs relevant to replication potential could be:

— BIM integration;

— operational digital platform for dynamic EPCs.

D^2EPC's ultimate goal is to provide an all-encompassing platform with numerous services and applications that inform the end-user about the pilot building's operation and performance. Two separate architecture features are made operational by the software components included in this platform:

— The Building Energy Performance Benchmarking (EPB) module provides a way to group buildings with similar traits together for the purpose of comparison.

— The Energy Performance Verification and Credibility (EPVC) module is responsible for verifying the accuracy of the dynamic data components used to generate the dynamic EPC.

B.2.6 Relevant documents and links

1. Koltsios, S., Katsaros, N., Mpouzianas, N., Klonis, P., Giannopoulos, G., Pastaltzidis, I., ... & Tzovaras, D. (2022, September). Digital Twin application on next-generation Building Energy Performance Certification scheme. In 2022 IEEE International Smart Cities Conference (ISC2) (pp. 1-7). IEEE. https://doi.org/10.1109/ISC255366.2022.9921821

2. https://www.d2epc.eu/en

B.3 Case Study 3: PLANON DT. SMART CLIMATIZED ASSET/SPACE MANAGEMENT

B.3.1 Description of the DT

Planon Digital Twins are realistic digital representations of physical assets or spaces. Using IoT connected to embedded logic to monitor and predict performance, feeding out insights and automating system responses to drive interventions. Figure B.4 shows a representation of the model.

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IoT based real-time monitoring and operational insights on (environmental) conditions of climatized assets (e.g. refrigerator, freezers) and spaces (e.g. server room, cold room, freezer room) and timely identified need for interventions. Figure B.5 shows a representation of the system response automation.

B.3.2 Business value

— Food health & safety;

— avoid financial loss of stored goods and energy;

— reduce reactive maintenance costs;

— maintain corporate and regulatory compliance.

B.3.3 Key features

— Real-time data capture of asset or space performance;

— notifications on anomalies;

— automatic alerts and workorder generation;

— business insights on asset or space conditions and related SLA's.

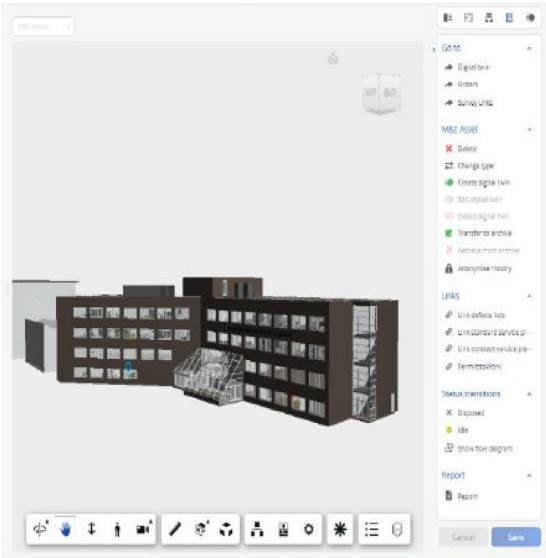


Figure B.4 — BIM model, location of fridge

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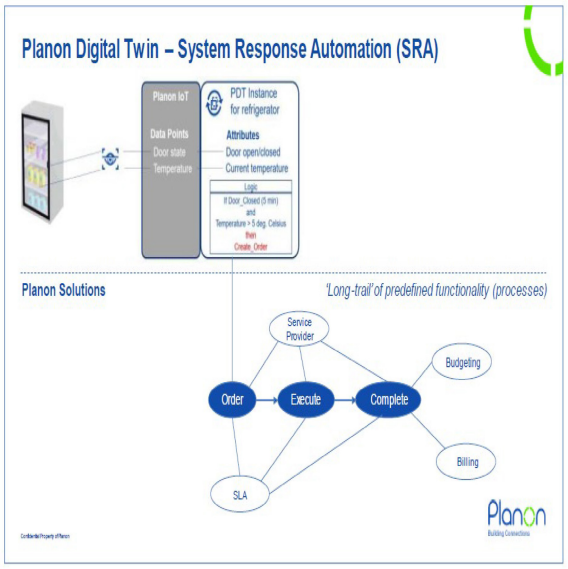


Figure B.5 — Planon, concept of system response automation (SRA)

Assume a retailer in food has a shop in which it has storage facilities for food, all refrigerated:

— One deep-freeze storage A for articles like meat;

— One cooled storage B for vegetables (above zero degrees Celsius).

Multiple aspects are measured:

— temperature;

— humidity;

— electricity consumption;

— door open/close;

— power on/off.

Calls to action based on threshold (with duration) to empower Planon business processes via business notification such as order generation. (Application response)

— temperature too high;

— temperature too low;

— temperature within range;

— humidity too high;

— humidity too low;

— humidity within range;

— outage too long.

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— power restored;

— door open too long;

— door restored.

B.3.4 Replication potential

The Smart Climatized Asset/Space Management Digital Twin is one of the many Digital Twin types. As each Digital Twin will need to behave quite differently, they will be using different sets of parameter inputs (Data Points), have different Attributes and contain specific business logic on that data.

EXAMPLE

'Climatization of e.g. a server room or a lab is different from a Freezer or Refrigerator. Clients want to manage them differently. In principle, this would introduce multiple types of 'digital twins'.

The Planon Digital Twin concept, however, is designed to allow one Digital Twin type to be used to serve multiple "Assets" (Fridge) or "Spaces" (Server room) in this example.

The Smart Climatized Asset/Space Management Digital Twin contains a use case that can be easily replicated and enhanced to fit other purposes.

B.3.5 Relevant documents and links

https://planonsoftware.com/uk/glossary/internet-of-things-iot/

https://planonsoftware.com/uk/software/planon-platform/

B.4 Case Study 4: SAMBA. SAMBA Smart Advanced Multitenant Building Automation – DT for occupants and manager

B.4.1 General information

Typology: offices, coworking

Location: Co+Fabb, Sesto San Giovanni (MI), Italy

Asset owner: VIARTE srl

Building Digital Twin (BDT) manager: Alchema srl, KALPA srl and Harpaceas srl

B.4.2 Main use of the DT

SAMBA Digital Twin is a photorealistic model of an existing coworking building located in Sesto San Giovanni, near Milan (Italy). It is meant to be used in the operational phase, focusing on space usage and wellbeing conditions for occupants in each office. See Figure B.6.

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Figure B.6 — SAMBA photorealistic model, escape route

B.4.3 Description of the DT

The SAMBA project - Smart and Advanced Multitenants Buildings Automation, is a research project ideated by Alchema and involving several partners: KALPA (project leader), Fondazione Eucentre, 3P Technologies, AGEvoluzione, Harpaceas, ATS.

SAMBA is working on a large building named Co+Fabb. The aim is to make the structure - almost 5 000 square metres housing several companies and start-ups - a smart building. An intelligent building that can be managed with a global and remote-control system. The idea is to implement a sort of "dashboard", a console for interpretation and management of everything that can happen inside. Project is focusing on transforming existing buildings into smart buildings with the use of IoT and DT.

The project includes technical installation of several sensor boards, communication networks, web application and databases. Beside those components and interacting with them, a specific Digital Twin application has been developed, comprising several functionalities for the end users. SAMBA Digital Twin is part of the Project as a photorealistic model for Windows and Android devices.

This digital model includes several functions meant for interacting with the asset and its real-world data. Some of those functions include:

— Path finding

  This functionality allows you to identify, from the location of the DT where you are at the time of starting the command, the shortest route to reach one of the spaces/offices of the building.

— Escape route finding

  This functionality allows you to identify, from the place of the DT where you are at the time of starting the command, the shortest route to reach the nearest emergency exit or the nearest fire extinguisher.

— Smart object: spheres

  The spheres located in the various rooms report the real-time values of the quantities measured by sensors in the respective environment such as: temperature, humidity, pressure, air quality, brightness...

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— Smart objects: Room gates and avatars.

  In the meeting rooms there are room *gates* displaying the number of people present in the room (data coming from the people counter). The detected people are virtualized in the form of symbolic avatars.

— Smart objects: Informative Tags

  For some elements of the DT there are informative tags graphically reporting specific information: fancoil status and consumption, windows and door status, human detection, light status...

— Overview Panel

  The panel allows you to navigate through the information of the various rooms, reporting different data divided into specific tabs.

— Environmental Sensors Tab displaying quantities and ranges

— Status Sensors Tab displaying status and allowing actuation on light/fancoil

— Graphs Tab displaying time series for different quantities

— Alarms Tab showing detected alerts for sensor boards

— Interactive Map: This functionality allows you to have an overview of the floor plans of the building. Each individual environment can be queried by selecting it directly on the map or from a list. This allows you to highlight the conditions detected in the individual environment and any values out of range.

— Seismic Data: The functionality allows you to view within the spaces of the Co+Fabb, the seismic data collected for some Non-Structural Elements (e.g. false ceilings, bookcases, cabinets, monitors, windows...).

— Training: fire event: It allows the simulation of a fire event, contextualizing the character in one place of the building. The functionality includes a timer for the completion of possible tasks and incorporates the search for the nearest emergency exit, dynamically adapted, as well as the search and use of a fire extinguisher for stopping the fire event.

— Training: seismic event

  Allows the simulation of a seismic event in an office. The intensity of the earthquake is randomly assigned. The dynamics of the objects in the room varies depending on the degree of intensity assigned by the system. The feature includes a timer for completing the task and incorporates the search for the nearest emergency exit, dynamically adapted.

— Indoor Positioning System

  The feature allows you to retrieve the user's current location. This system uses the Bluetooth of the mobile device and, in the background, the application developed by another partner which sends to the server the last positions detected based on the nearest beacons at that time.

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B.4.4 Main improvements beyond the state of the art

Considering the nature of an existing building such as the Co+Fabb, SAMBA introduced an innovative level of technology on a physical and digital level. The entire system, comprising the Digital Twin, allows the user and the building manager to control the ongoing and historical situation of the agreed parameters in the Co+Fabb. This approach facilitates several topics like energy consumption, space usage, safety and security and enables data collection useful for implementing algorithms for building behaviour learning. See Figure B.7.



Figure B.7 — SAMBA, room monitoring and occupancy

B.4.5 Replication potential

According to the tailored and scalable nature of the Digital Twin, this method could be improved for the Co+Fabb and of course it could be extended and potentiate for another asset. This could include bigger coworking buildings or other asset categories such as hospitals, airports. Some of the functions could be replicated with the same logics and algorithms, other could be revised for different user needs.

B.4.6 Relevant documents and links

Official Project website: https://italiansmartbuilding.eu/index.php

B.5 Case Study 5: H2 ELECTRO. H2Energy Electrolyser – DT for technical marketing

B.5.1 General information

Typology: plant

Location: -

Asset owner: H2Energy

Building Digital Twin (BDT) manager: Daniele Arnone, H2Energy

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B.5.2 Main use of the DT

H2E Digital Twin is a photorealistic model of an electrolyser plant hosted in a container, located in a fictitious area (see Figure B.8). At the moment it is meant to be used for technical marketing purposes, focusing on displaying plant components and key information.

B.5.3 Description of the DT

H2E Digital Twin has been developed for a request of H2Energy company. H2E provides turnkey solutions of hydrogen production systems for various applications: for blending in the natural gas grid, railway and automotive transport systems, steel production, port systems and various industrial and domestic uses to be studied together with customers. Green hydrogen is mainly produced by electrolysers, although this is still a niche industry.

This Digital Twin has been realized elaborating photos and videos taken on site.

Result model comprises two main functions meant for interacting with the asset and its information:

— clickable objects (e.g. door animation);

— information sheets.

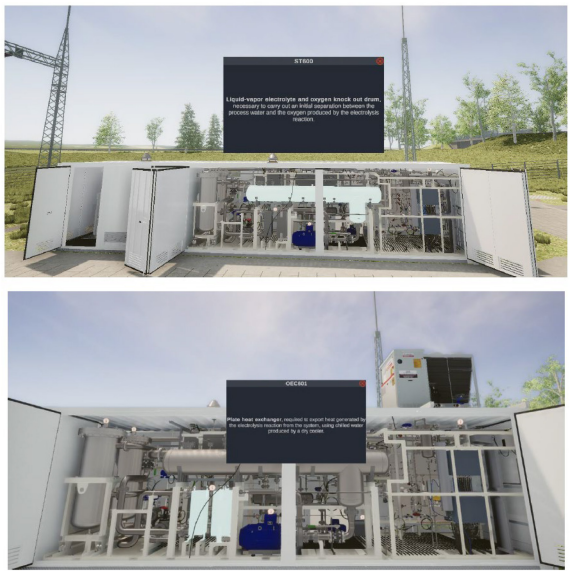


Figure B.8 — H2 electrolizer

B.5.4 Main improvements beyond the state of the art

For the purposes of promoting this innovative technology during exhibition related to renewable energy, H2Energy decided to invest in recreating a DT of their container plant. This introduces new ways of showing and explaining – with associated information – the whole package without the need of moving and physically installing the plant in each fair.

The DT also allows to inspect the components in the quickest and easiest way, especially in narrow areas inside the container.

B.5.5 Replication potential

Although the main goal is to technically promote the plant, this DT could be improved for several uses such as simulation, training, connection with the existing plant, also from the point of view of getting data from the onsite sensors.

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B.5.6 Relevant documents and links

Company website: https://www.h2e.it/h2energy/en/

B.6 Case Study 6: BRIDGE WEBGL. Bridge DT for technical marketing maintenance oriented

B.6.1 General information

Typology: Civil Infrastructure (Bridge)

Building Digital Twin (BDT) manager: Harpaceas srl

B.6.2 Main use of the DT

Digital Twin is a photorealistic model of a scene able to present and interact with various types of bridge degradations. It's meant to be used in the maintenance phase, focusing on degradation types and necessary steps to restore the structure according to methodologies and products proposed by a typical producer of infrastructures' restoring products.

B.6.3 Description of the DT

The DT is developed as a WebGL (Web-based Graphic Library) application and allows the user to navigate in an agreed scene. The DT is designed to show different types of bridge degradation and enables the selection of several products included in the technical and methodological proposal of the Client.

In the scene there will be a bridge with different types of degradation that can be activated through a special user interface. The same user interface will allow a user to interactively represent the processing phases to restore the damaged portion.

Each phase will be distinguished by a specific activity (using a maximum of one product for each phase) and will allow the reference to a specific web address (e.g. to a product page on the producer's website).

For each type of degradation, it will be possible to download a zip file containing PDF documentation (provided by producer). See Figure B.9.

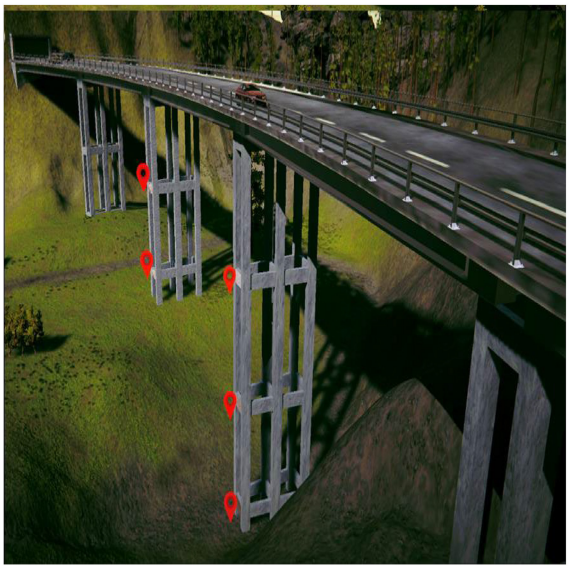


Figure B.9 — Web interface of the application for bridges

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Workflow and features:

— The application proposes a typical bridge, with a geographical environment (houses, roads, surrounding land, etc.).

— The user can choose the location and the type of deterioration on which they want to operate, through a predefined library of deteriorations.

— The application will show guidelines on how to solve the deterioration, with the proposal of the most appropriate products.

— The user can download a PDF with the procedure to be applied and the link to the various products.

— The user will have a "fly" navigation mode with the possibility of directly viewing the required deterioration.

As a BIM oriented application, the DT also allows exporting IFC files representative of the steps necessary to restore a typical portion of the structure, e.g. an element of 1 000 mm x 1 000 mm, representative of an indefinitely extended wall.

The input model of the bridge could be in common BIM format (such as Tekla Structures version 2021 or 2022) in order to allow the insertion of the bridge model in the WebGL application. The Contractor will proceed with the following steps:

— export of the model in IFC format;

— conversion of the model in IFC format to format suitable for import into WebGL;

— possible manipulation of the model to simulate degradation (e.g. lack of concrete portions);

— addition of photorealistic textures provided by the Customer (e.g. in the form of high-resolution photos specially to represent degradation) and/or deriving from Asset store.

B.6.4 Main improvements beyond the state of the art

Digital Twin enables a new way of technical marketing introducing specific features:

— provide the customer with an interactive and three-dimensional product, for the choice of products to be applied in the various cases of deterioration;

— provide guidelines on the applicability of various products in different deterioration situations;

— innovative method for product choices and learning about their use, through a visual approach;

— web application integrated into the customer's site;

— allowing product description and promotion everywhere, without the need of physically moving components and assets.

B.6.5 Replication potential

This Digital Twin has a technical and marketing value for the owner and can support better decisions regarding maintenance and intervention. This approach can be also replicated for different kinds of technical marketing purposes such as MEP, civil and other domains.

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B.7 Case Study 8: CRANE. Real-time Discrete Event Simulation of Crane operations (HORIZON 2020 - NUMBER 958161 – Ashvin "Assistants for Healthy, Safe, and Productive Virtual Construction Design, Operation & Maintenance using a Digital Twin")

B.7.1 General information

Typology: Office building, but applicable for many kinds of buildings

Location: Barcelona, Spain

Building Digital Twin (BDT) manager: ASHVIN

B.7.2 Main use of the DT

The DT will be used for improved construction planning, especially in the short term. Due to real-time data, information can be gained, which enables real-time discrete event simulation. Thus, more reliable forecasts of crane operations are possible.

B.7.3 Description of the DT

Kinematic data are collected by sensors mounted on a crane hook (see Figures B.10 and B.11). By analysing the data with artificial intelligence, this information offers valuable information about movements and construction processes.

In particular, activity durations are extracted. These durations are used for stochastic discrete event simulations of construction works.



Figure B.10 — Crane on construction site

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