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CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

Digital Twins in the context of energy assessment of the built environment
&
Notable case studies of Digital Twins

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DT context in the built environment

Most DT implementations in the built environment are focused on asset monitoring and managing operations.

Mainly in two ways:

- As a replacement or in-conjunction w/ BIM
- A conceptual conduit to enable remote asset monitoring and to make more efficient the operations and maintenance of complex built assets

We will focus on this

Energy-reduction goals & digitization of buildings

To meet energy-reduction goals, cities are challenged with assessing building energy performance and prioritizing efficiency upgrades across existing buildings

New advances in smart metering →new data streams increasingly accessible via smart metering infrastructure

Connecting objects at the micro level using IoT →gateway allowing electric devices to contribute to the energy system building even bigger ecosystem for the distributed energy resources.

Hence, digital innovation & data analytics in the energy industry aided by the emergence of IoT → real-time synchronization & monitoring of energy systems via computerized & virtual world modeling

Incorporate previously undetectable temporal fluctuations into top-down building benchmarking analyses.

Digitization in the energy sector can further help stabilizing transmission grid simply by stabilizing reserve from fluctuating energy sources (solar, wind)

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Building energy systems & BMS

Building energy systems are hierarchically structured, and equipment is decentralized around to serve each system in a building. In practice, the measurement of energy consumption usually takes place at an aggregated level

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Typically, meters and submeters are installed to measure the energy delivered to zones in a building, where equipment is located

↓

Building Management System (BMS) is deployed in the building, which accumulatively collects building-scale data from the mechanical and electrical systems

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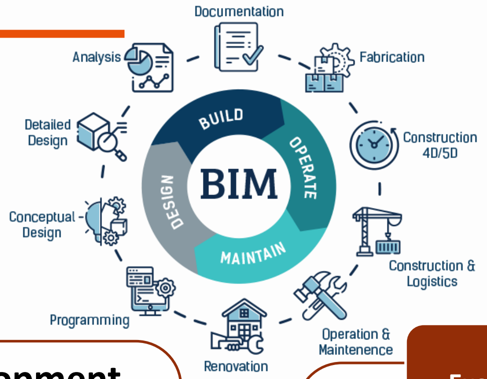
To integrate information from different sources, a common data representation is needed to realise the semantic interoperability for building geometries, topology and system hierarchies (e.g., the hierarchy for submetering, HVAC, lighting & sensor systems

BIM technology & energy context

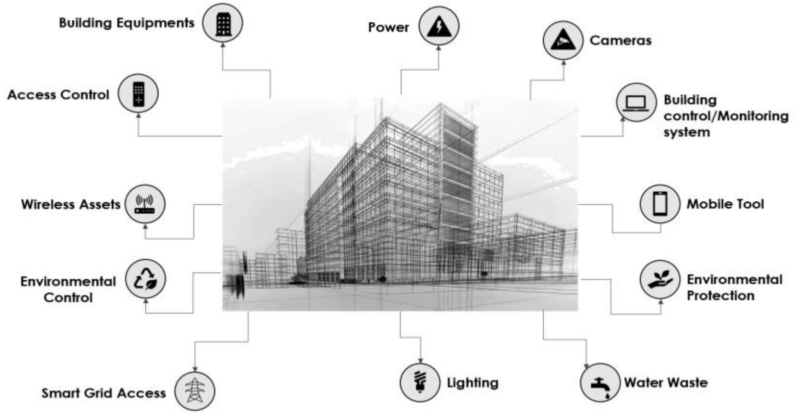


With the development of BIM technology, 3D building feature modeling provides a perspective centered on individual buildings

The potential of ICT, IoT, big data and AI are combined interacting with BIM.

Example: using IFC or gbXML schemas for energy diagnosis purposes

Expresses the functional operational and physical characteristics of the building



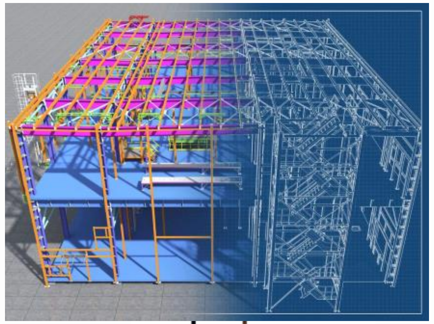
Creation of building energy model (BEM)→ indicates physical or virtual entities that generate time-series data

For existing buildings→ 3D laser scanning

e.g. BrickSchema → emerging schema→ standardised ontology representing different locations,, sensors, relationships used in building operations

Applications can flexibly retrieve required data in a plug-in manner and portable building energy analysis

Energy consumption analysis based on BIM modelling→ profound significance for the development of building energy-saving technology



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Advantages & challenges of energy-related DT

Advantages

- Ability to model complex systems and interactions that are difficult to assess using traditional methods
- Includes modeling interactions between the building envelope, HVAC systems, and occupants

Challenges

- Availability/quality of energy-related data needed to create accurate models
- Building information is usually stored in different formats across the lifecycle → data integration a challenging task

Notable DT case studies

1. University of Cambridge, West Cambridge site, Alan Reece Building

A 3-story building @ West Cambridge site (home of the Institute for Manufacturing (IfM)

- Includes teaching, study, office, research, laboratory spaces
- Stands over a over a 370 m^2 area

Sensor type	Locations	Function
Temperature	Lecture theatres, seminar rooms, meeting rooms and plantroom	Measures indoor room temperature
Humidity	Lecture theatres, seminar rooms, meeting rooms and plantroom	Measures relative air humidity
Motion detection	Lecture theatres, seminar rooms and meeting rooms	Detects motion (e.g. detects whether anyone is present in the room).
Light meter	Lecture theatres and seminar rooms	Tracks light level in the environment.
Open/ closed	Meeting rooms	Detects whether a door or a window is opened or closed
Carbon monoxide	Surrounding of the biomass boiler	Measures carbon monoxide gas level in the air
Vibration count	Surface of the milling machines, lathes, pumps and robotic arms	Measures the number of vibrations of a component above a predefined threshold.
AC current meter	Lathes and robotic arms	Measures amp hours, maximum RMS current, minimum RMS current and average RMS current used by the equipment.

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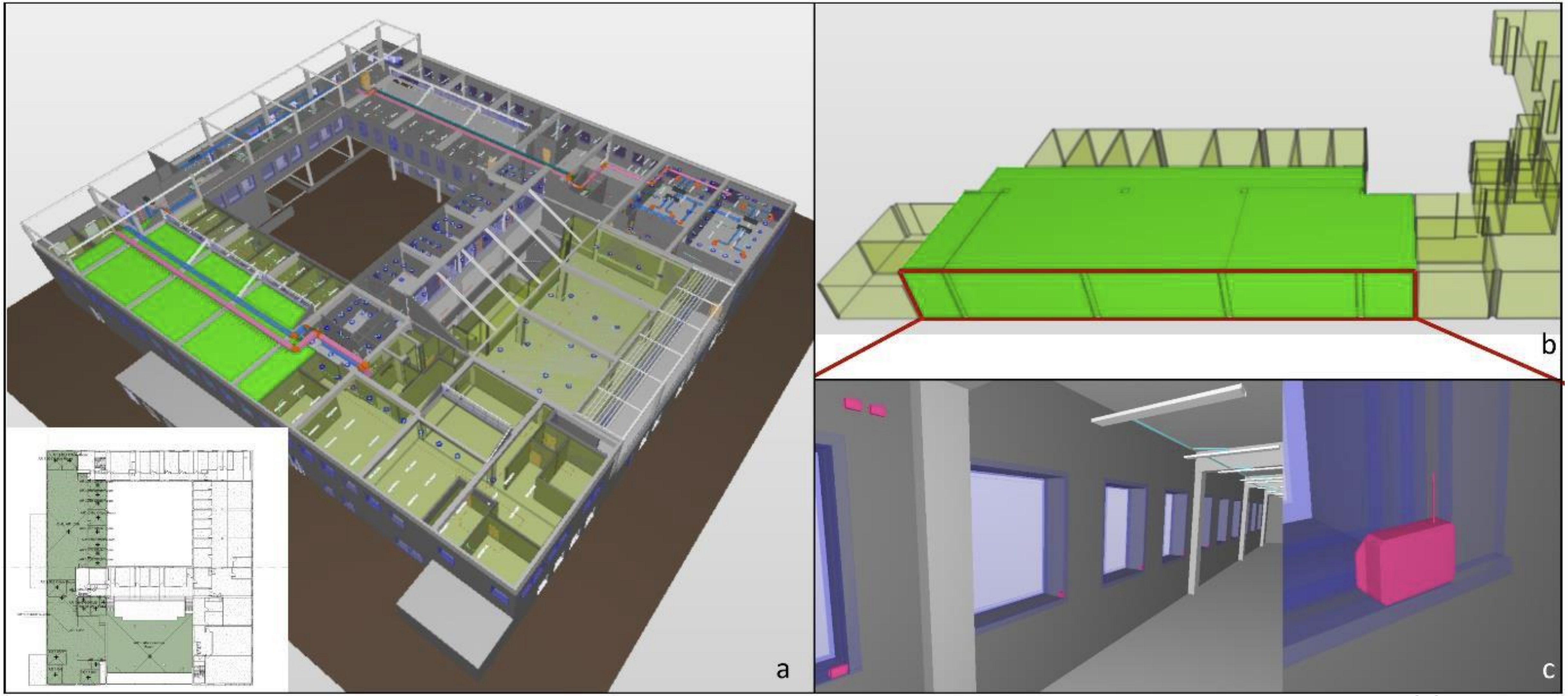
IFC model: 3D view of BIM-based metered zones



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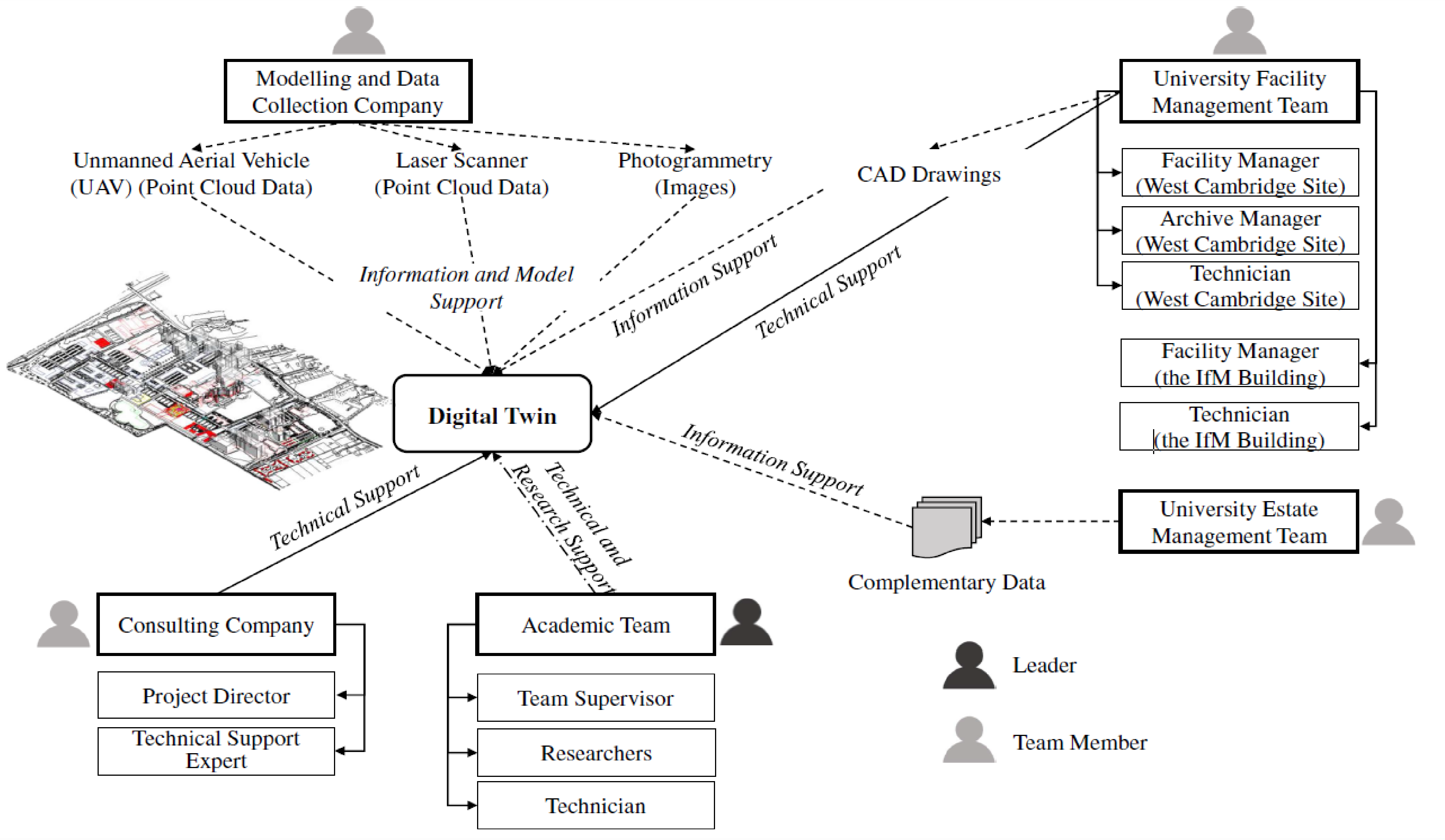
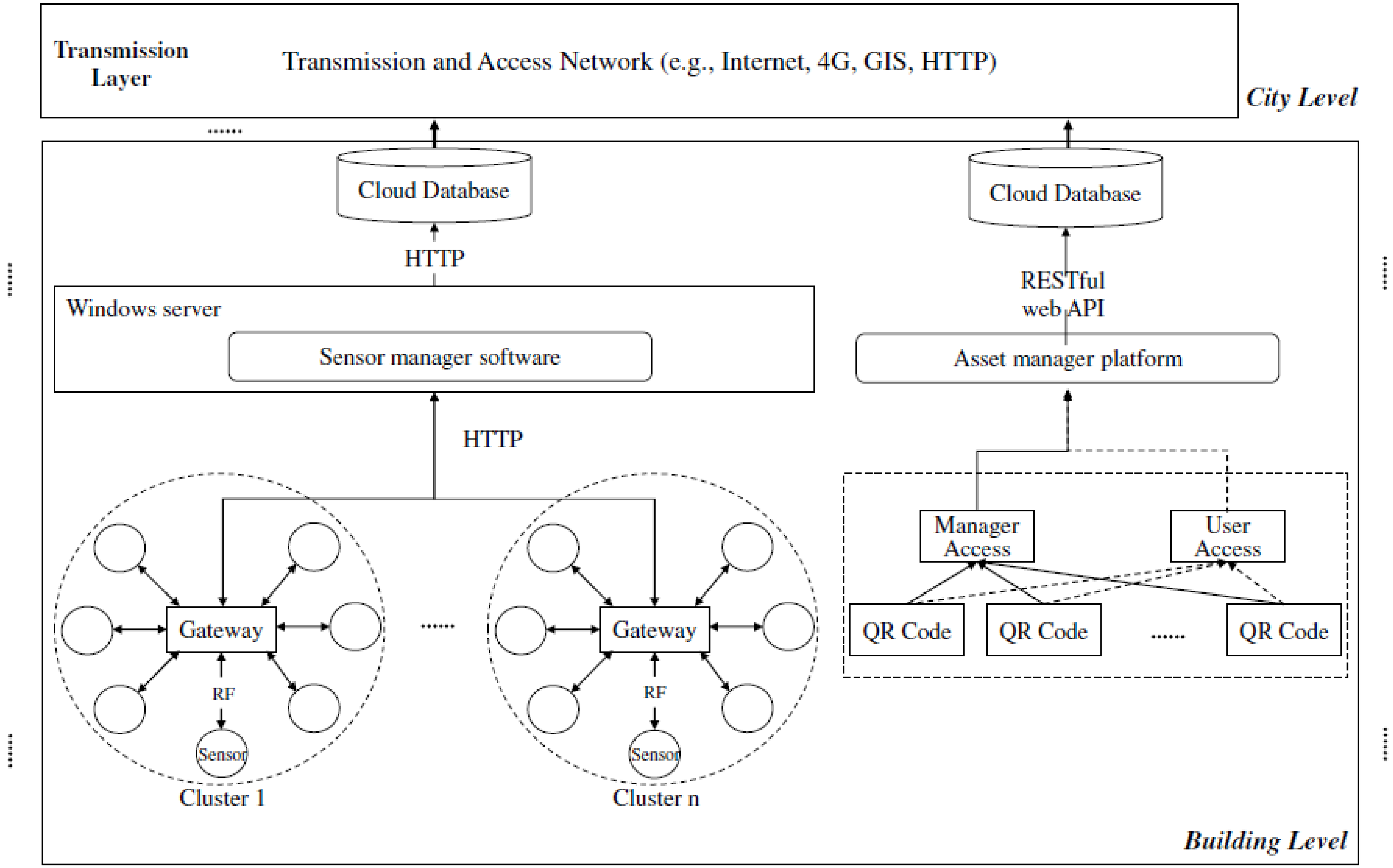
Stakeholders in the West Cambridge Digital Twin



Schematic of the data acquisition from the assets.



Source: https://doi.org/10.1061/(ASCE)ME.1943-5479.000076

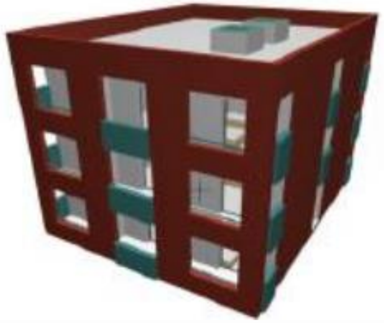
2. Technical University of Crete (TUC), Campus buildings

Technical University of Crete (TUC) developed a building management system of low-cost IoT sensors,

Installed in a number of campus buildings→to augment building energy management system (BEMS)

Student hall→3-story building, consisting of ensuite student rooms & communal kitchen per floor.

Each space contains:
• A/C • Thermostat to control indoor climate • Occupancy sensor



System architecture

A data linking methodology is proposed to combine static building design data from IFC and dynamic data using the Brick Schema

A Building Topology Ontology (BOT) is used as foundation in combination with other ontologies, including building elements (BEO), product catalogues (BPO), IoT sensor observations (SSN)

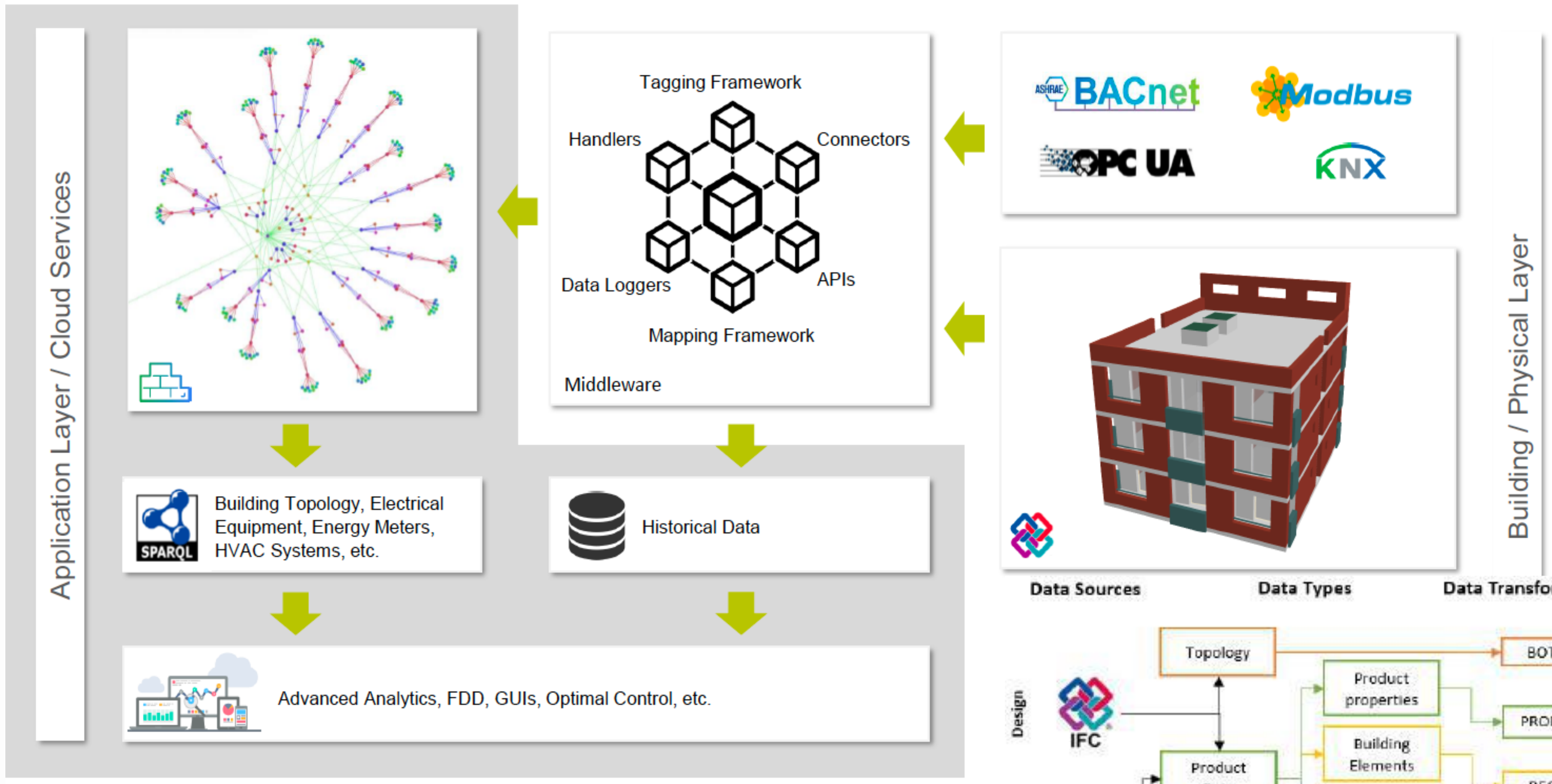
User can extract IFC data and transform them to RDF format, using modular ontologies (i.e. BOT, PROPS, BEO etc.)

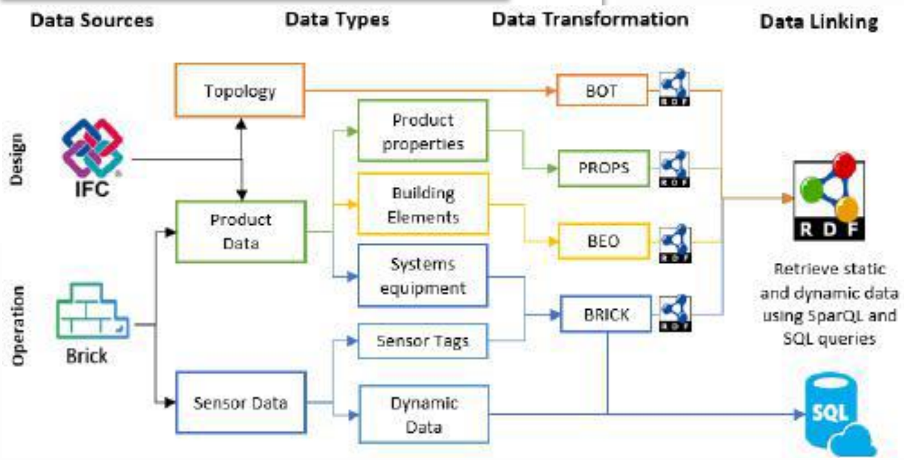
In addition, systems equipment and sensor tags are represented using the Brick Schema

Time series data corresponding to the sensor tags are stored in a historical time-series database

Overall, static building data are stored in RDF format while dynamic data are stored in a SQL database and Brick Schema provides the connection between the two databases

Proposed IFC-Brick integration framework





Source: Mavrokapnidis, Dimitris & Katsigarakis, Kyriakos & Pauwels, Pieter & Petrova, Ekaterina & Korolija, Ivan & Rovas, Dimitrios. (2021). A linked-data paradigm for the integration of static and dynamic building data in digital twins

Project Partners

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