BDTA

BUILDING DIGITAL TWIN ASSOCIATION

Driving innovation in Building Digital Twins

WG2 Update

Ontologies and Construction with Building Digital Twins

Bram Bazuin
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SUSTAINABLE PLACES 2024

We're here now

BDTA as **initiator**

2024

Provide Digital Twin Ontologies in a BDTA Catalog

2025

Add toolkit and guidelines to BDTA Catalog

2026+

Align Values and Principles for Ontology Networks

BDTA as **facilitato r**

Scope

- Different users, different information needs
- Less is often more

“Ontology-based apps are indistinguishable from Magic”

Apps

- **Leverage ontologies through user-friendly apps.**
- Different apps, different scope & technology requirements.
- Provide developer toolkit and developer support.

BDTA

- Ontologies Catalogue & Guidelines in progress.
- We will reach out to gather your input on Ontologies.

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MEMBER

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Align Values and Principles for Ontology Networks

BDTA as **facilitato r**

Compromises & Conclusions

- Different users need different things
- Model Based Software aids broad adoption of standards
- Toolkit and support foster development of Model Based Software

Judith Fauth: Domain Expert Perspective on Ontologies

- Different people need different things
- But… what has already been standardized?

DigiChecks: Semantics in Permits

- Limited ontology scope *required*
- Focus: End user & Developer experience

BDTA: Building Energy Simulation Ontology

- Different users, different needs (e.g., sensor details)
- Though: keep the core small

HYPERGRID: Building Data Connectivity with Utilities Data

- Better standardization & devkit would have reduced privacy challenges

BDTA: Ontology Catalogue Status

- Developers need Ontology Catalogue
- Users need Applications
- Alireza needs your ontologies knowledge

MetabuildingLabs: Semantic Testing Facility

- *Very specific* ontologies lacking – main components are there
- Tech stack for apps does not need to equal Semantic Web

BIM2TWIN: Semantics in Construction Phase:

- Ontologies: pick and choose to meet use case

OptimiseAI:

- Combining existing standards enables integrated use cases
- End users don’t need to know about ontologies

Compromises and Conclusions

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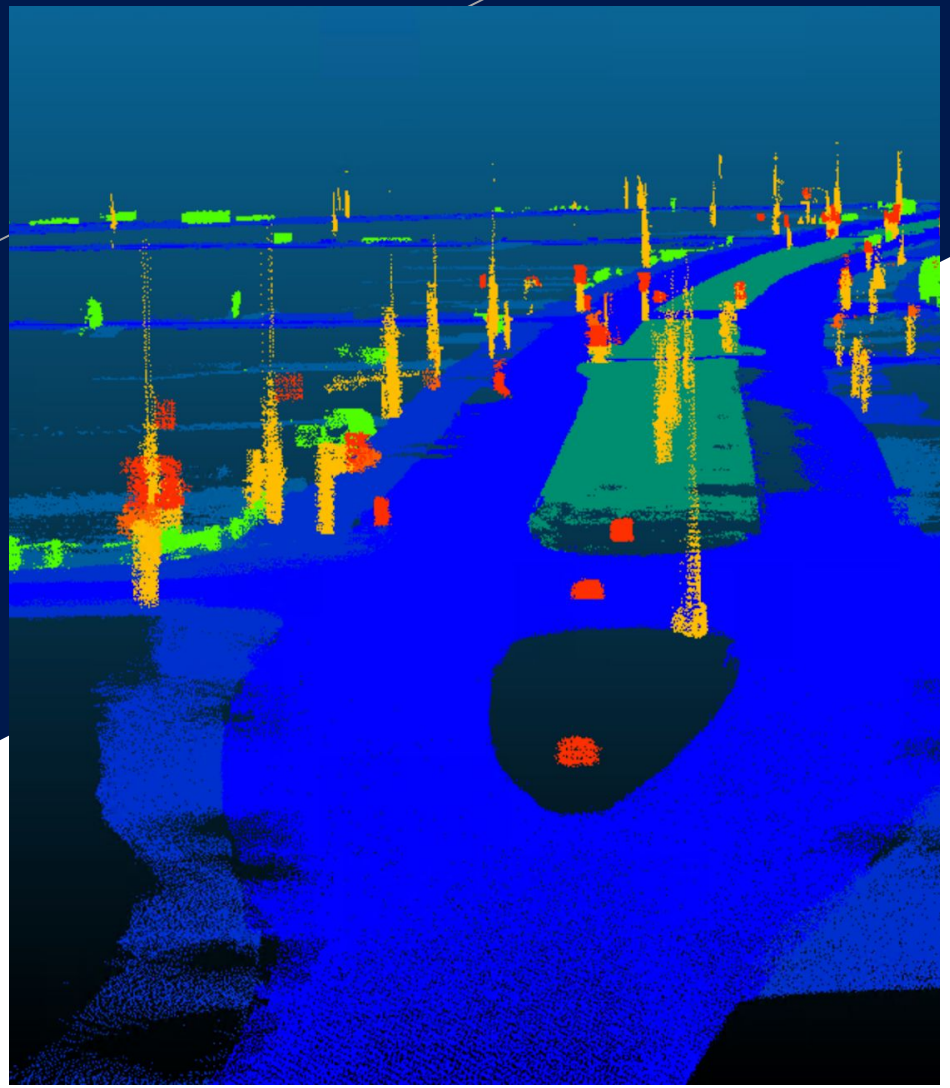


Ontologies in Building Permitting from a Domain Expert Perspective - Ongoing Work and Examples

Judith Fauth

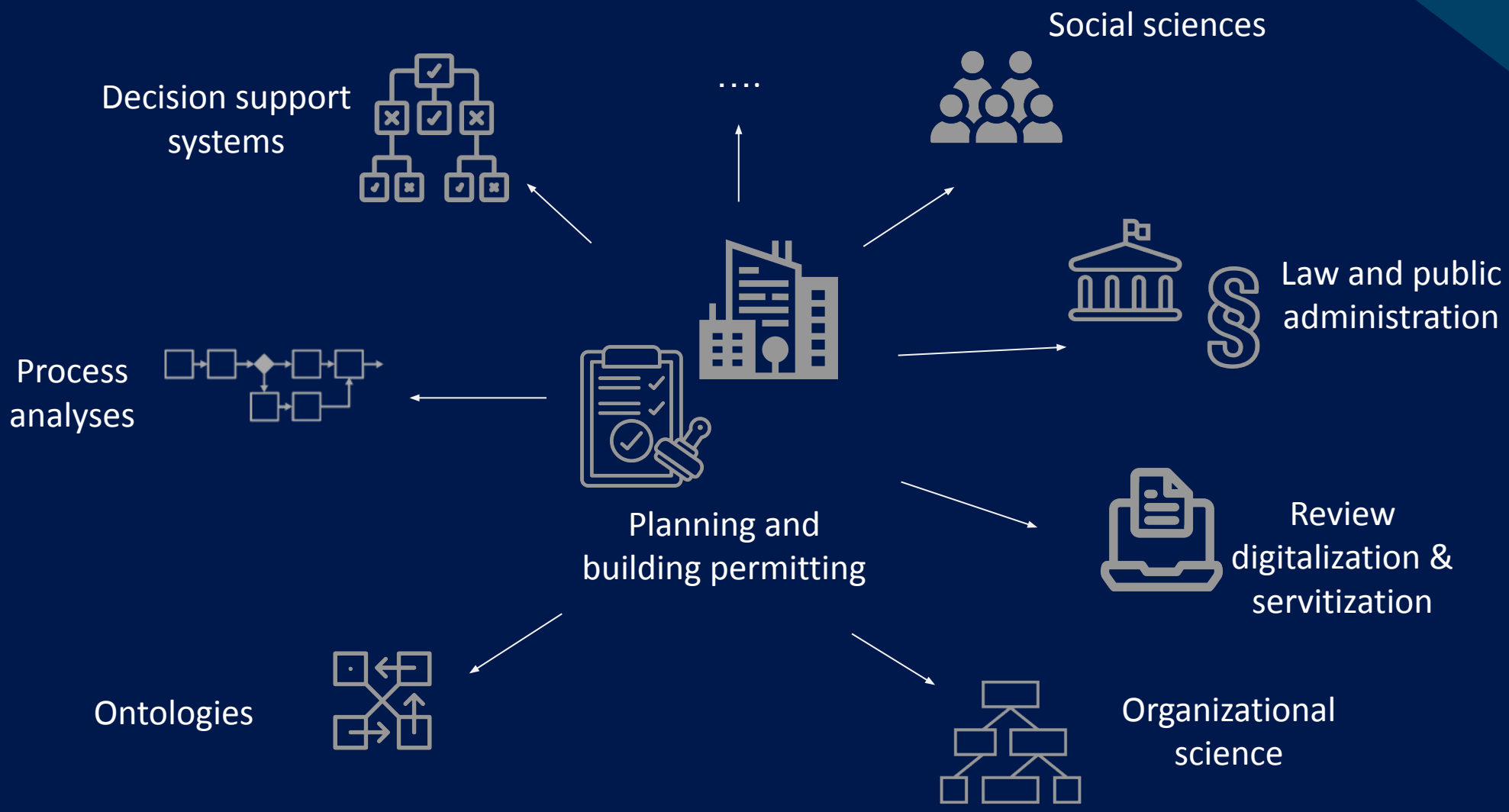
25th September 2024

Sustainable Places 2024

UNIVERSITY OF CAMBRIDGE

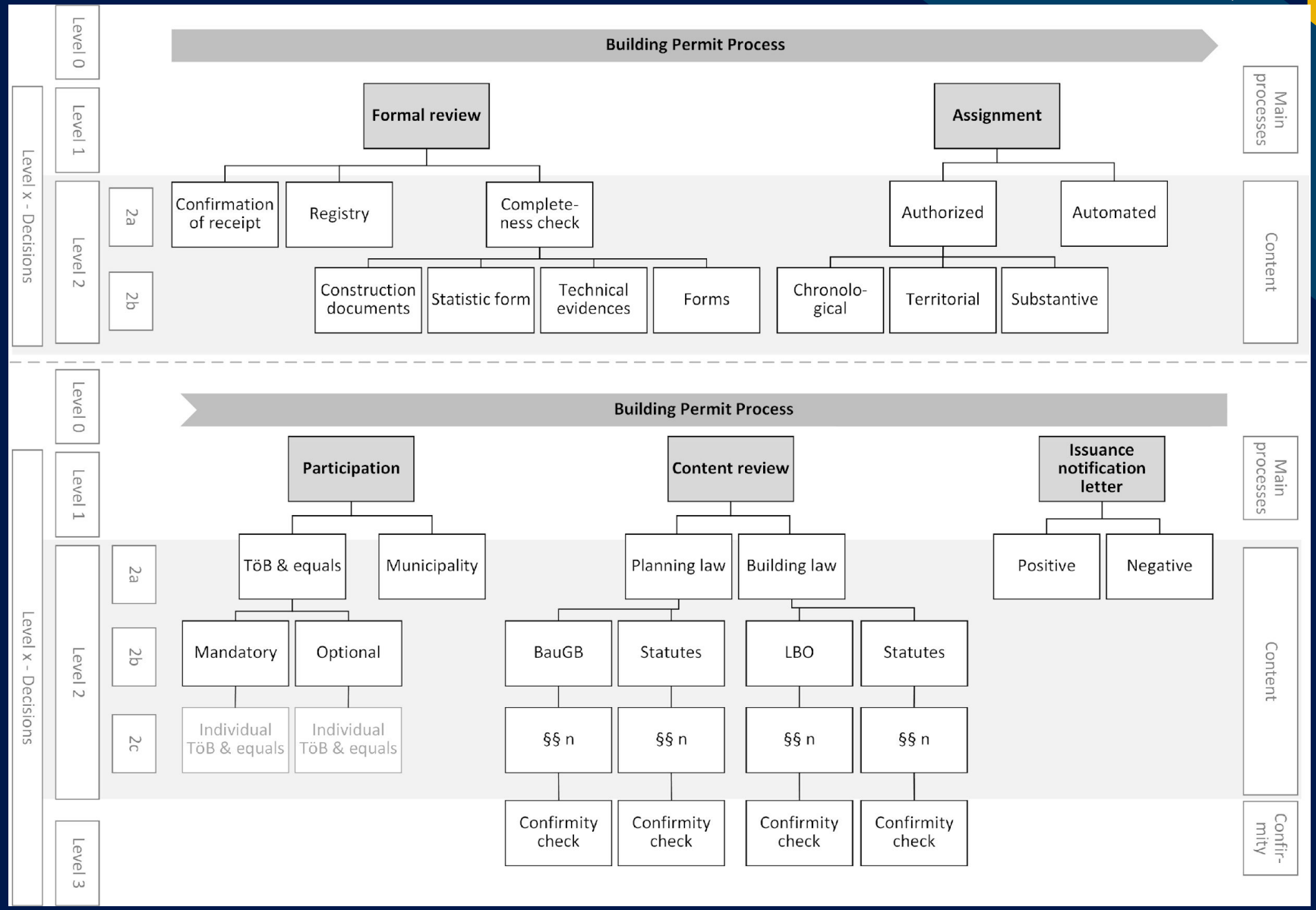
Intro

Research focus



Building Permit Processes

Process system



Reference: Fauth 2021

Building Permit-Related Ontologies

Taxonomy for building permit system

Preferred Label

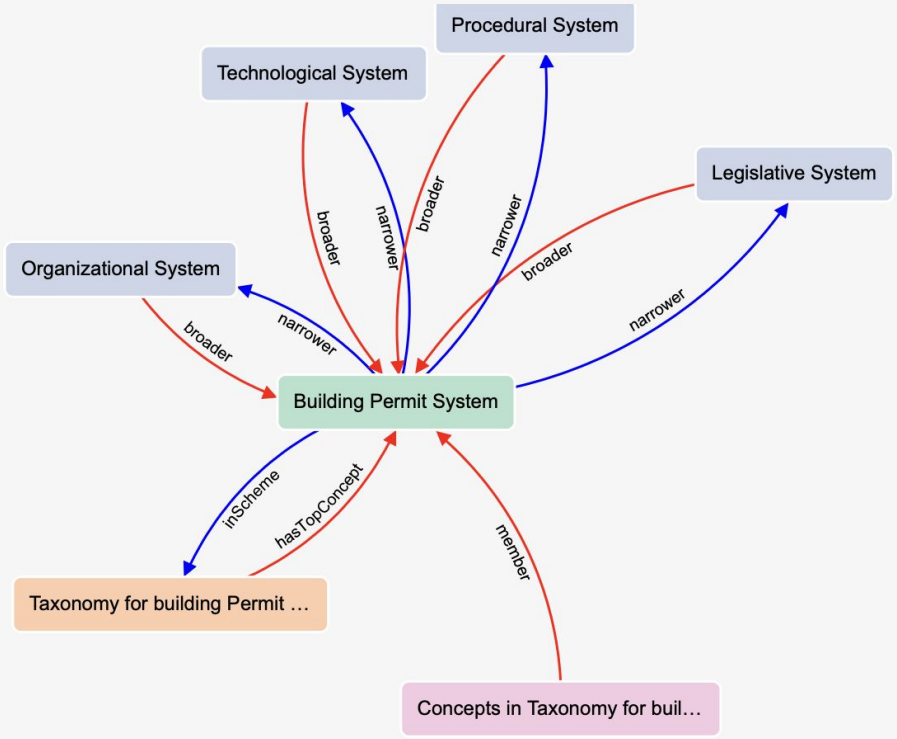
Building Permit System

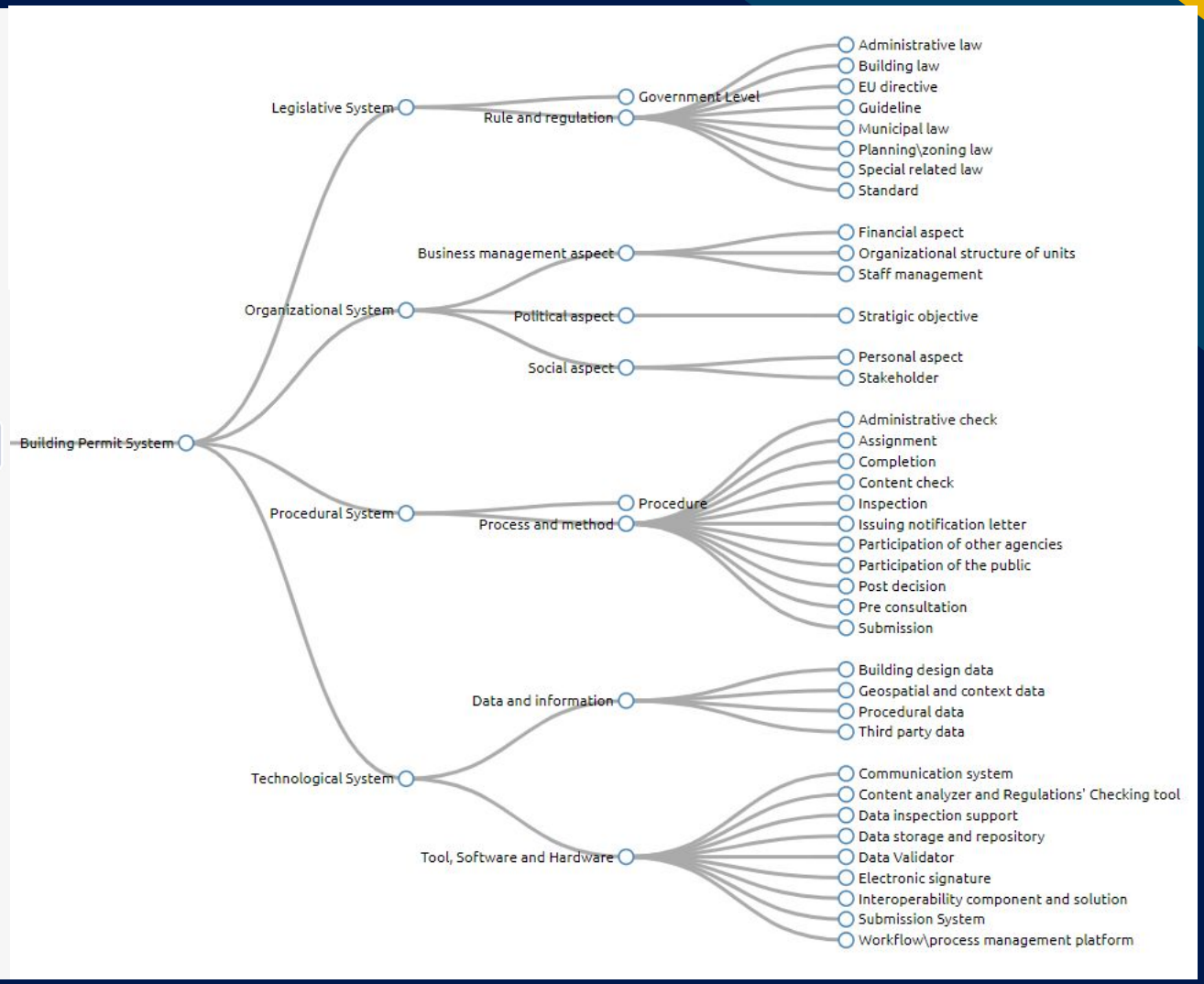
URI

http://data.taxonomy.bp/taxonomy/BP/Building_Permit_System ↗

Within Vocab

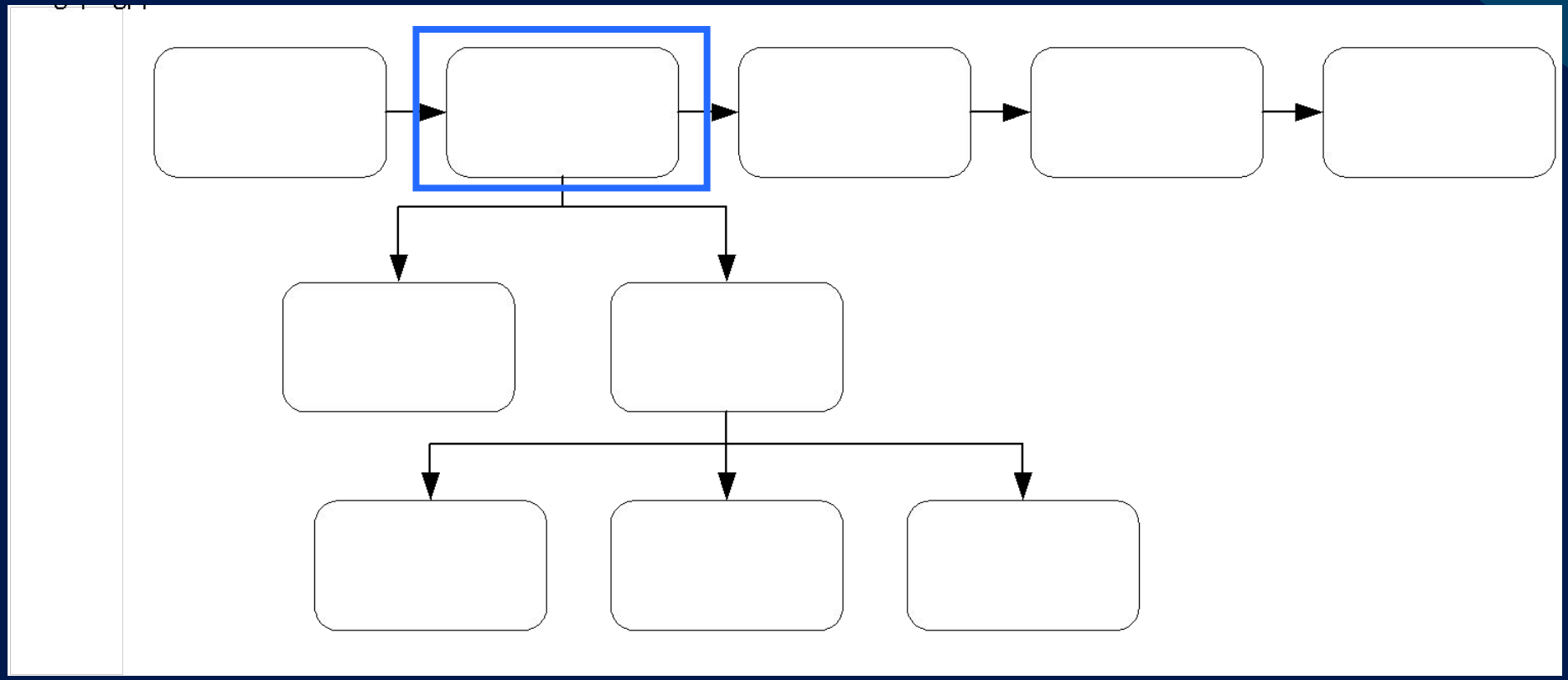
Taxonomy for building Permit system



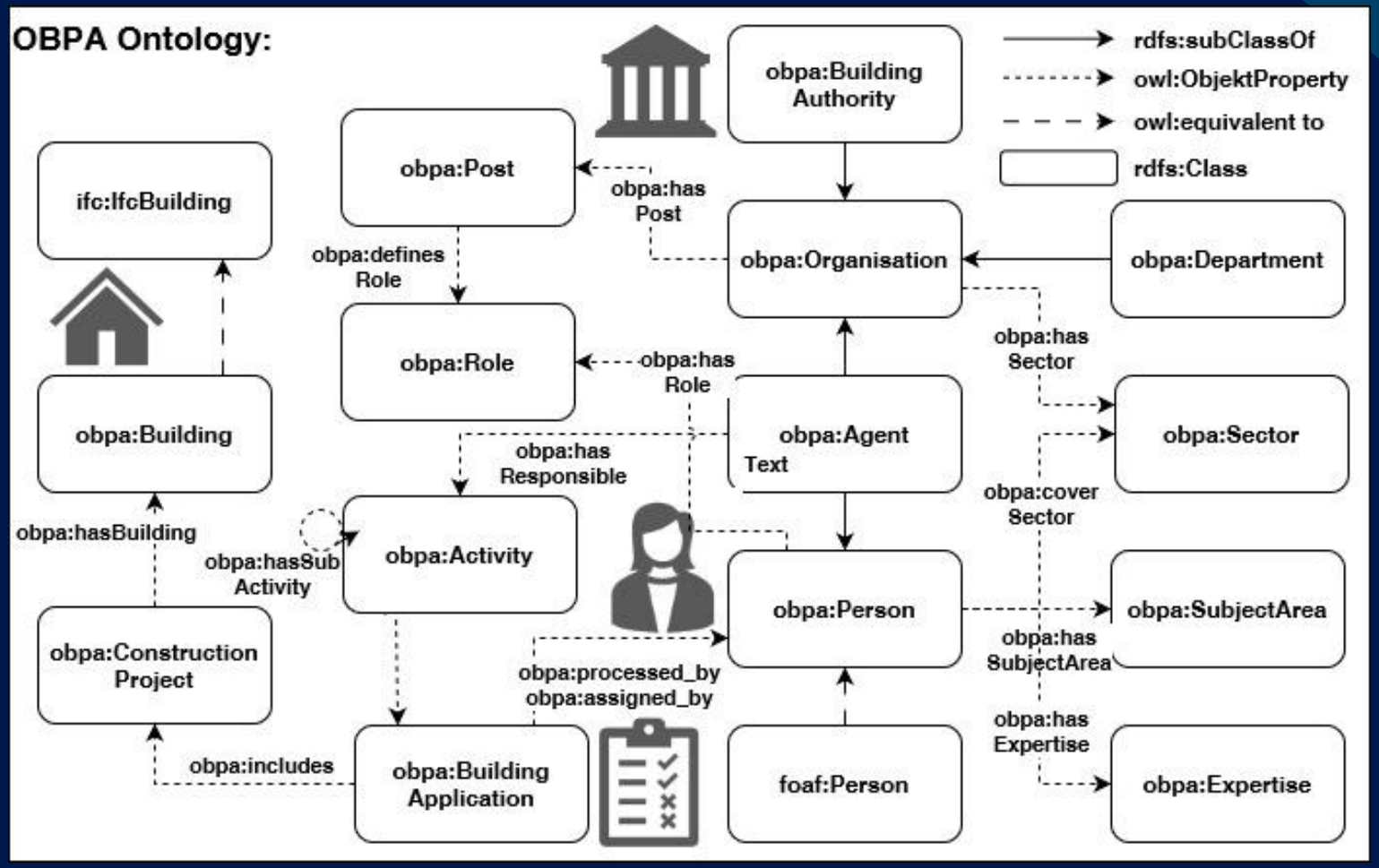


Reference: Fauth et al. 2024

Ontology for Building Permit Authorities (OBPA)

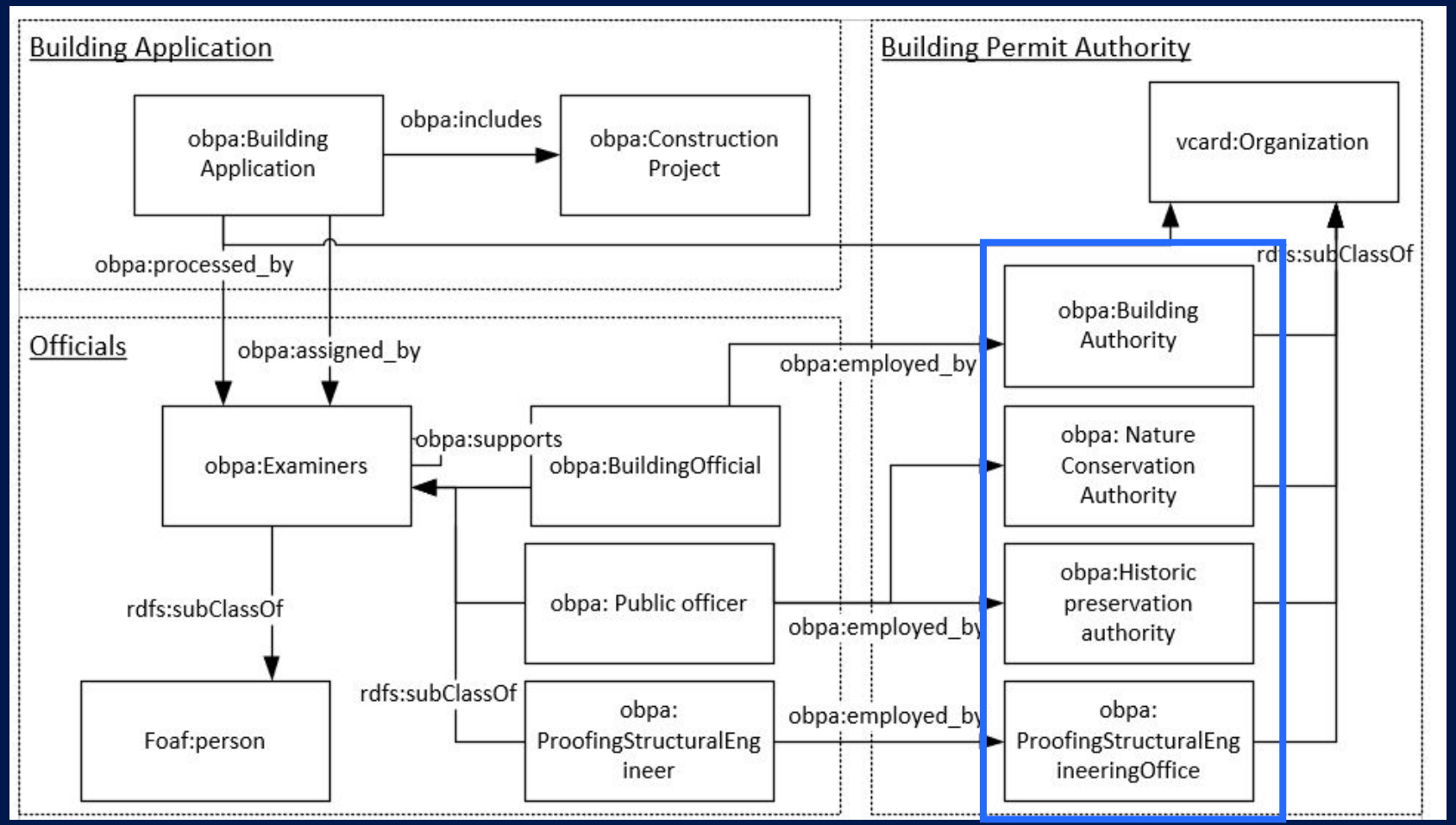


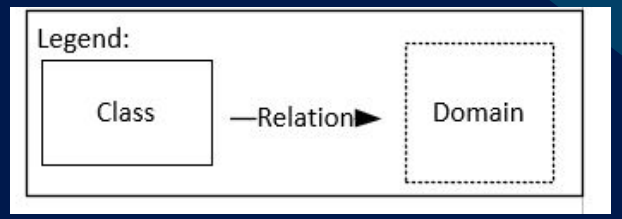
Ontology for Building Permit Authorities (OBPA)



Reference: Fauth and Seiss 2023

Ontology for Building Permit Authorities (OBPA)





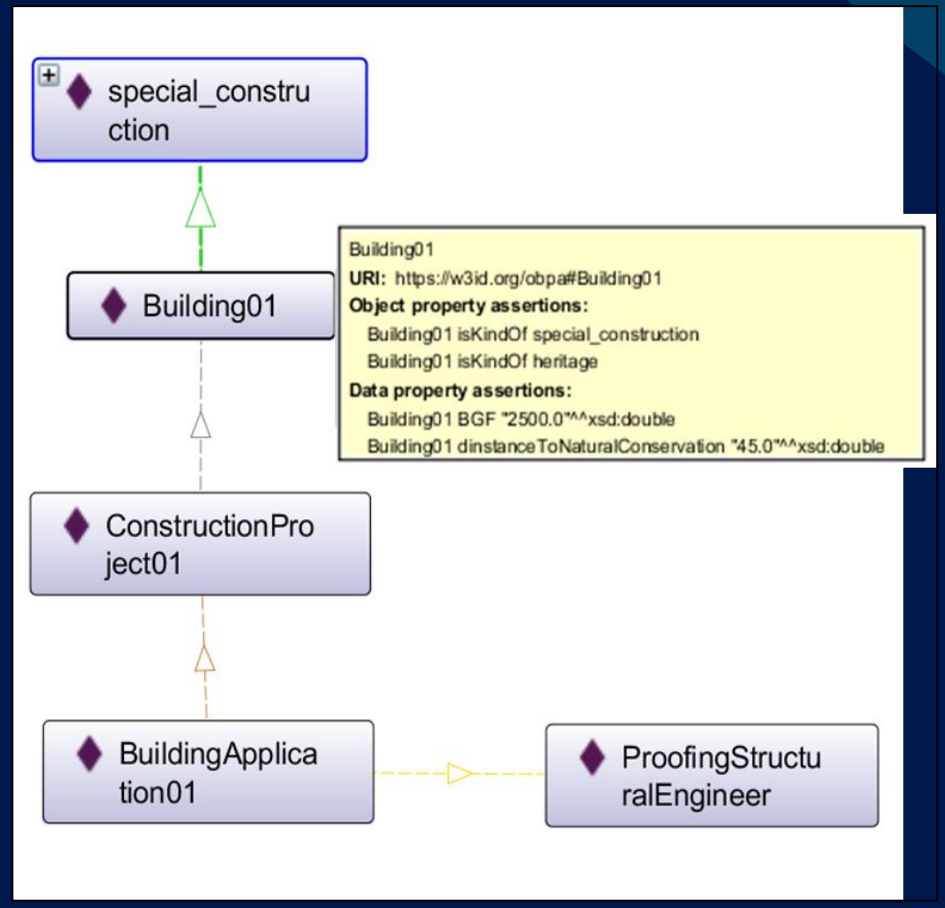
Reference: Fauth, Seiß and Müller 2022

Ontology for Building Permit Authorities (OBPA)

Table 1. DMN logic to select AoPI

	Input		Output
	Historical building	Distance to nature conservation	Gross floor area (GFA)	AoPI
a)	true	-	-	Historic preservation authority
a)	false	-	-	-
b)	-	>=50m	-	Nature conservation authoriy
b)	-	<50m	-	-
c)	-	-	>1000m^2	Proofing structural engineering office
c)	-	-	<=1000m^2	-

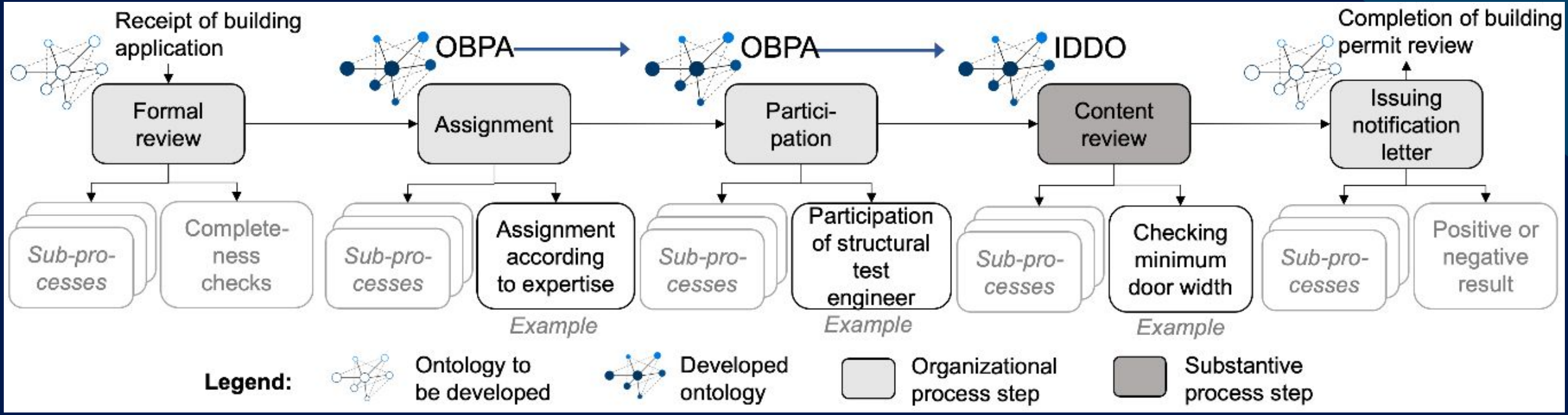
Reference: Fauth, Seiß and Müller 2022



Inferred AoPI for BuildingApplication01 with a total floor area of 2500 m^2.

Building Permit Ontology Alignments

OntoBPR –Ontology-based workflow and concept for building permit reviews



Reference: Zentgraf et al. 2023

“Advanced” OntoBPR

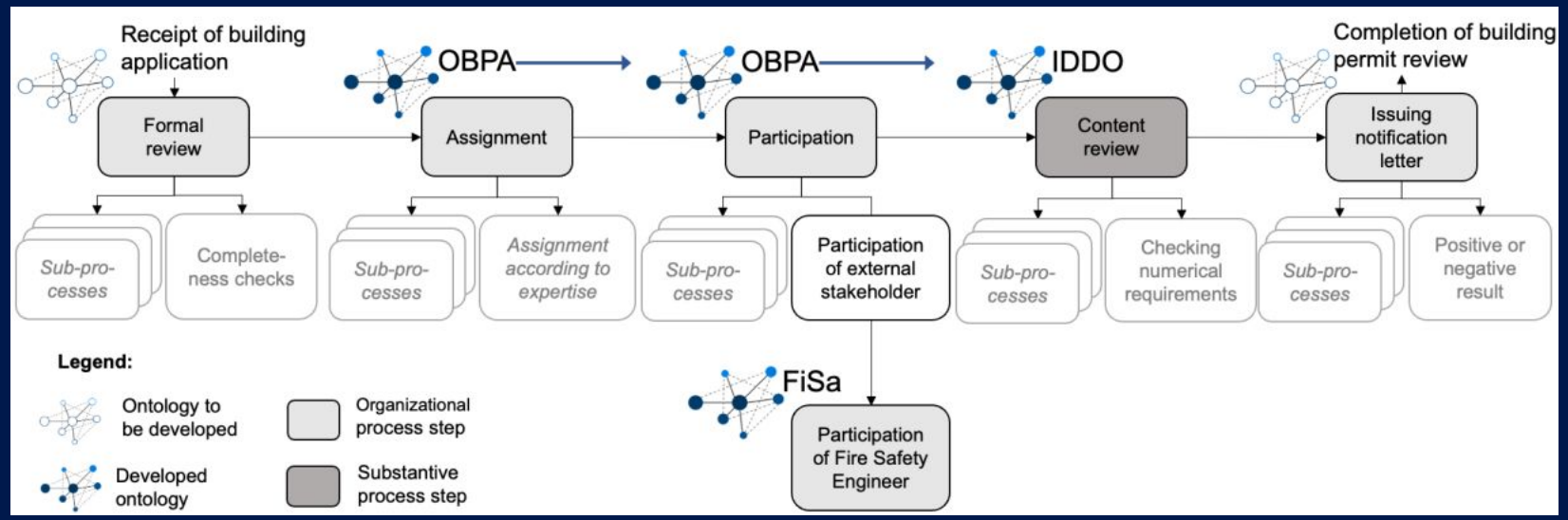
Reference: Hagedorn, Fauth, Zentgraf, Seiß, König, Brilakis

“Advanced” OntoBPR

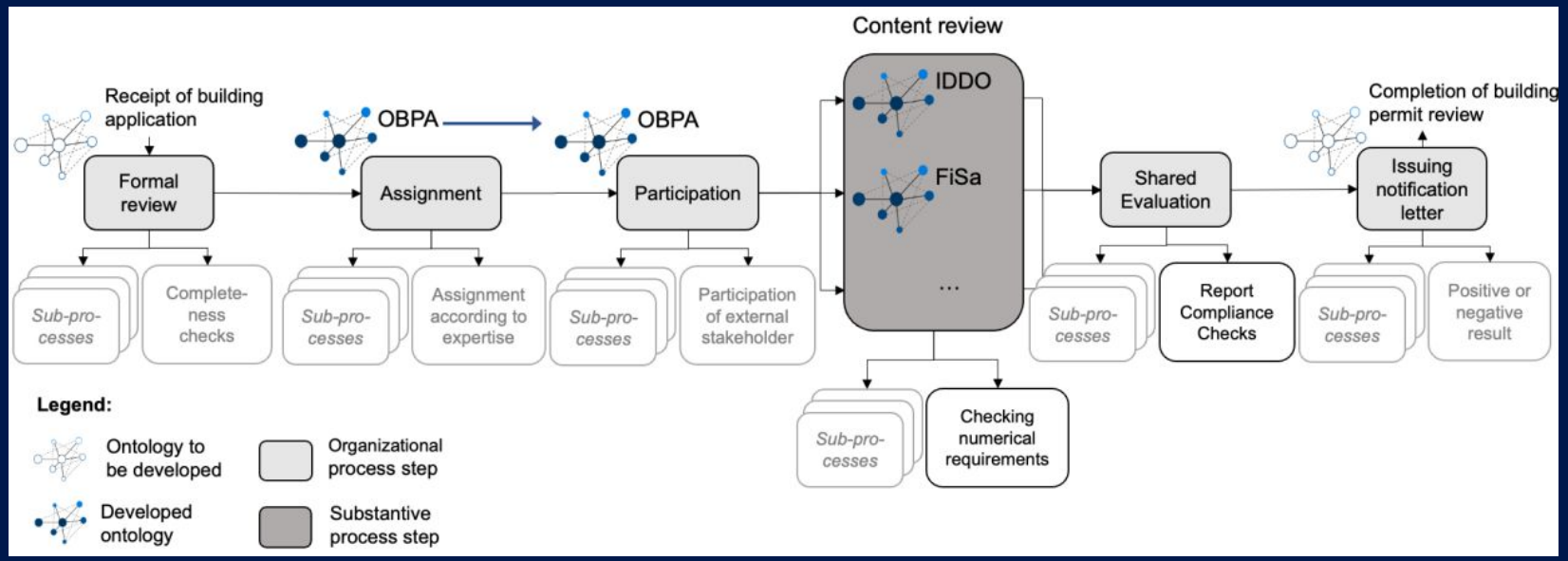
Reference: Hagedorn, Fauth, Zentgraf, Seiß, König, Brilakis

“Advanced” OntoBPR

BEssi - Built-Environment-Thesauri-Ontology



Use Case 1



Use Case 2

Reference: Fitkau, Fauth, Seiß, Hartmann 2024

BEssi - Built-Environment-Thesauri-Ontology

Table 1: Mapping of OBPA and FiSa through SKOS-Concepts.

	Related Concepts		
	FiSa	OBPA	SKOS
1	bot:Building	bot:Building	hasCloseMatch
2	fisa:SpecialPurposeConstruction	obpa:SpecialConstruction	hasExactMatch
3	fisa:RuleOfApplication	obpa:Regulations	hasRelatedMatch
4	fisa:TechnicalStructuralCertificate	obpa:BuildingApplication	related
5	fisa:Surrounding	obpa:PlotOfLand	hasExactMatch

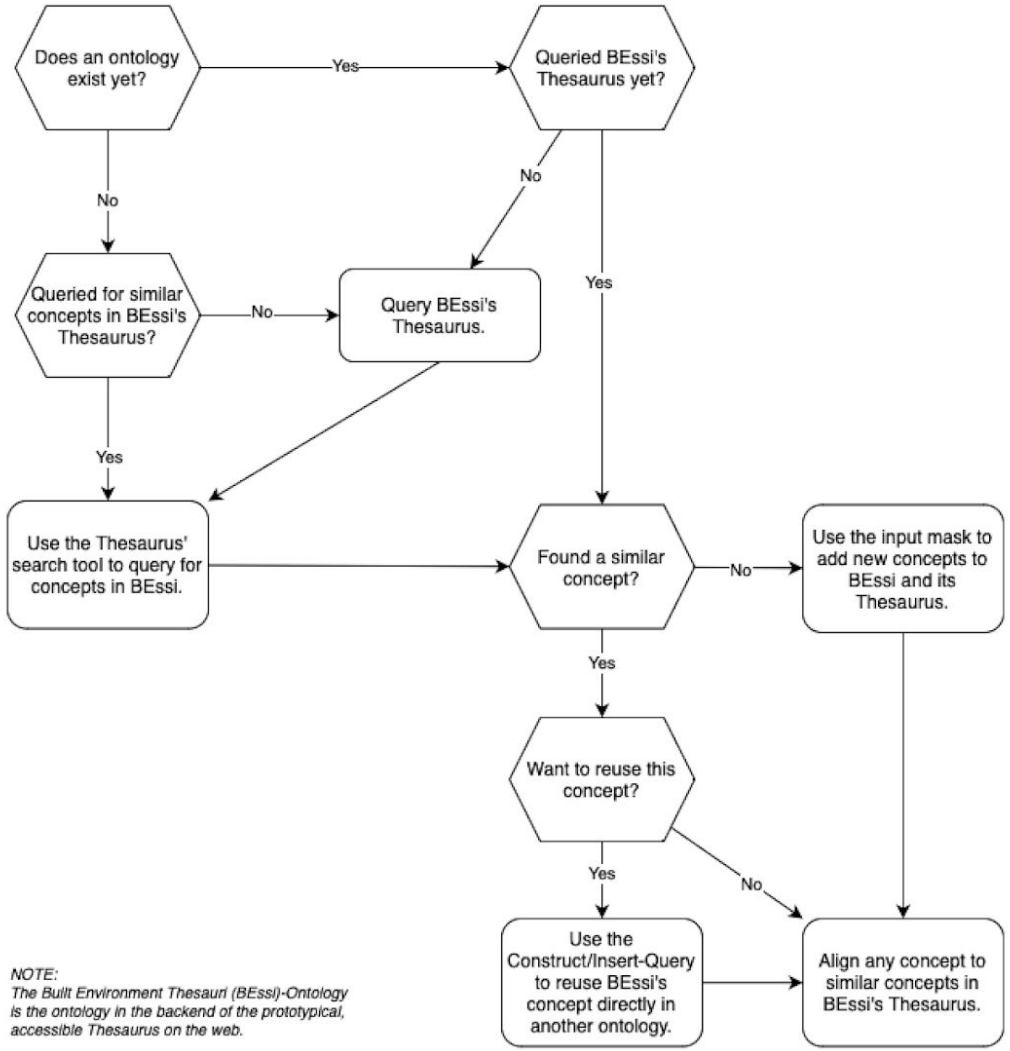
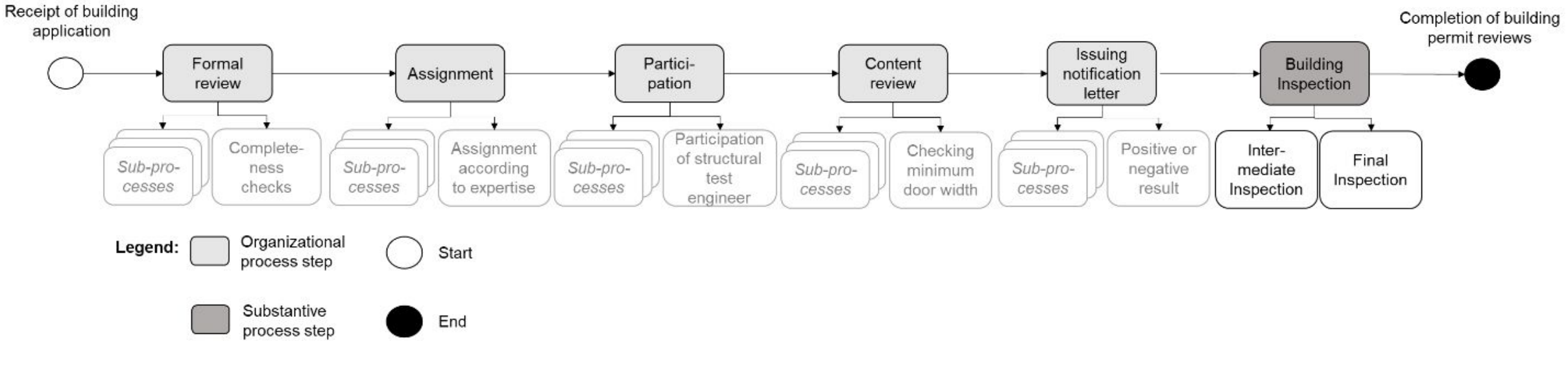


Figure 4: Mapping-Workflow of ontology modelers to support the reuse of similar domain concepts.

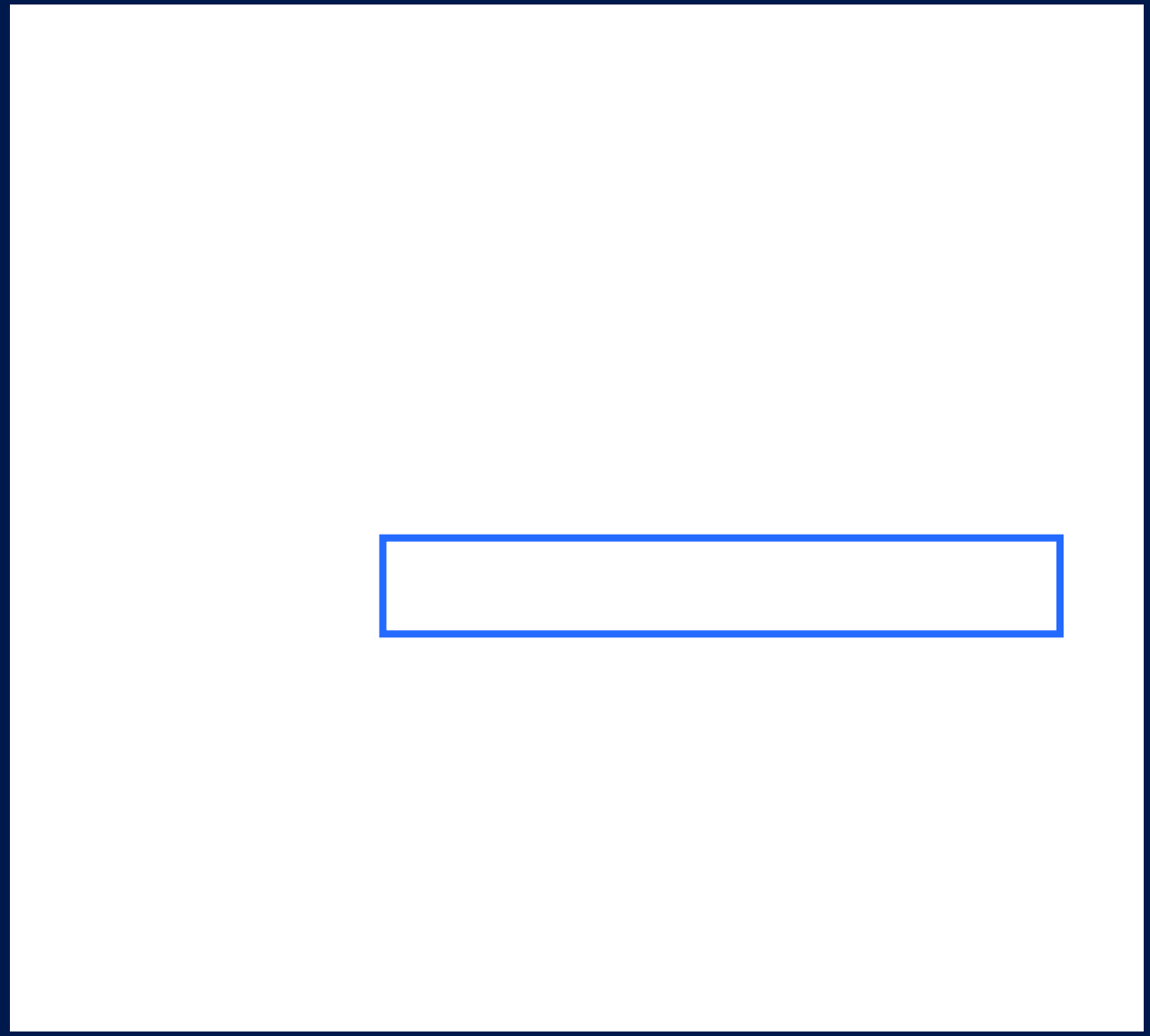
Reference: Fitkau, Fauth, Seiß, Hartmann 2024

OBPI – Building Permit Inspections



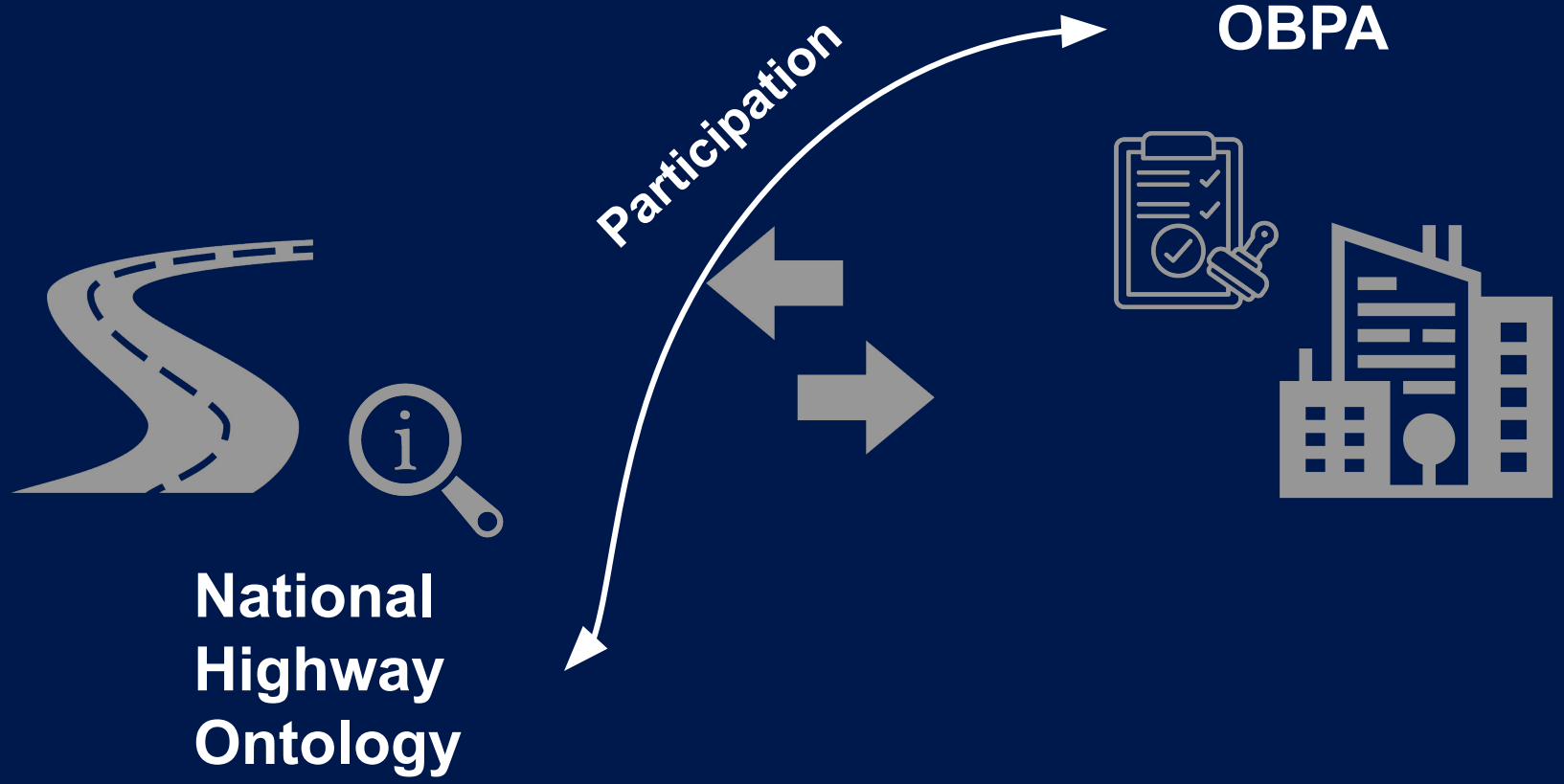
Reference: Seiß, Zhang, Fauth

OBPI – Building Permit Inspections



Reference: Seiß, Zhang, Fauth

Cross-Domain Alignment



Reference: Fauth, Yin, Brilakis

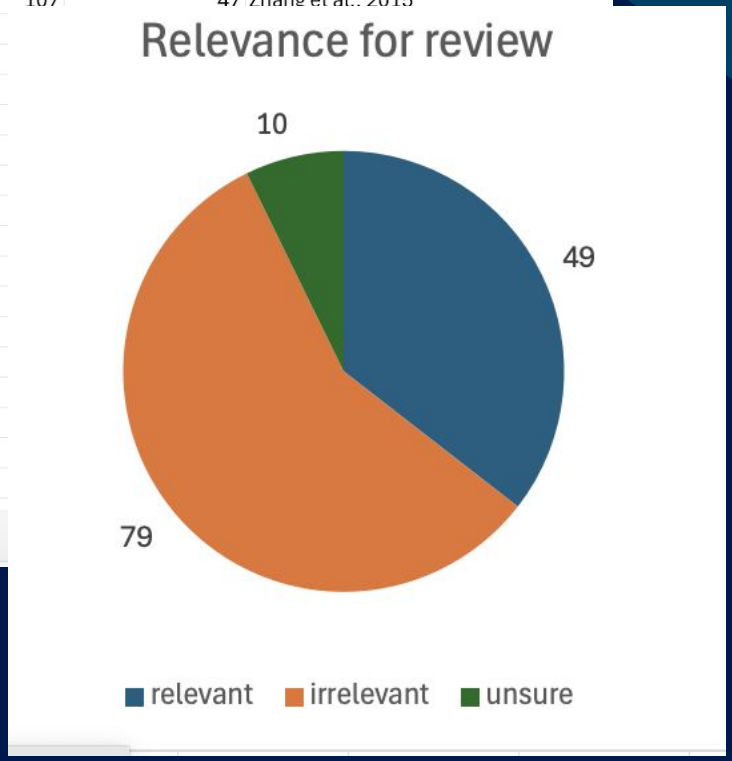
Scientific Review

Review on Building Permit –Related Ontologies

	keywords	
	technical	**legislative**
	ontology	building permit
	semantic web	digital building permit
	resource description framework	permission
	RDF	approval
	linked data	consent
		review
		planning
		zoning
		resource permit
		regulations
		code
		rules
		legislation
		automated code compliance checking
		automated compliance checking
		compliance checking
		ACCC
		ACC
		building information modeling
		BIM
	amount of combinations	100

literature grid | charts | **keyword combinations** | (checks) | (WoS export) | (dropdowns) | +

	amount of articles	**articles related to construction**	
ontology + building permit	2	2	Fauth & Seiss, 2023
ontology + digital building permit	0	0	
ontology + permission	0	0	
ontology + approval	2	1	Jiang et al., 2022c
ontology + consent	6	1	Stoffel et al., 2024
ontology + review	73	15	Gispert et al., 2023
ontology + planning	107	47	Zhang et al., 2015
ontology + zoning			
ontology + resource permit			
ontology + regulations			
ontology + code			
ontology + rules			
ontology + legislation			
ontology + automated code compliance checking			
ontology + automated compliance checking			
ontology + compliance checking			
ontology + ACCC			
ontology + ACC			
ontology + building information modeling			
ontology + BIM			
semantic web + building permit			
semantic web + digital building permit			
semantic web + permission			



Reference: Nuyts, Donkers, Werbrouck, Verstraeten, Fauth

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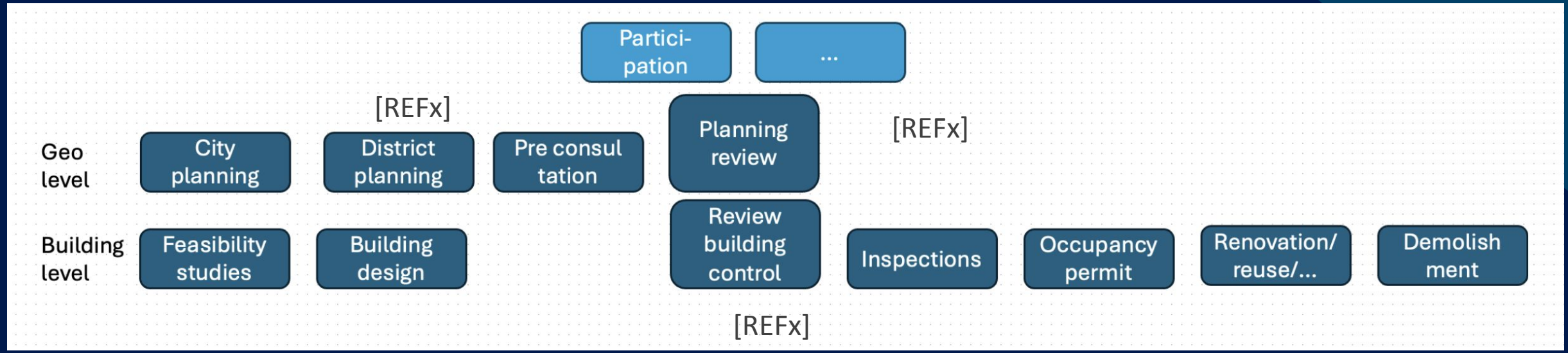
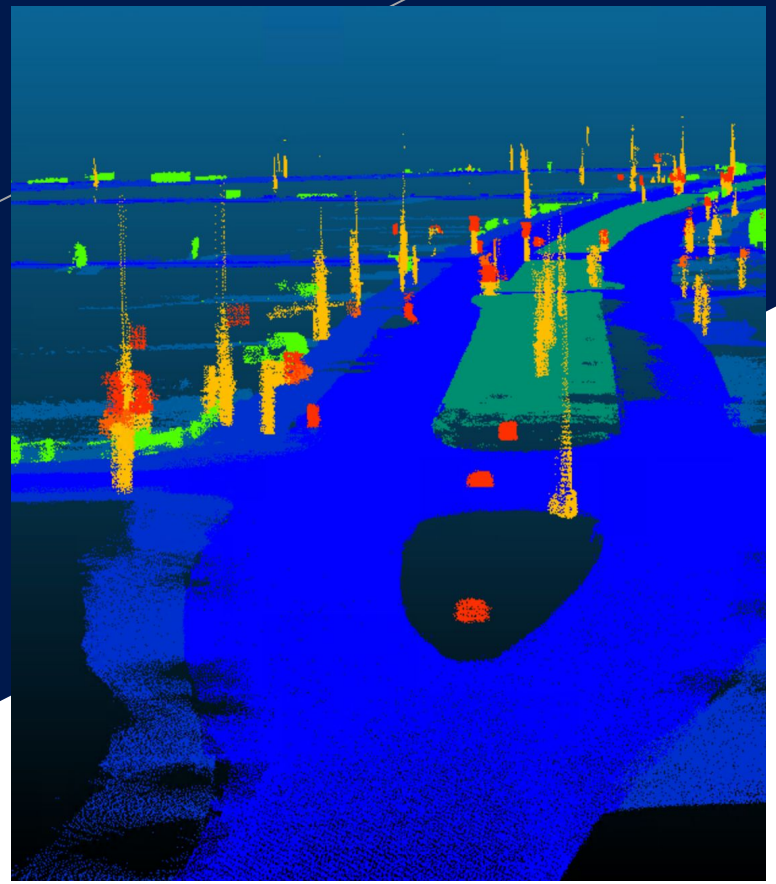


Reference: Nuyts, Donkers, Werbrouck, Verstraeten, Fauth



Thank you!
Questions?

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https://drf.eng.cam.ac.uk/staff/dr-judith-fauth

REFERENCES I

Fauth 2021 Fauth, J. (2021). A process-oriented decision model for determining the permissibility of construction projects. English translation of the German PhD dissertation, Bauhaus-Universität Weimar. DOI: https://doi.org/10.25643/bauhaus-universitaet.4602

Fauth, Seiß and Müller 2022 Fauth, J.; Seiß, S. und Müller, W. (2022). Process-based building permit review – a knowledge engineering approach. In: Proceedings of the 14th European Conference on Product & Process Modelling (ECPPM 2022), September 2022, Trondheim (Norway).

Fauth, J., Bloch, T. Noardo, F., Nisbet, N., Kaiser, S.B., Nørkjær Gade, P. & Tekavec, J. (2023). Taxonomy for building permit system - organizing knowledge for building permit digitalization. In: Advanced Engineering Informatics. DOI: https://doi.org/10.1016/j.aei.2023.102312.

Fauth, J. & Seiss, S. (2023). Ontology for Building Permit Authorities (OBPA) for Advanced Building Permit Processes. In: Advanced Engineering Informatics, 58: 102216. https://doi.org/10.1016/j.aei.2023.102216.

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Zentgraf, S., Fauth, J., Hagedorn, P., Seiss, S., Smarsly, K., König, M. & Melzner, J. (2023). OntoBPR: Ontology-based workflow and concept for building permit reviews. In: Proceedings of EG-ICE 2023, London (United Kingdom), July 2023. https://www.ucl.ac.uk/bartlett/construction/sites/bartlett_construction/files/ontobpr_ontology-based_workflow_and_concept_for_building_permit_reviews.pdf

Fitkau, I., Fauth, J., Seiß, S., Hartmann, T. (2024). Ontology Reuse in Building Permitting. In: Proceedings of CIB W78, Marrakesh (Morocco), October 2024.

SUSTAINABLE PLACES 2024

Semantics and construction with Building Digital Twins

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY LIST

R2M RESEARCH TO MARKET SOLUTION

WORKSHOP

24th September

SEMANTICS IN BUILDING OPERATION: THE O4BSIM

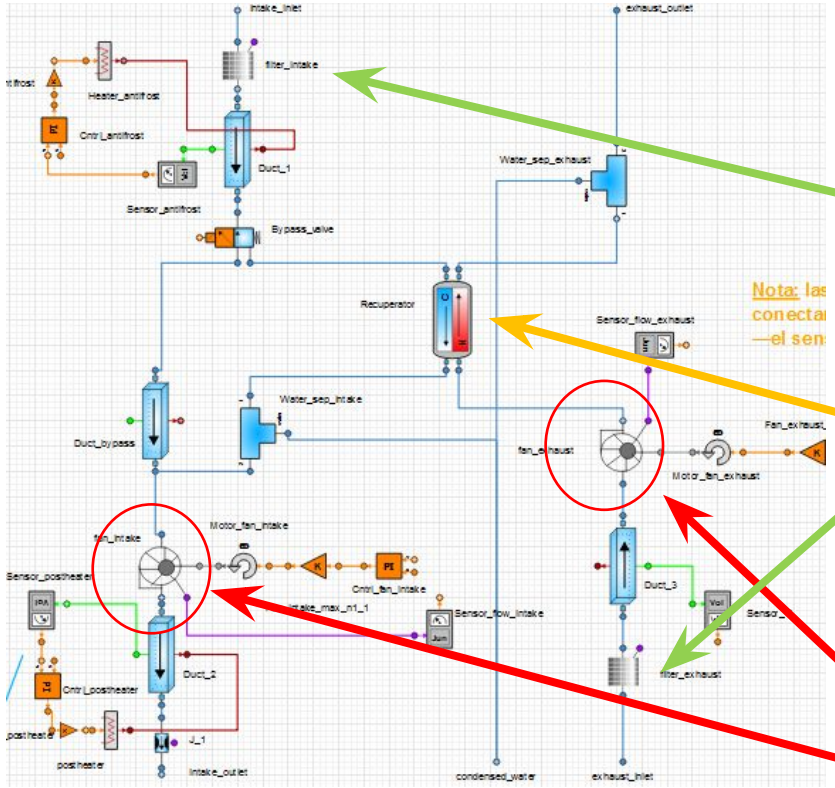
Pablo Vicente-Legazpi (PMO) – p.Legazpi@buildingdigitaltwin.org
BDTA - Borsbeeksebrug 34, 2600 Antwerpen, Belgium

BDTA BUILDING DIGITAL TWIN ASSOCIATION

MATHEMATICAL SIMULATION FOR REAL TIME, WHY?

- What is real time? (1 ms, 1 sec, 5 min, 15 min, 1 h)
- Intelligent operator for “non existing”
- From off-line evaluation TO response in real-time
- Sensors fail (a lot!)
- Improved maintenance (predictive)
- Working in the “edge” (less privacy content level, metrics)

SIMBOT concept



FILTERS

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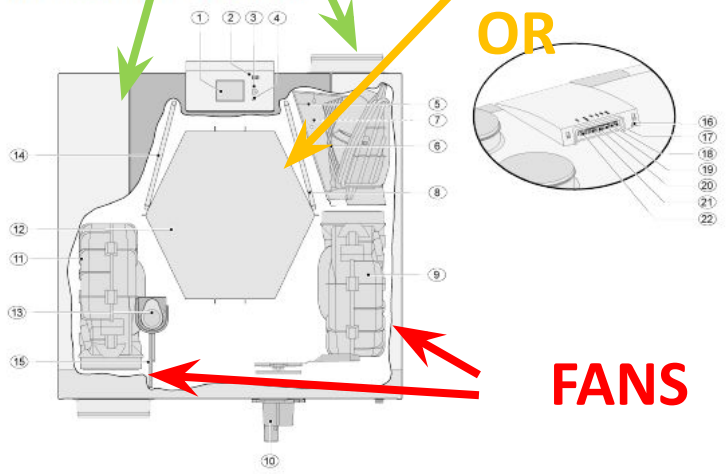
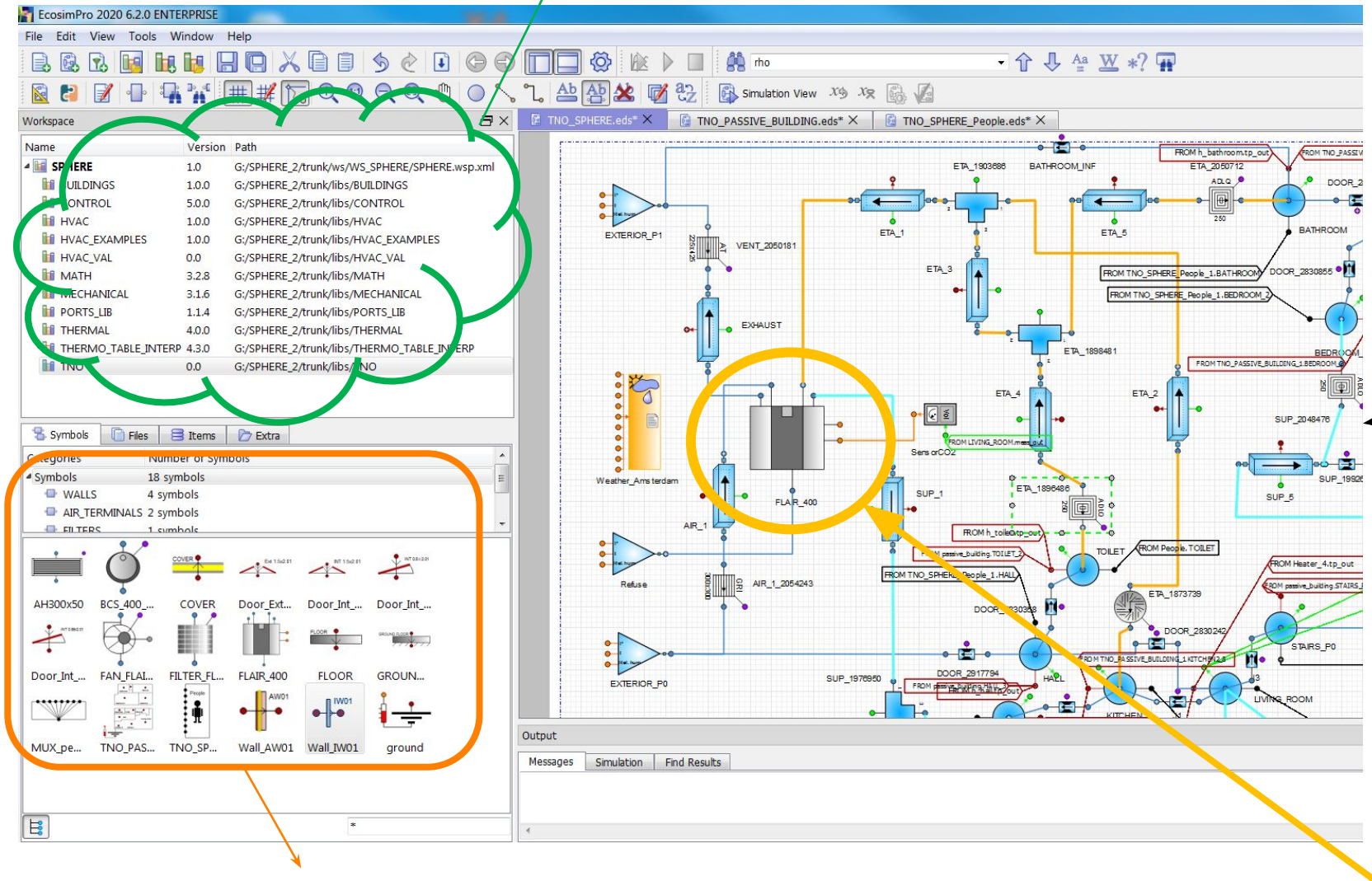


FANS

The appliance shown above is a left-hand version: in the case of a right-hand version, the connector of the preheater, bypass valve and the siphon connector are installed in mirror image!				
1	Touchscreen		12	Heat exchanger
2	USB connector (X13)		13	Motor bypass valve
3	Service connector		14	Exhaust air filter
4	LED indicator		15	Bypass valve
5	Maximum protection preheater		16	Power cable 230 volt
6	Preheater		17	Relay output (X19))
7	Temperature sensor		18	24 volt connector (X18)
8	Supply filter		19	eBus connector (X17)
9	Exhaust fan		20	24 volt connector (X16)
10	Siphon connector		21	Modbus/ Brinkbus connector (X15)
11	Supply ventilator		22	Multiple switch connector (X14)

Workspace: set of libraries



Canvas to edit both graphic and alphanumeric models

SIMBOT

Library: Components, functions, Ports, Symbols, Files, Items, Extra

Projects and SIMBOT dissemination

- Sand-box (Data centers), BDTA projects running: HyCool-IT, DYMAN
- Developers (3DS Dassault, ESRI Simulation X, EAI Ecosimpro,…)
- Fabricators (chillers, in-rack cooling equipments)
- Assocciations (RHEVA, ASHRAE)

HYCOOL-IT
HYBRID COOLING & MANAGEMENT FOR IT INFRASTRUCTURES

Hycool-IT GA 101138623 (2024-2027)

DYMAN
DYNAMICALLY MANAGED SELF-COOLING HPC DATA CENTERS

Dyman GA 101161930 (2024-2027

O4BSIM, Why?

- Developers implementation: each one must derive their own library implementation
- Fabricators to developers: one equipment definition for all (SIMBOT)
- BMS, SCADA interoperability
- BIM interoperability (BOT)
- Sensors interoperability

O4BSIM implementation

- Initial steps: disciplines, entities, clasifications
- Objective: Smaller (controllable!) but knowledge intensive (Protegé)
- Intensive maintenance (BDTA)
- Market value and exploitation
- Standard “carrier” (CEN442 WG9)
- The main need: CONSENSUS (developers, fabricators, assocaitions)

SEMANTICS IN BUILDING OPERATION: THE O4BSIM

Thank you!

Questions

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R2M RESEARCH TO MARKET SOLUTION

INTRODUCTION TO HYPERGRYD

HYPERGRYD: Hybrid coupled networks for thermal-electric integrated smart energy Districts. An **energy management and optimization platform**, designed to seamlessly **integrate hybrid energy networks**, enabling dynamic operational adjustments. This approach optimizes energy usage, minimizes environmental impact, and enhances system efficiency and resilience across diverse energy infrastructures.

ARC BCN | ENGINYERS CONSULTORS · Consiglio Nazionale delle Ricerche · ITAE · AIT AUSTRIAN INSTITUTE OF TECHNOLOGY · encoord · R2M RESEARCH TO MARKET SOLUTION · eurac research

comet Global Innovation & Commercialization · Sorption Technologies · GET · Gridgularity · ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente · IMP PAN GDAŃSK

KTH VETENSKAP OCH KONST · RANOTOR · IDP ingeniería · medio ambiente · arquitectura · RINA · OCHSNER HEAT PUMPS · SONNENPLATZ Großschönau · EIM

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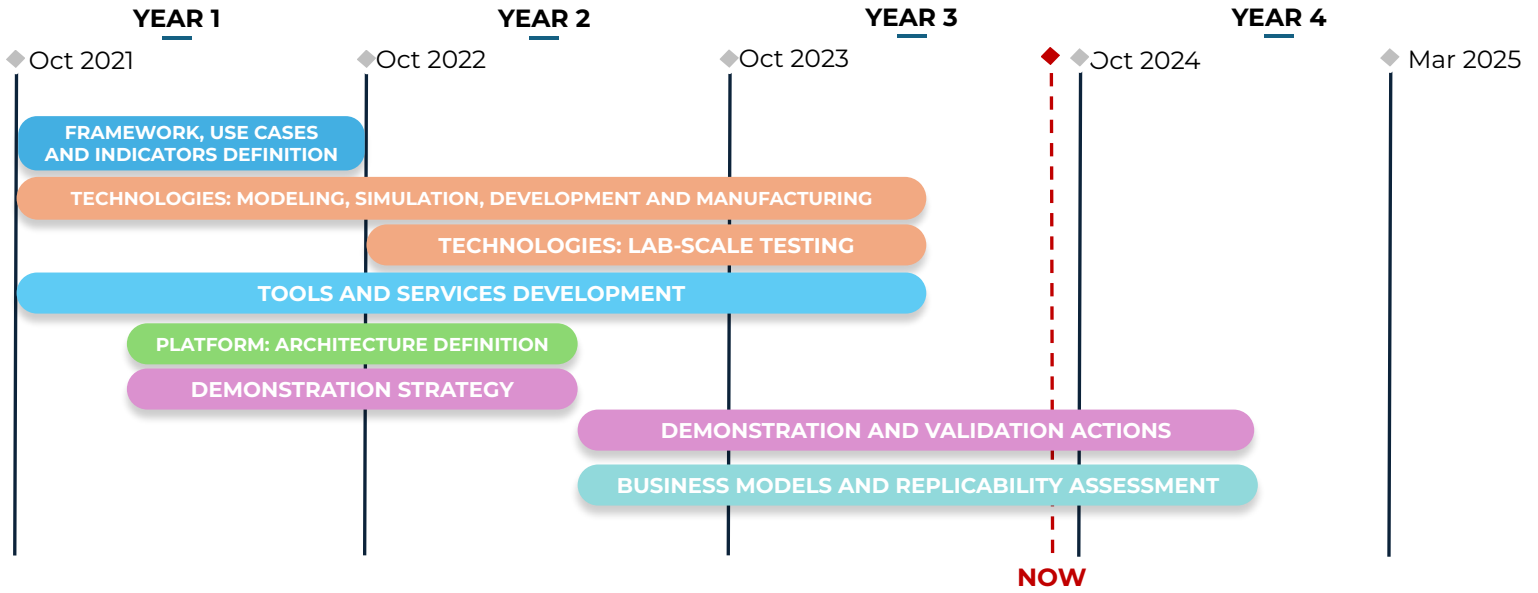
HYPERGRYD STATUS



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R2M RESEARCH TO MARKET SOLUTION

HYPERGRYD Data groups (First data group)

BIM-GIS toolkit for DHC network piping and configuration planning

This tool supports decision-making and optimizes network layouts and dimensions for planning next-generation district heating networks, applicable to both new and existing systems.

Exergoeconomic optimization tool for 4th and 5th generation of DHC

Exergy-based analysis and assessment of energy-conversion systems for district heating and cooling.

- Data models adhere to GIS standards for identifying and classifying geometric data and associating metadata/properties.
- Serves as an information source to identify components linked to geometries and as a base for energy simulations.

HYPERGRYD Data groups (Second data group)

SAInt - Scenario Analysis Interface for Energy Systems

Modelling tool to physically simulate the operation of an integrated energy system that couples heating and electricity networks.

- Data models are not part of an open-source standard.
- This group of data models is based on the requirements and definitions set by ENCOOR simulation tools.

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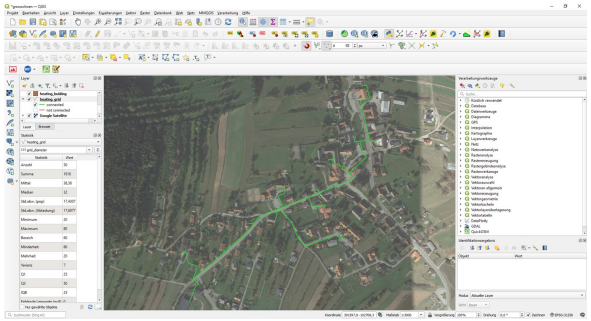
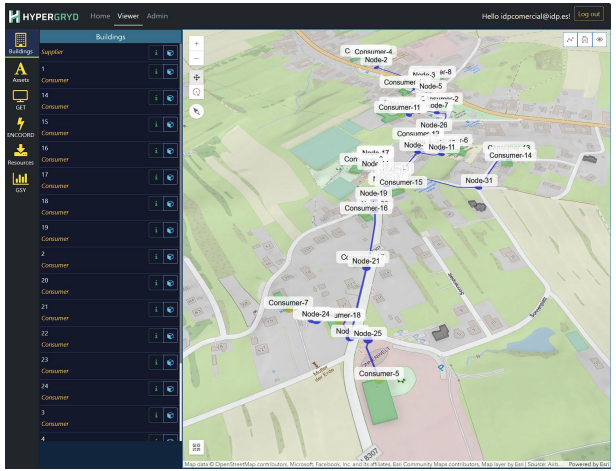
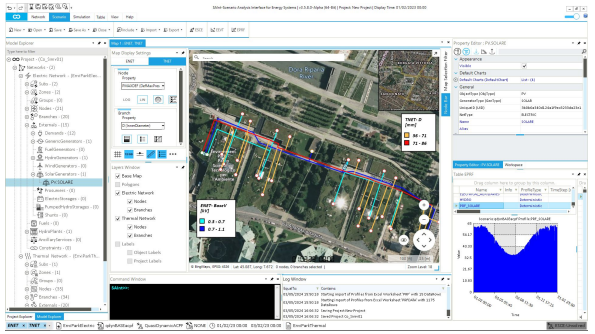
HYPERGRYD Interface with integrated tools



Exergoeconomic optimization tool for 4th and 5th generation of DHC



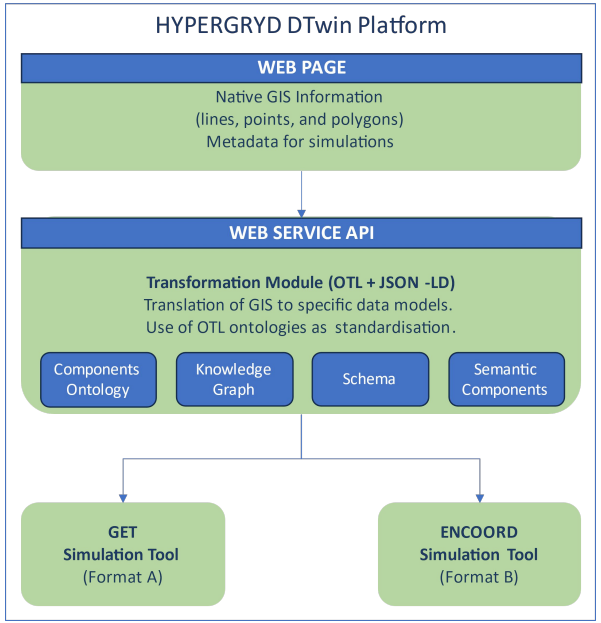
HYPERGRYD DTwin platform



SAInt - Scenario Analysis Interface for Energy Systems

If standardized ontologies had been applied..

- A single data model would have been used.
- Definitions, typologies, and integration services would share the same structure, adapting information exchange to a unified data model.
- This would reduce development time, making it more flexible and generic.



BDTA

BUILDING DIGITAL TWIN ASSOCIATION

Driving innovation in Building Digital Twins!

SUSTAINABLE PLACES 2024

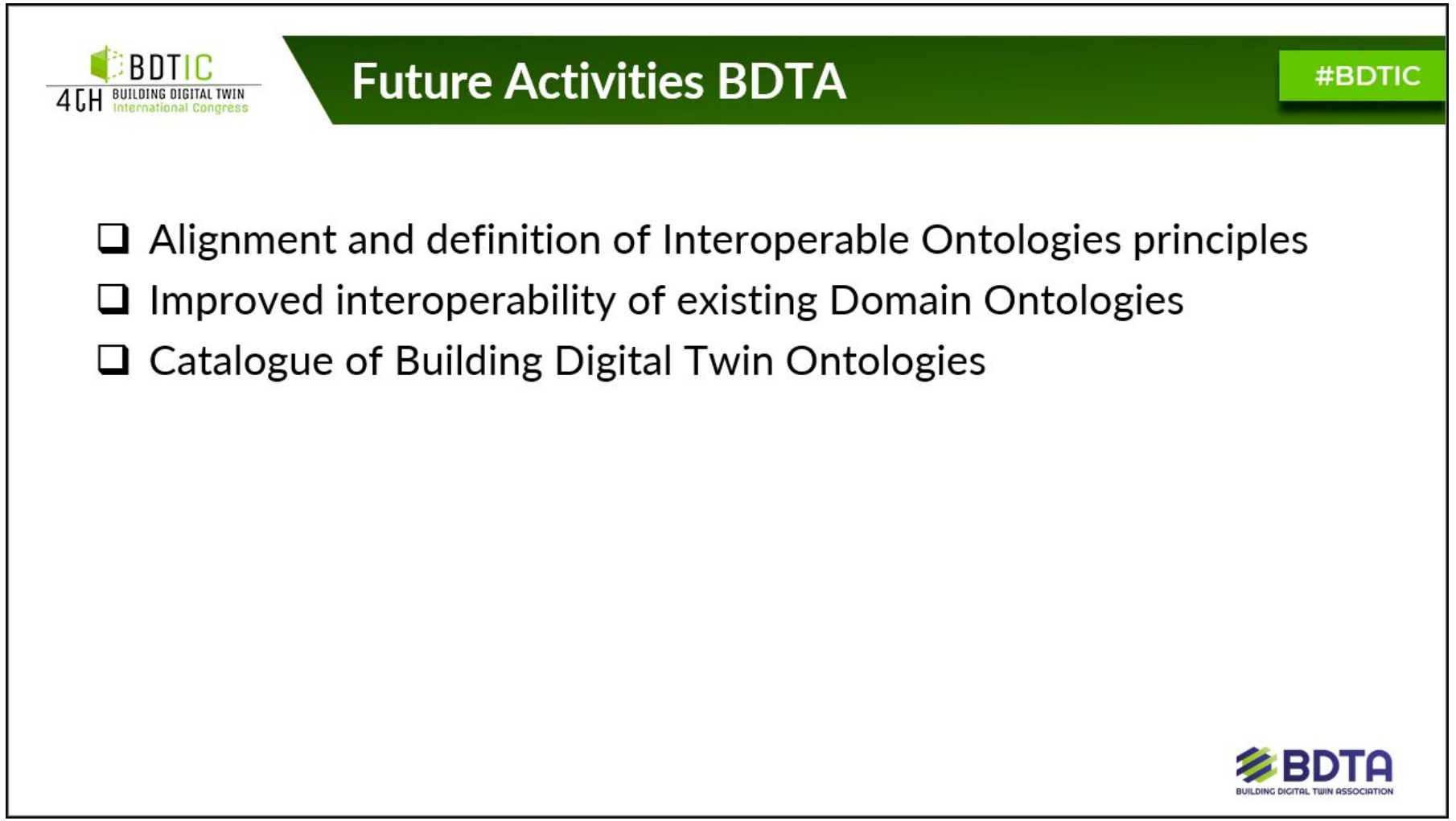
Ontology Catalogue

Alireza Emad
Consultant
Semmtech
alirezaemad@semmtech.nl

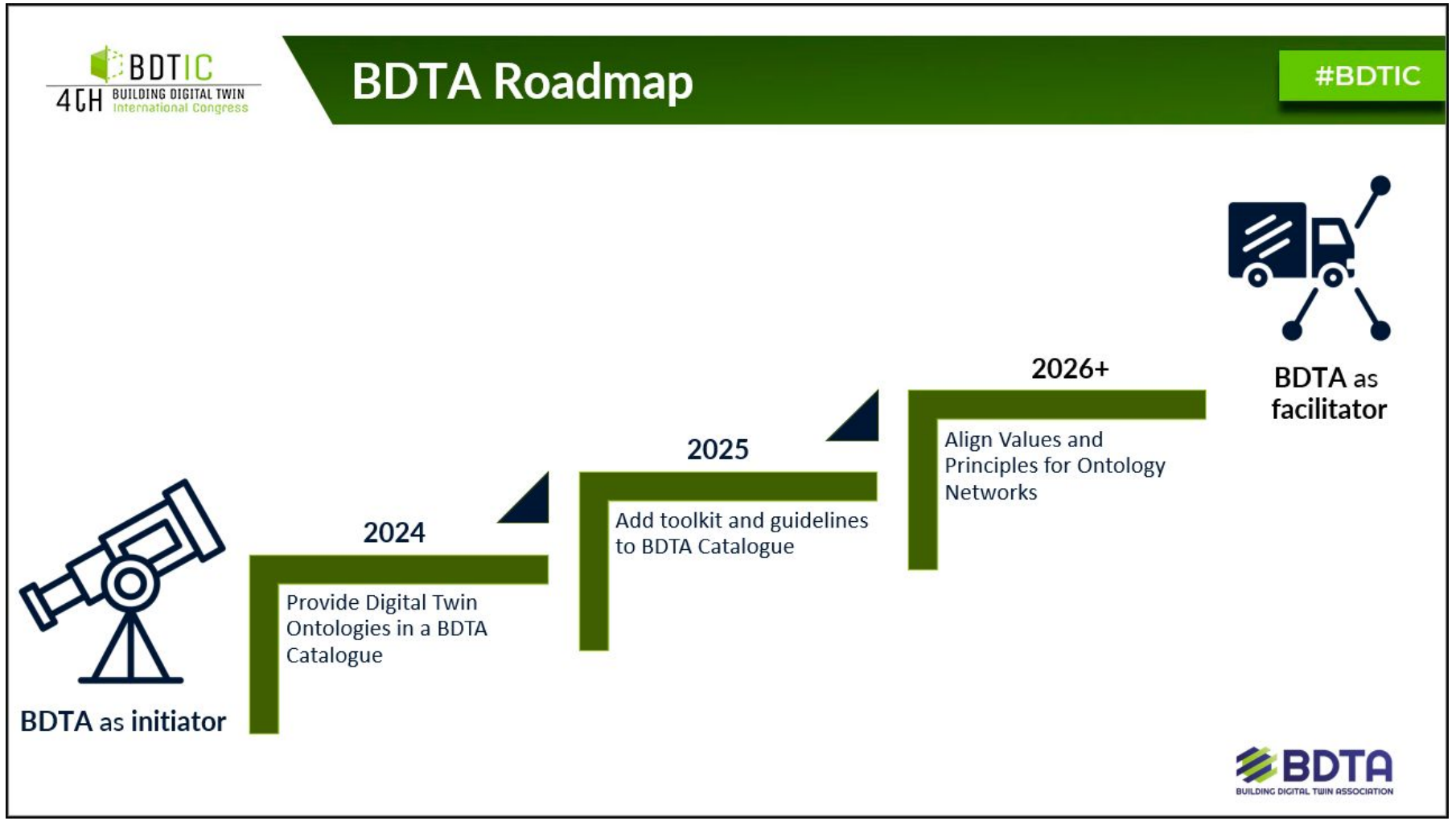
September 2024

BDTIC4 Recap

BDTIC Closing Remarks (1)



BDTIC Closing Remarks (2)



Ontology Catalogue

Project Definition

Description:

The main project goal is to progress on the BDTA Roadmap as defined at BDTIC4 in April 2024. To create a central hub for the ontologies in the Building Digital Twin domain

Project Definition

Description:

To create a central hub for the ontologies in the Building Digital Twin domain.

Why?

To ensure BDT ontologies can:

- ✔ Shared
- ✔ Explored
- ✔ Accessed
- ✔ Used

Users

Users:

- Ontology Developers (Academia & Industry)
- Software Developers and Providers
- Ontology Users

Project Plan

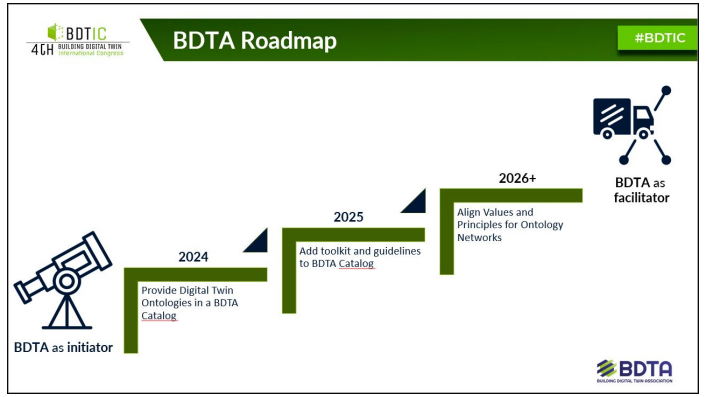
- **Phase 1:** Listing Ontologies (MVP)
  - A catalogue of ontologies with necessary information and guidelines

- **Phase 2:** Feedback Incorporation, Improvement and Feature Addition
  - Improvement of the catalogue and introducing additional features

- **Phase 3:** Advanced Use & Accessing Ontologies
  - Addition of advanced features (e.g. Querying and exploring ontologies on the platform)

BDTIC Closing Remarks (3)

The main goal is to progress on the BDTA roadmap as defined at BDTIC4.



2024 – Ontologies Catalogue

- A comprehensive directory of Ontologies in the BDT domain
- Facilitate easy search of Ontologies in the BDT domain
- Enable users to understand the scope, purpose and structure of available ontologies

2025 – Toolkit and guidelines

- Ontology adoption and interaction supported for various applications and projects
- Improved collaboration among software providers, ontology developers and users
- Basic training and guidelines available for users

Requirements and Features

Requirements:

- ❑ Discover ontologies relevant to use-cases
- ❑ Find ontologies to integrate in software applications
- ❑ Learn about different ontologies and their relevant usecases
- ❑ Showcase ontologies
- ❑ Connect to other creators in the BDT field

Requirements and Features

Features:

- ❑ List of available ontologies
- ❑ Details of each ontology
- ❑ Browsing ontologies
- ❑ Guidelines and tutorials

Discussion Points

- Ontology Selection Scope
- Metadata
- Available Ontologies in the BDT Domain
- Guidelines

Questions?

SUSTAINABLE PLACES 2024

BDTA
BUILDING DIGITAL TWIN ASOCIATION
MEMBER

SUSTAINABLE PLACES 2024

Luxembourg 2024

Defining semantics for digital twins of façade component testing facilities

Presenter: Calin Boje

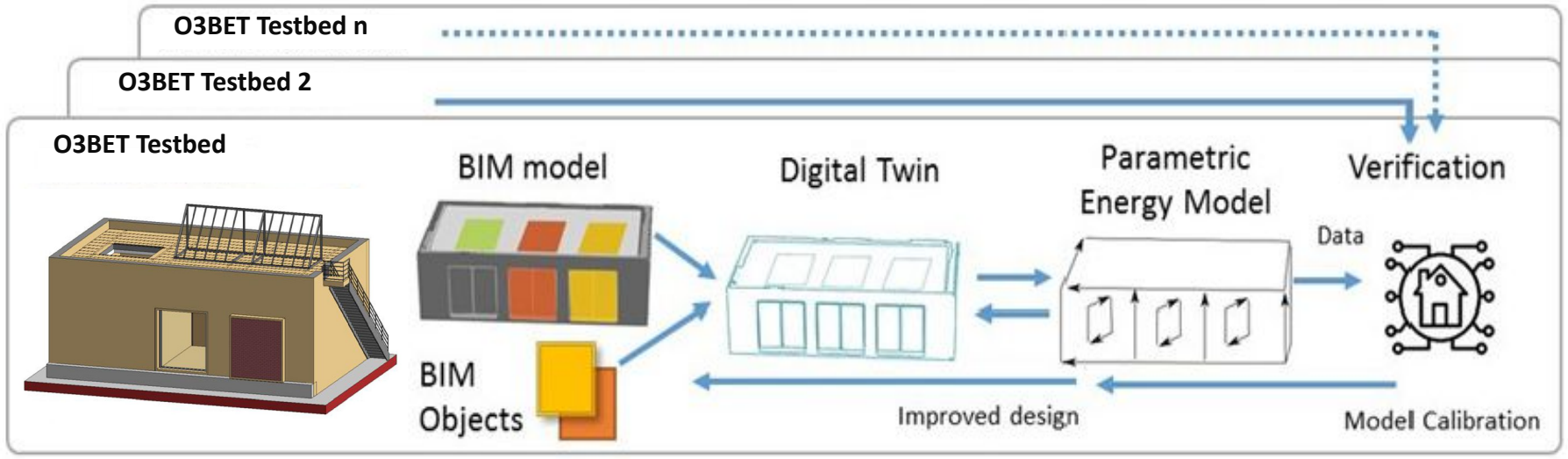
LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY | LIST

METABUILDING LABS Project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 953193. The sole responsibility for the content of this document lies entirely with the author's view. The European Commission is not responsible for any use that may be made of the information it contains.

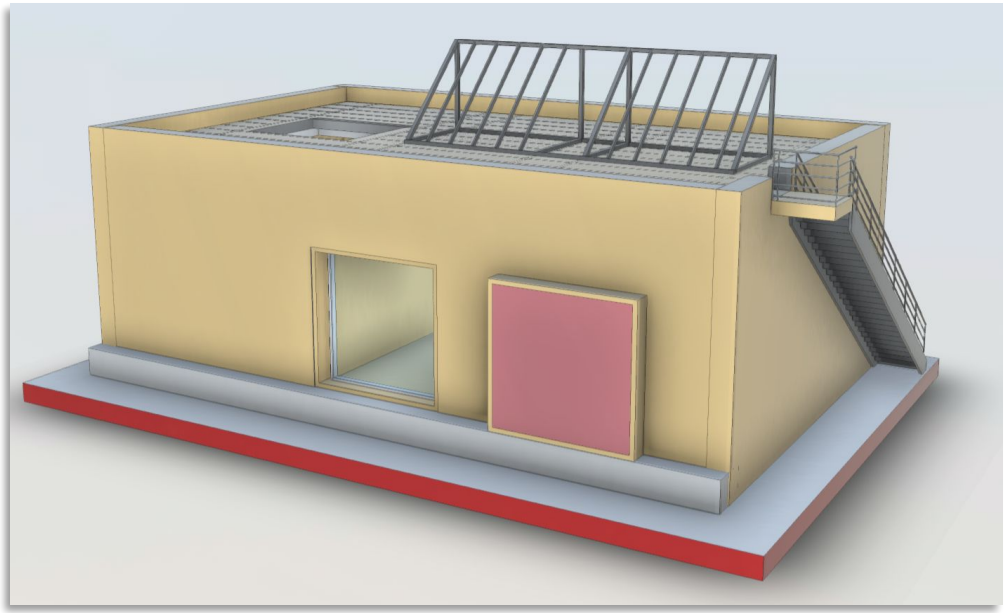
metabuilding labs

What is an O3BET-DT?

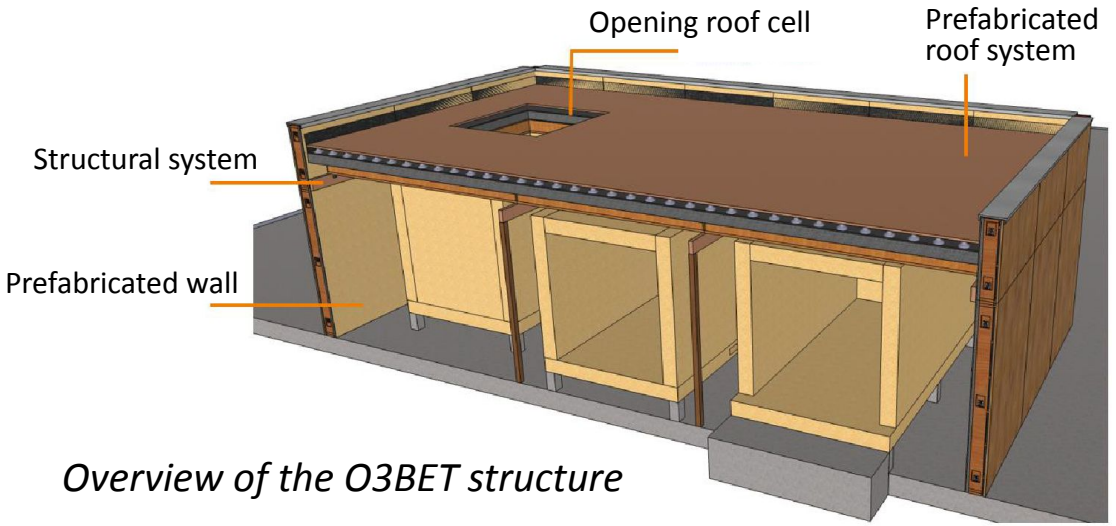
O3BET | Open Source
Open Data
Open Access | **Building Envelope Testbench**



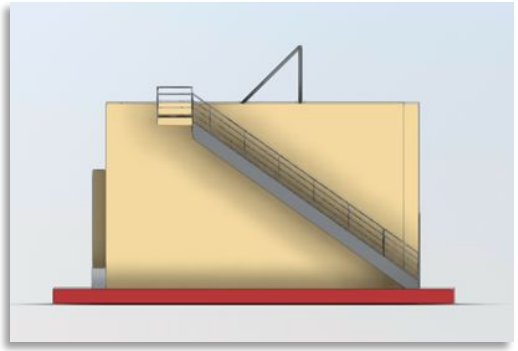
Design of the O3BET dismountable and movable modules

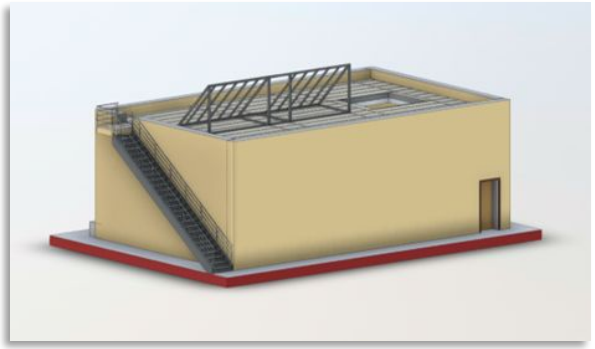


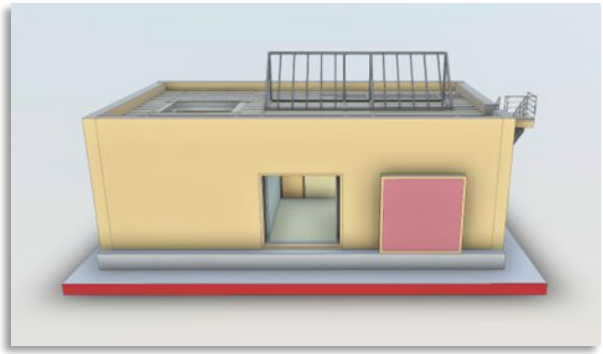
Alternative with two façade cells and one roof cell

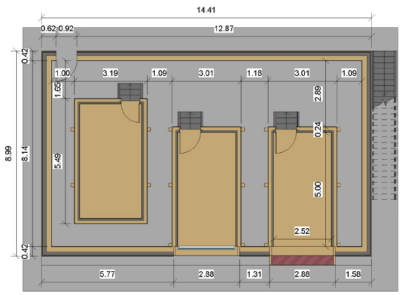


Overview of the O3BET structure







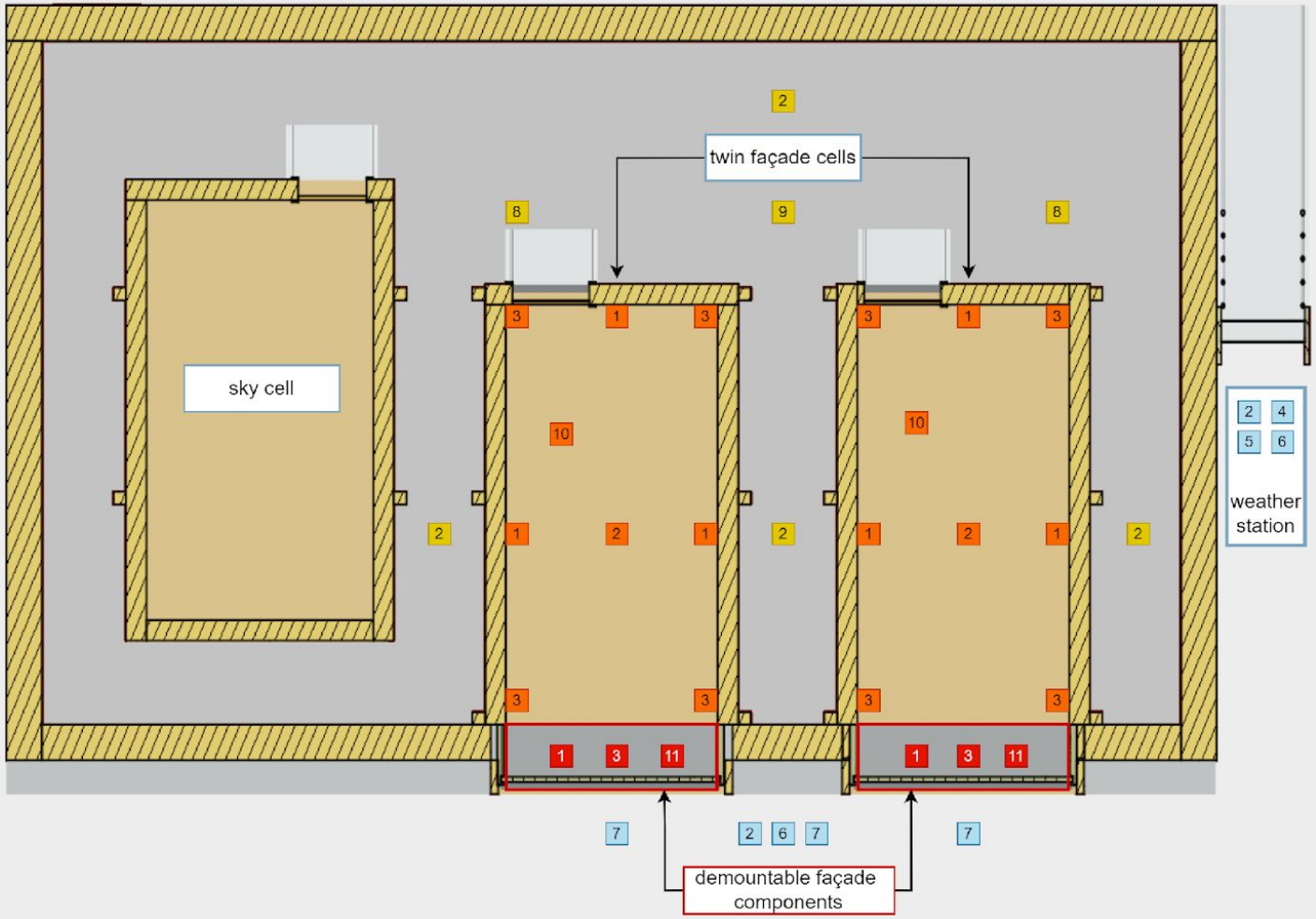


Cartif’s O3BET in Valladolid, Spain – October 2023

O3BET network in:

- France
- Spain
- Italy
- Sweden
- Poland
- Hungary
- Ireland

What does an O3BET look like on the inside?



SCOPES

- Facade element
- Internal (cell)
- Internal (guard zone)
- External

MEASUREMENTS & DEVICES

1. Temperature (suface)
2. Temperature (air)
3. Heat flux (tiles)
4. Humidity
5. Rainfall
6. Wind speed & direction
7. Pyranometer (+diffusometer)
8. Power meter
9. Tightness test equipment (blower door)
10. Actuator for Heater & blower
11. Fluxometer

(Boje et al., 2023)

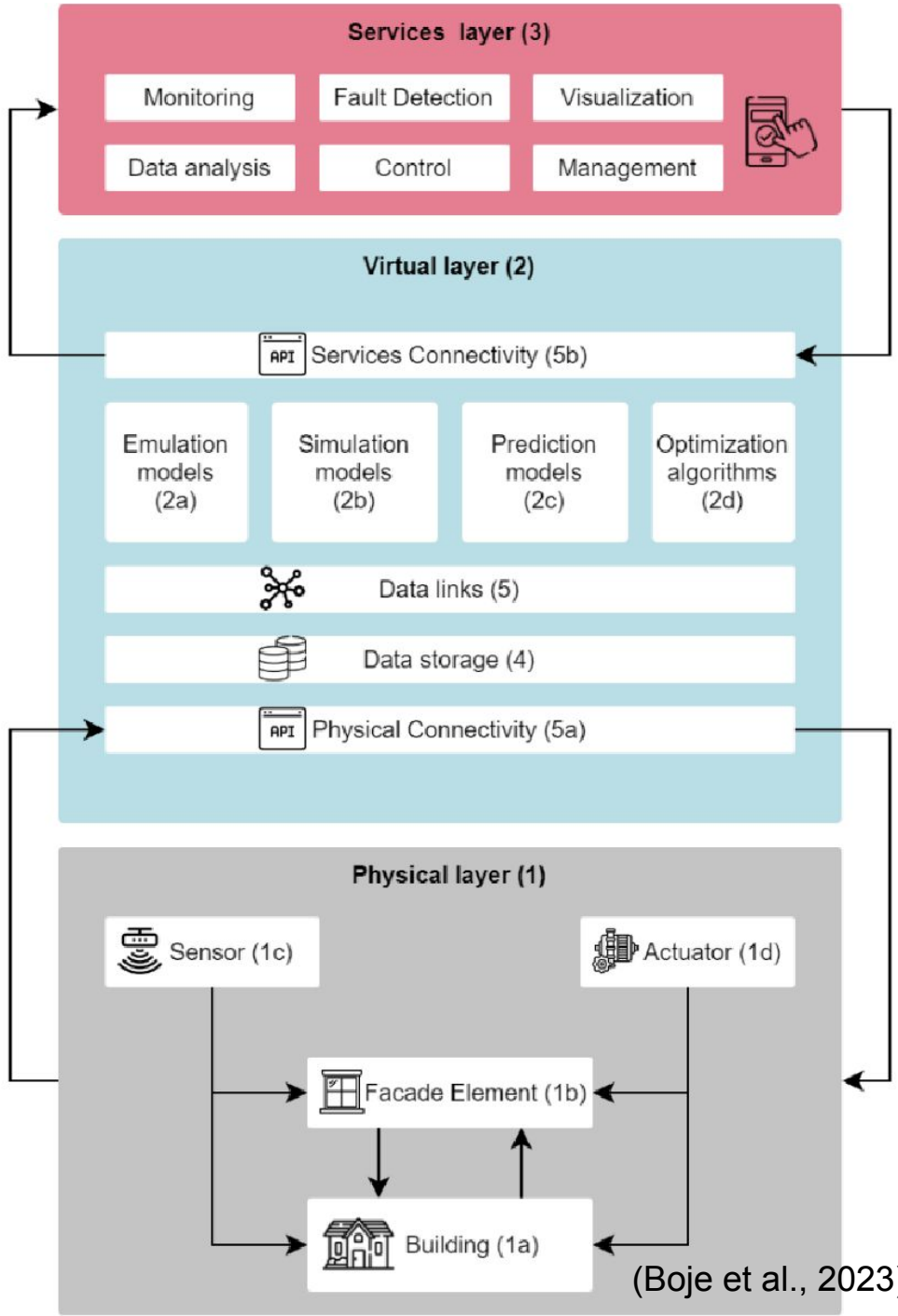
Why do we need a digital twin paradigm?

Digitalise and streamline the modular testing process.

Monitor the testing environment in different contexts.

Simulate different scenarios for novel technologies.

Explore design options, models and different applications.



(Boje et al., 2023)

What are the constraints of the O3BET testing process?

Procedural – things which are part of the process: the testing campaign, the different actors and users of the digital twin, etc.

Spatial – things which represent the facility spatially, delimitating the motoring, testing and modelling boundaries.

Equipment and sensing – facility sensors and actuators, their locations, properties and related components.

Measurements – sensor observations, units, properties etc.

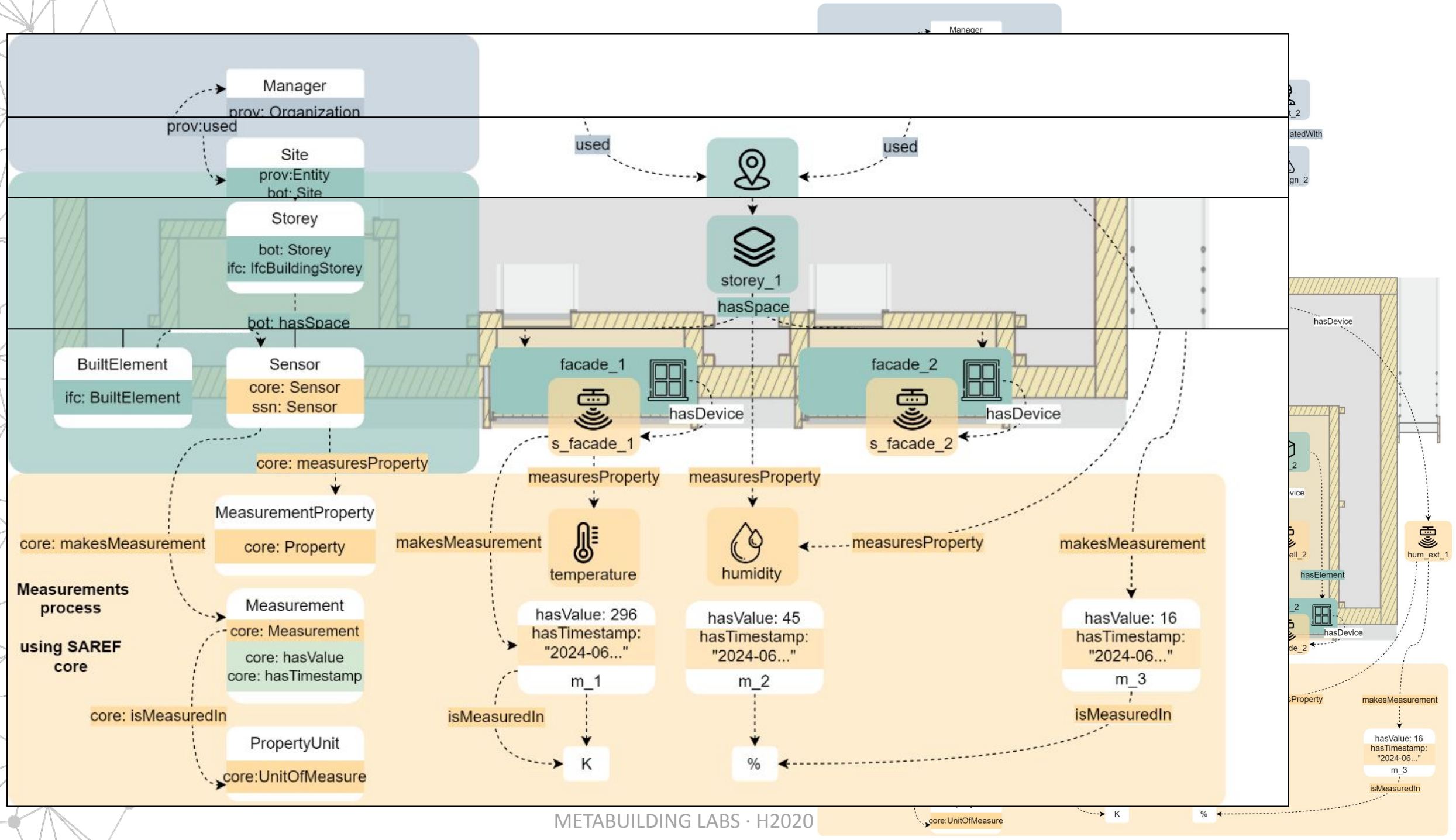
Virtual system boundaries – modularity of testing, the connections between the different contexts and digital twin instances (e.g. façade DT, cell DT, facility DT contexts).

What ontologies can define the O3BET-DT?

Table 1

List of selected ontologies for the O3BET-DT and their requirements coverage

Prefix	Namespace	Coverage
bot	https://w3c-lbd-cg.github.io/bot/	Spatial, Element
core	https://saref.etsi.org/core/	Sensing, Equipment, Measurements
ifc	http://standards.buildingsmart.org/IFC/DEV/IFC4_3/OWL#	Element, Components, Properties,
prov	https://www.w3.org/TR/prov-o/	Process, Actors
noria	https://w3id.org/noria/ontology/	Diagnosis, Fault Detection
props	http://www.w3id.org/opm#	Properties


Manager
prov: Organization
prov:used
Site
prov:Entity
bot: Site
used
used
Storey
bot: Storey
ifc: IfcBuildingStorey
storey_1
hasSpace
bot: hasSpace
BuiltElement
ifc: BuiltElement
Sensor
core: Sensor
ssn: Sensor
facade_1
facade_2
hasDevice
hasDevice
s_facade_1
s_facade_2
core: measuresProperty
measuresProperty
measuresProperty
MeasurementProperty
core: Property
core: makesMeasurement
makesMeasurement
temperature
humidity
measuresProperty
makesMeasurement
Measurements process
using SAREF core
Measurement
core: Measurement
core: hasValue
core: hasTimestamp
hasValue: 296
hasTimestamp: "2024-06..."
m_1
hasValue: 45
hasTimestamp: "2024-06..."
m_2
hasValue: 16
hasTimestamp: "2024-06..."
m_3
core: isMeasuredIn
isMeasuredIn
isMeasuredIn
PropertyUnit
core:UnitOfMeasure
K
%
hasDevice
hasElement
hasDevice
hum_ext_1
makesMeasurement
hasValue: 16
hasTimestamp: "2024-06..."
m_3
isMeasuredIn
core:UnitOfMeasure
K
%

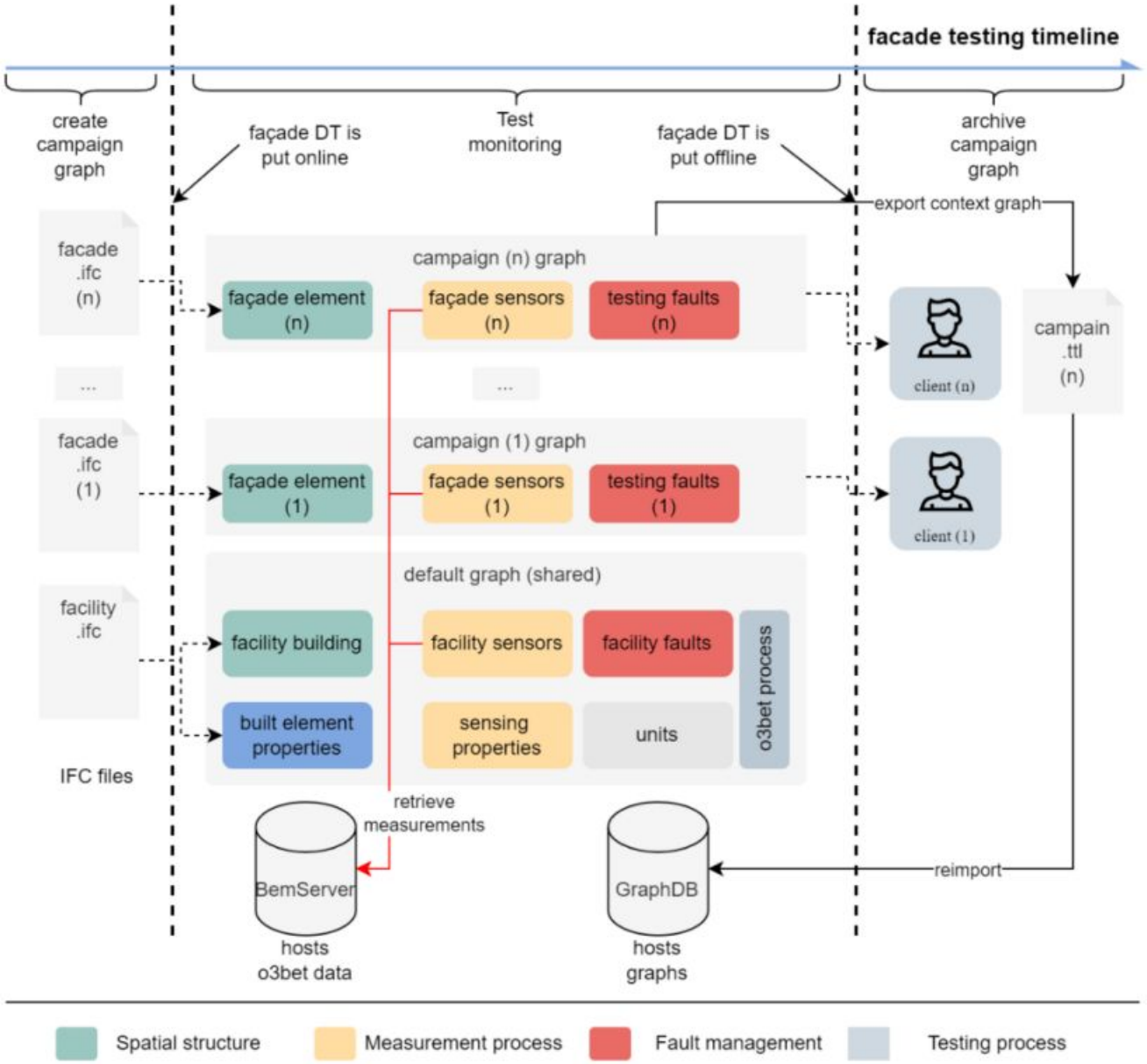
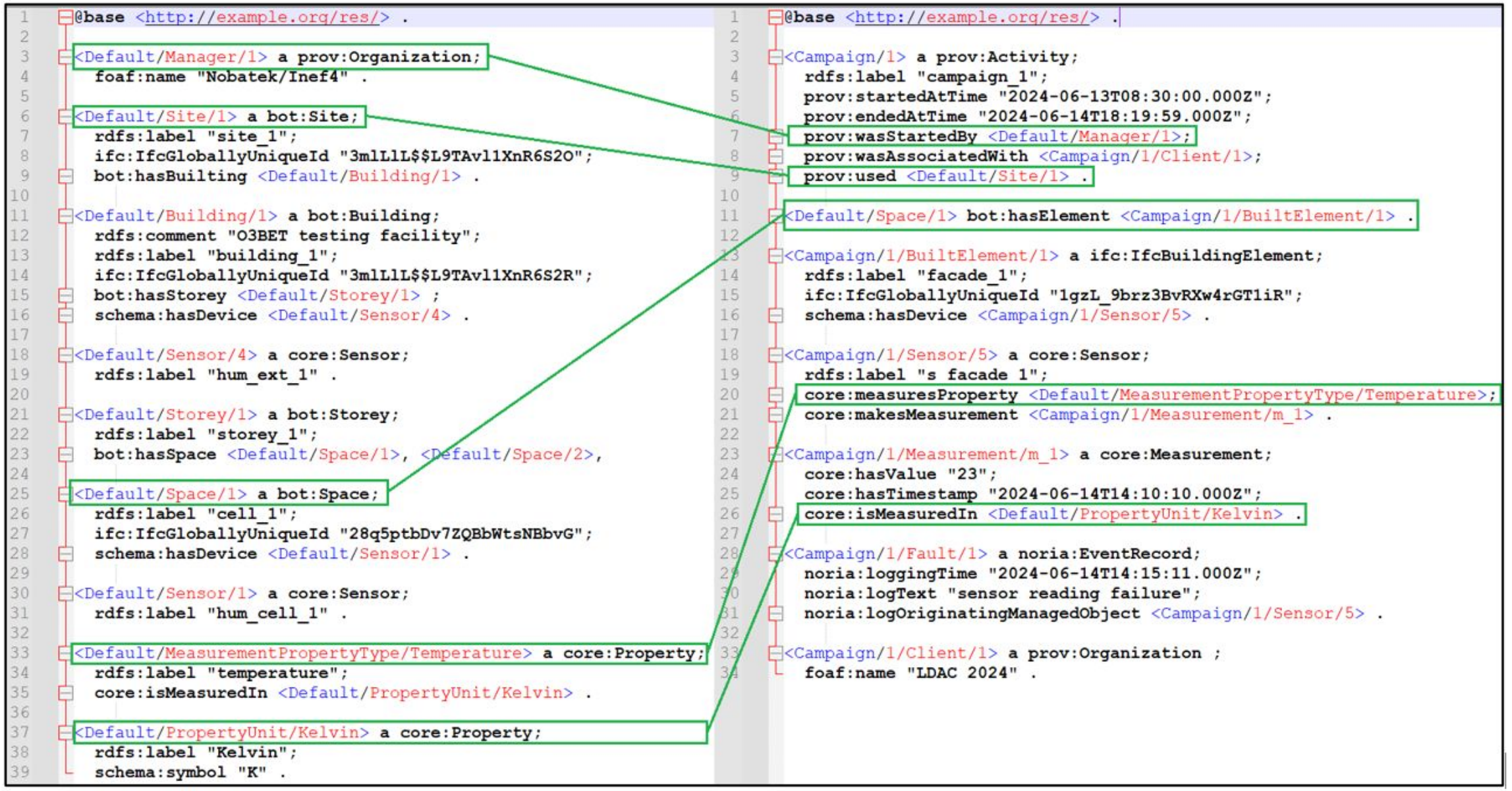


Figure 2: Data flows within the test environment, with federation, import and export per testing campaign.



```
@base <http://example.org/res/> .

<Default/Manager/1> a prov:Organization;
  foaf:name "Nobatek/Inef4" .

<Default/Site/1> a bot:Site;
  rdfs:label "site_1";
  ifc:IfcGloballyUniqueId "3mlLlL$$L9TAvl1XnR6S2O";
  bot:hasBuilting <Default/Building/1> .

<Default/Building/1> a bot:Building;
  rdfs:comment "O3BET testing facility";
  rdfs:label "building_1";
  ifc:IfcGloballyUniqueId "3mlLlL$$L9TAvl1XnR6S2R";
  bot:hasStorey <Default/Storey/1> ;
  schema:hasDevice <Default/Sensor/4> .

<Default/Sensor/4> a core:Sensor;
  rdfs:label "hum_ext_1" .

<Default/Storey/1> a bot:Storey;
  rdfs:label "storey_1";
  bot:hasSpace <Default/Space/1>, <Default/Space/2>,

<Default/Space/1> a bot:Space;
  rdfs:label "cell_1";
  ifc:IfcGloballyUniqueId "28q5ptbDv7ZQBbWtsNBbvG";
  schema:hasDevice <Default/Sensor/1> .

<Default/Sensor/1> a core:Sensor;
  rdfs:label "hum_cell_1" .

<Default/MeasurementPropertyType/Temperature> a core:Property;
  rdfs:label "temperature";
  core:isMeasuredIn <Default/PropertyUnit/Kelvin> .

<Default/PropertyUnit/Kelvin> a core:Property;
  rdfs:label "Kelvin";
  schema:symbol "K" .
```

```
@base <http://example.org/res/> .

<Campaign/1> a prov:Activity;
  rdfs:label "campaign_1";
  prov:startedAtTime "2024-06-13T08:30:00.000Z";
  prov:endedAtTime "2024-06-14T18:19:59.000Z";
  prov:wasStartedBy <Default/Manager/1>;
  prov:wasAssociatedWith <Campaign/1/Client/1>;
  prov:used <Default/Site/1> .

<Default/Space/1> bot:hasElement <Campaign/1/BuiltElement/1> .

<Campaign/1/BuiltElement/1> a ifc:IfcBuildingElement;
  rdfs:label "facade_1";
  ifc:IfcGloballyUniqueId "1gzL_9brz3BvRXw4rGT1iR";
  schema:hasDevice <Campaign/1/Sensor/5> .

<Campaign/1/Sensor/5> a core:Sensor;
  rdfs:label "s facade 1";
  core:measuresProperty <Default/MeasurementPropertyType/Temperature>;
  core:makesMeasurement <Campaign/1/Measurement/m_1> .

<Campaign/1/Measurement/m_1> a core:Measurement;
  core:hasValue "23";
  core:hasTimestamp "2024-06-14T14:10:10.000Z";
  core:isMeasuredIn <Default/PropertyUnit/Kelvin> .

<Campaign/1/Fault/1> a noria:EventRecord;
  noria:loggingTime "2024-06-14T14:15:11.000Z";
  noria:logText "sensor reading failure";
  noria:logOriginatingManagedObject <Campaign/1/Sensor/5> .

<Campaign/1/Client/1> a prov:Organization ;
  foaf:name "LDAC 2024" .
```

Figure 3: Sample TTL statements of the default graph (left) which is shared, and linked statements in the testing campaign graph (right) outlined in green.

a)

```
PREFIX bot: <https://w3id.org/bot#>
PREFIX core: <https://saref.etsi.org/core/>
PREFIX prov: <http://www.w3.org/ns/prov#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
select ?campaign ?site ?building
# select everything in the triple store
where {
    ?campaign rdf:type prov:Activity . # from campaign graph
    ?campaign prov:used ?site . # from campaign graph
    ?site bot:hasBuilding ?building . # from default graph
}
```

	campaign	site	
1	http://example.org/res/Campaign/1/	http://example.org/res/Default/Site/1	http://example.org/res/Default/Building/1
2	http://example.org/res/Campaign/2/	http://example.org/res/Default/Site/1	http://example.org/res/Default/Building/1

b)

```
PREFIX bot: <https://w3id.org/bot#>
PREFIX core: <https://saref.etsi.org/core/>
PREFIX prov: <http://www.w3.org/ns/prov#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
select ?campaign ?site ?building
from default # default(shared) graph
from <http://example.org/res/Campaign/1/> # the context of only 1 campaign graph
where {
    ?campaign rdf:type prov:Activity . # from campaign graph
    ?campaign prov:used ?site . # from campaign graph
    ?site bot:hasBuilding ?building . # from default graph
}
```

	campaign	site	
1	http://example.org/res/Campaign/1/	http://example.org/res/Default/Site/1	http://example.org/res/Default/Building/1

Figure 4: Sample SPARQL on retrieving campaigns (a) unspecified, (b) named graphs.

```graphql
query SampleQuery($graph: [String!]) {
  sensor(from: $graph) {
    rdfs_label
    makesMeasurement {
      isMeasuredIn {
        id
      }
      hasValue
      hasTimeStamp
    }
  }
}
```

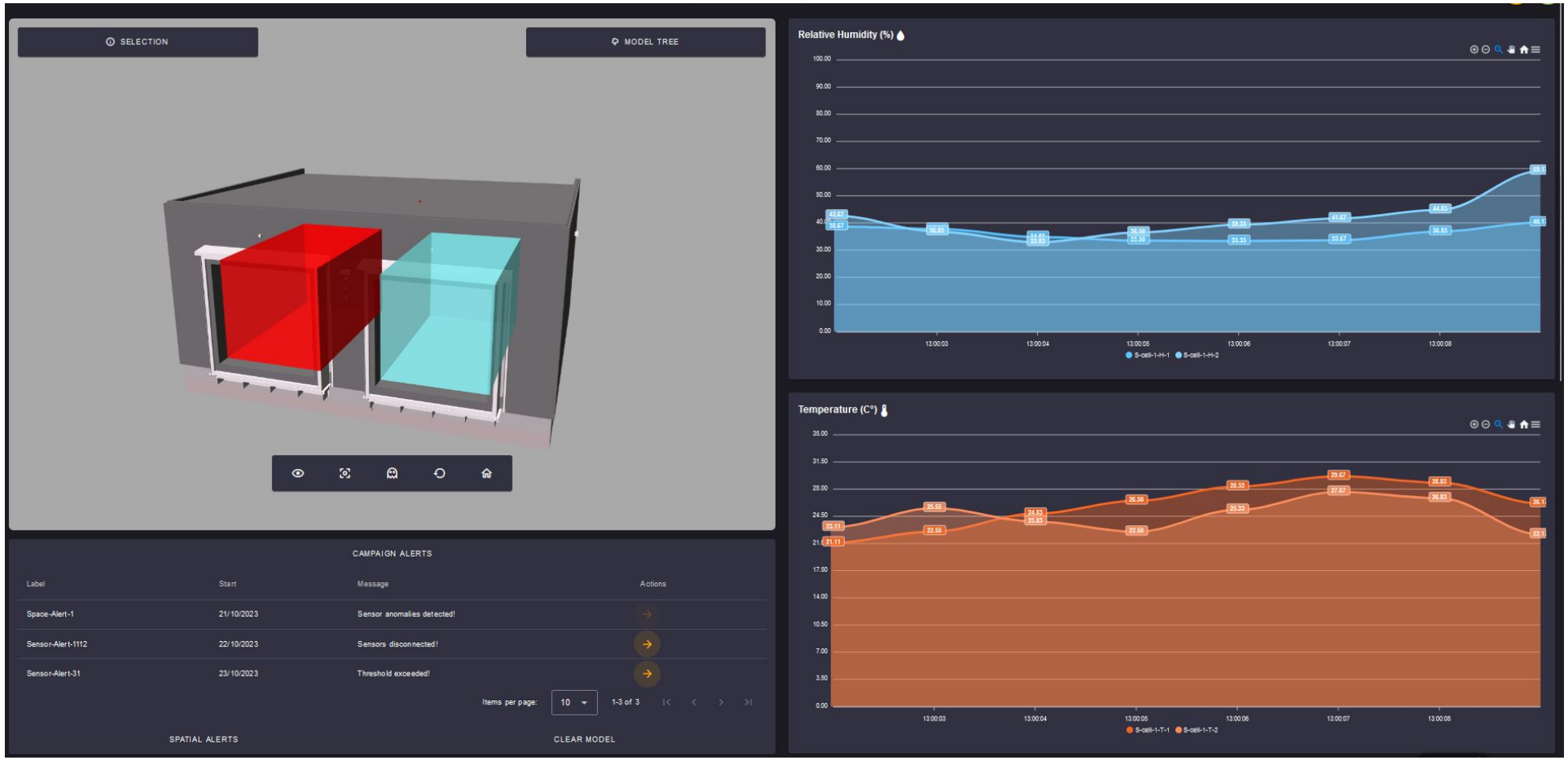
QUERY VARIABLES

```json
{
  "graph": "http://example.org/res/Campaign/2/"
}
```

```json
{
  "data": {
    "sensor": [
      {
        "rdfs_label": "s_facade_2",
        "makesMeasurement": [
          {
            "isMeasuredIn": {
              "id": "http://example.org/res/Default/PropertyUnit/Kelvin"
            },
            "hasValue": "26",
            "hasTimeStamp": "2024-06-14T14:10:10Z"
          }
        ]
      }
    ]
  }
}
```

Figure 5: GraphQL on finding a sensor and its measurements within the context scope of a single campaign.

Prototype – User Interface development ongoing



metabuilding labs

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GraphDB

- Import
- Explore
  - Graphs overview
  - Class hierarchy
  - Class relationships
  - Visual graph
  - Similarity
- SPARQL
- Monitor
- Setup
- Lab
- Help

Graphs overview

Search Graphs

Showing 1 - 5 of 5 results Graphs per page: All

Clear repository Export repository

Graphs
The default graph
http://www.list.lu/buildsemantix/campaign/buildingModule/
http://www.list.lu/buildsemantix/campaign/iotModule/
http://example.org/res/Campaign/1/
http://example.org/res/Campaign/2/

O3BET-DT – has very specific needs for context creation which lacks ontologies for testing, alerts and facility management. This requires a highly customisable use case.

Alignment and links Ontology modelling limitations:

- difficult mapping,
- many choices of ontologies
- many use cases that we need to explore for Digital Twin cases#
- New concepts are created ad-hoc, when needed, to connect mapping ontologies

GraphQL – very flexible and transparent for the front-end application, but certain functionalities are not usable, such as querying more than one graph in one query.

Future work – inclusion of energy modelling and LCA modelling

References

Boje, C., Mack, N., Kubicki, S., López Vidal, A., Casado Sánchez, C., Dugué, A., & Brassier, P. (2023, July 10). *Digital Twin systems for building façade elements testing*. https://doi.org/10.35490/EC3.2023.240

- Hot!
- https://linkedbuildingdata.net/ldac2024/files/papers/LDAC2024_Camera_13.pdf

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SUSTAINABLE PLACES 2024

BIM2TWIN

Semantics & Construction with Building Digital Twins

Jonas Schlenger (PhD Candidate)

TUM Chair of Computational Modeling and Simulation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 958398.

BIM TWIN

Project Info

- **Start:** Nov. 2020
- **End:** Apr. 2024

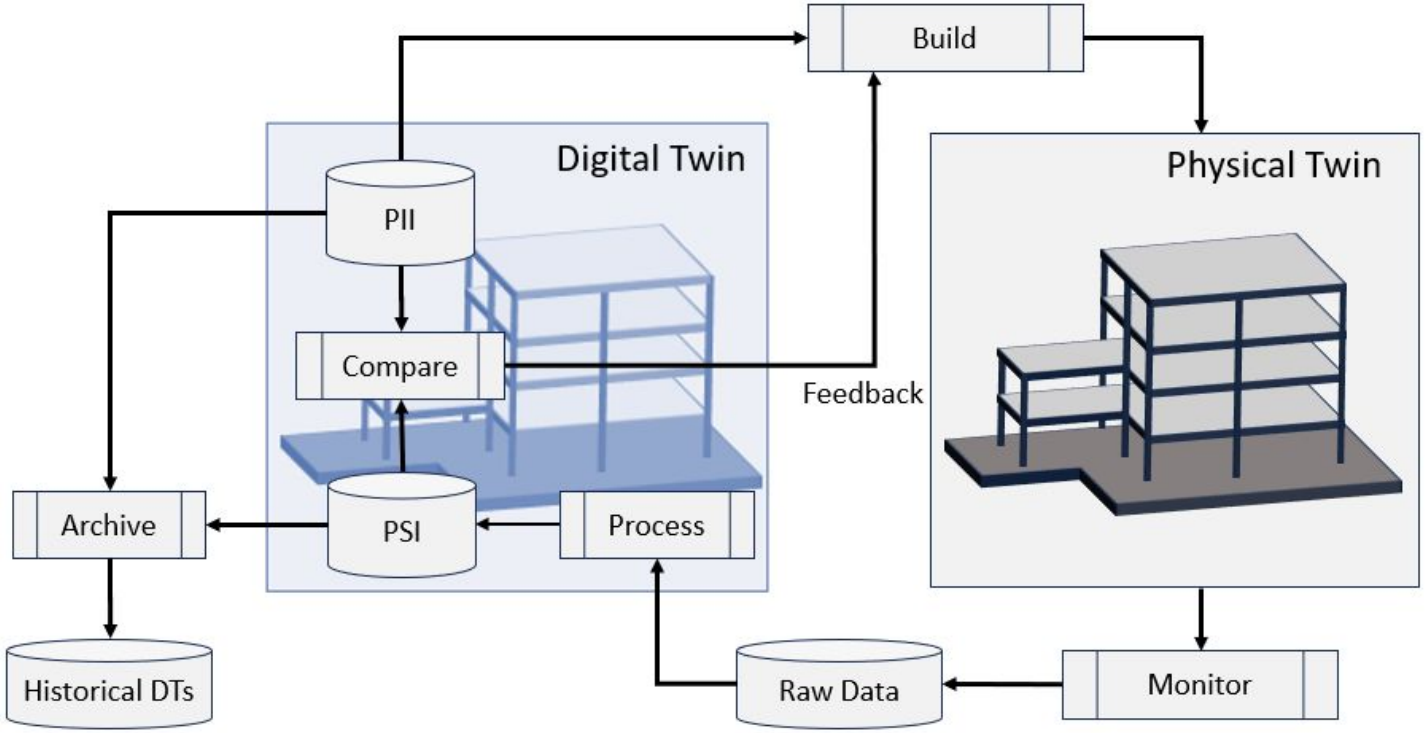
- **Partners:** 16
- **Budget:** 6M€

Project Vision

- Digital twin of the construction phase
- Lean construction inspired workflow
- Situational awareness to support construction managers

Workflow

- Real-time construction monitoring
- Comparison of Project Intent Information (PII) and Project Status Information (PSI)
- Regular feedback loops for continuous learning

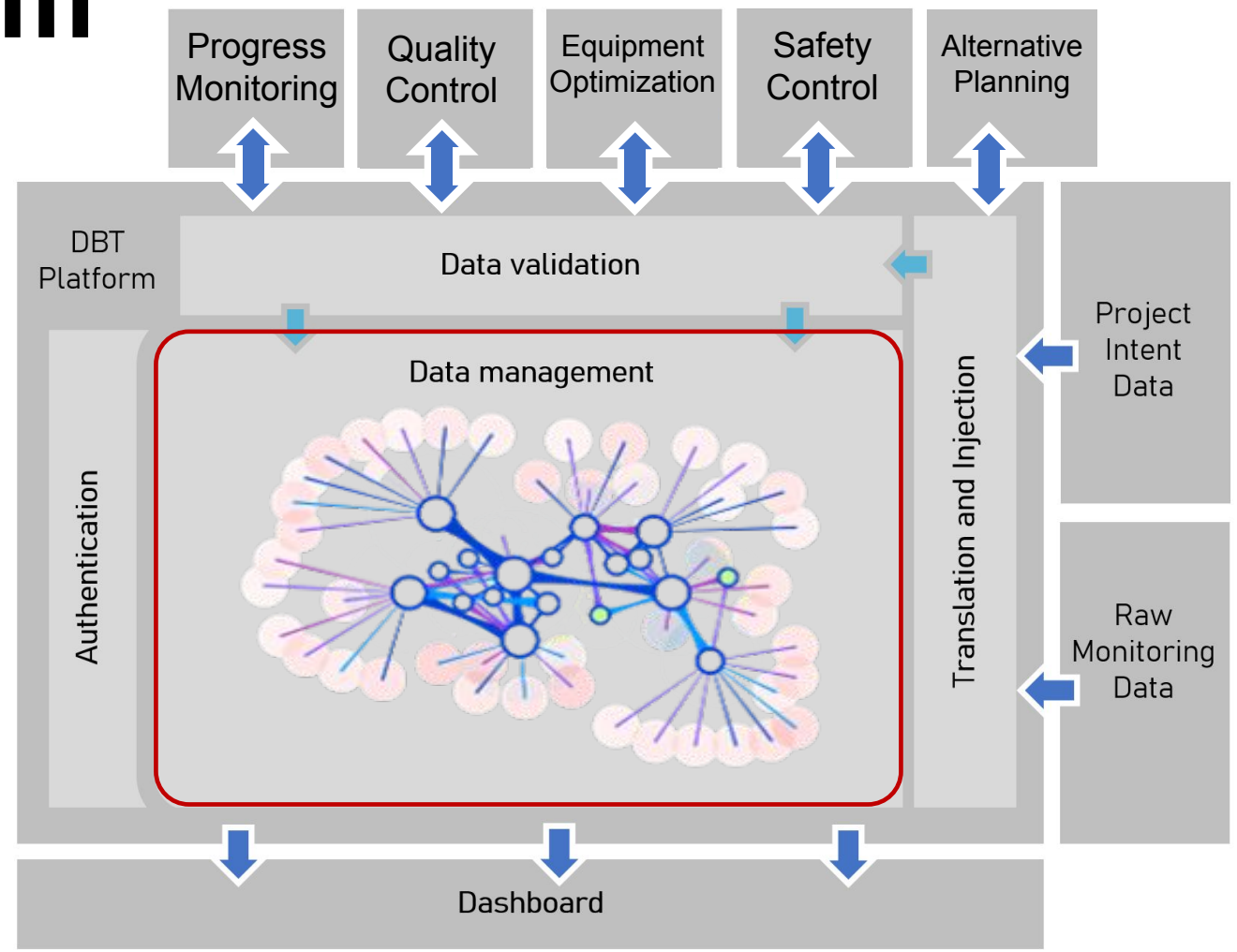


Digital Twin Platform

Central components:

- Data management
- Translation and injection
- Data validation
- Dashboard

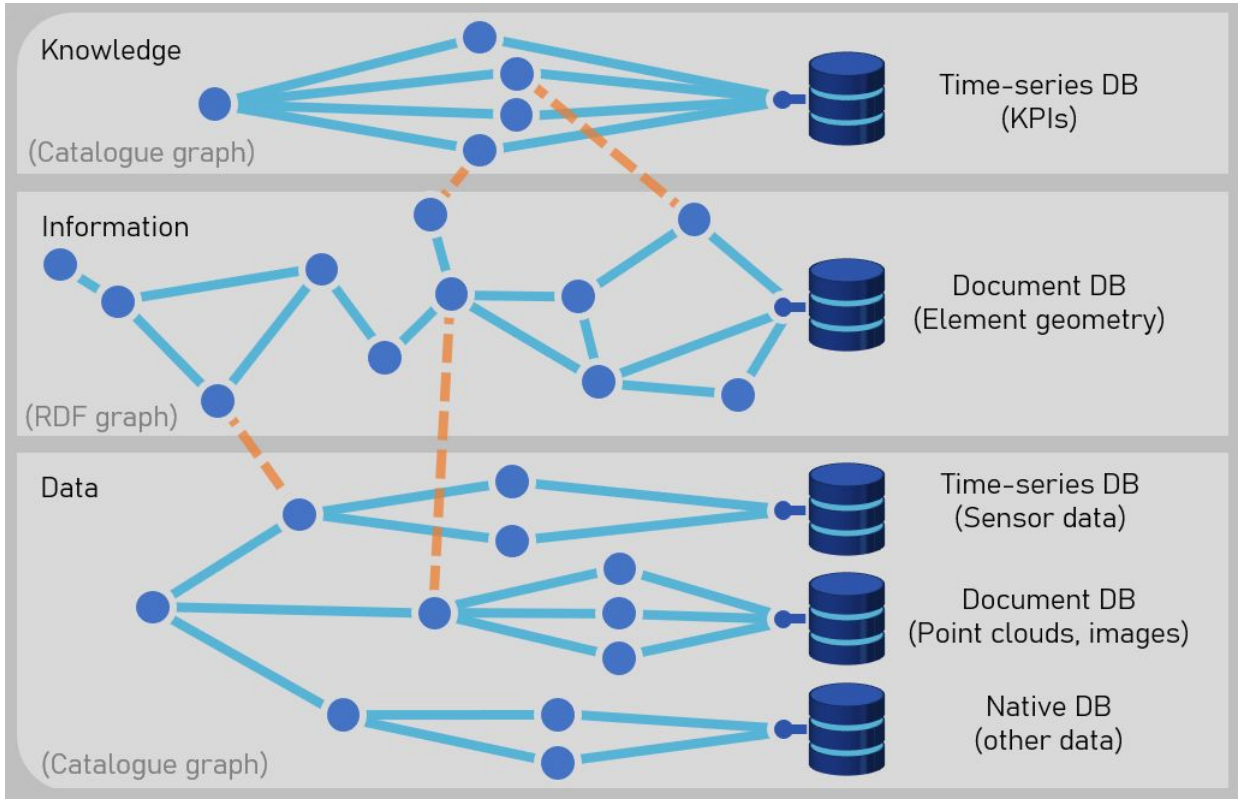
Data analysis performed by digital twin services



Data Management Module

Separation into **Data**, **Information**, and **Knowledge**

- RDF graph as overarching system
- Data and knowledge graph serve as catalogue system
- Supported by data-specific databases



Used Ontologies

Data:

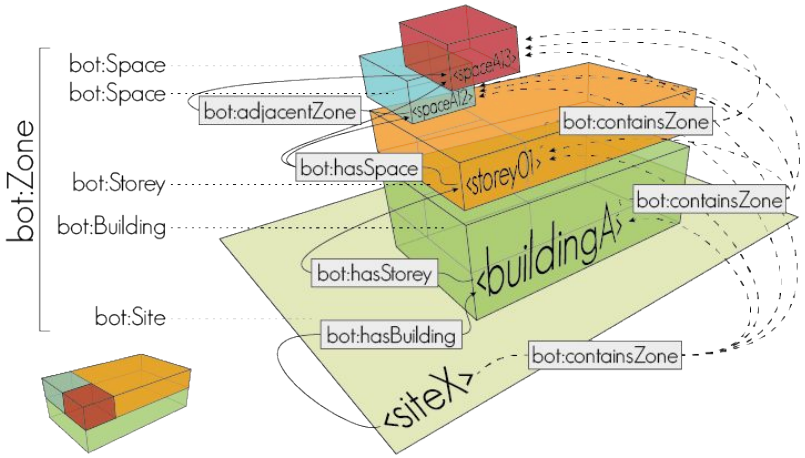
- SOSA/SSN
- DCAT

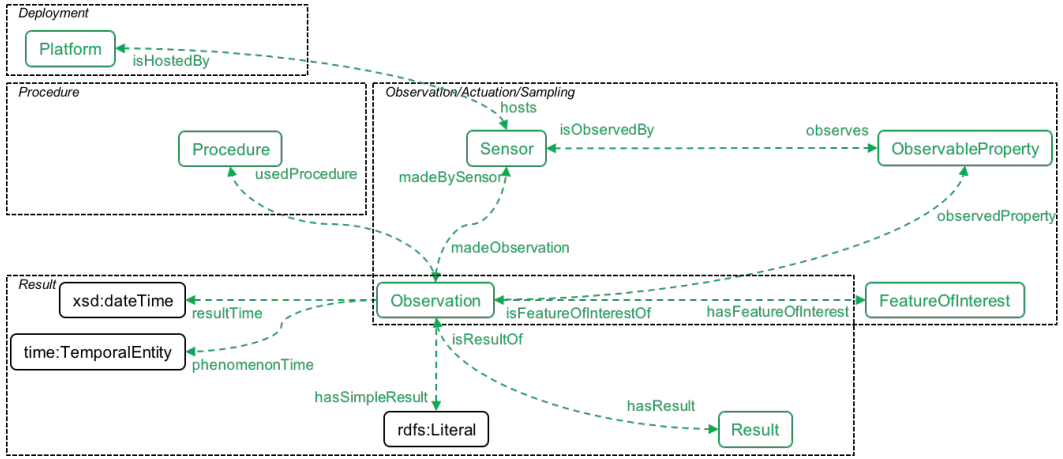
Knowledge:

- Saref4City
- Company-specific KPIs

Information:

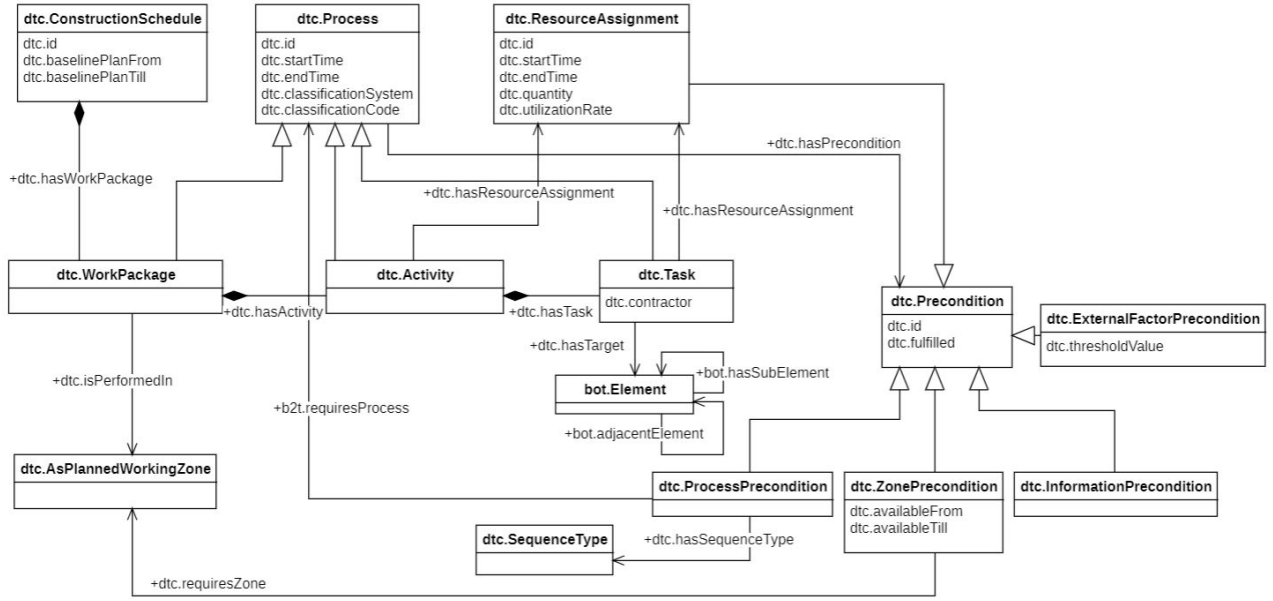
- BOT + BEO
- FOG
- WGS84
- DTC Ontology (new)





Digital Twin Construction Ontology

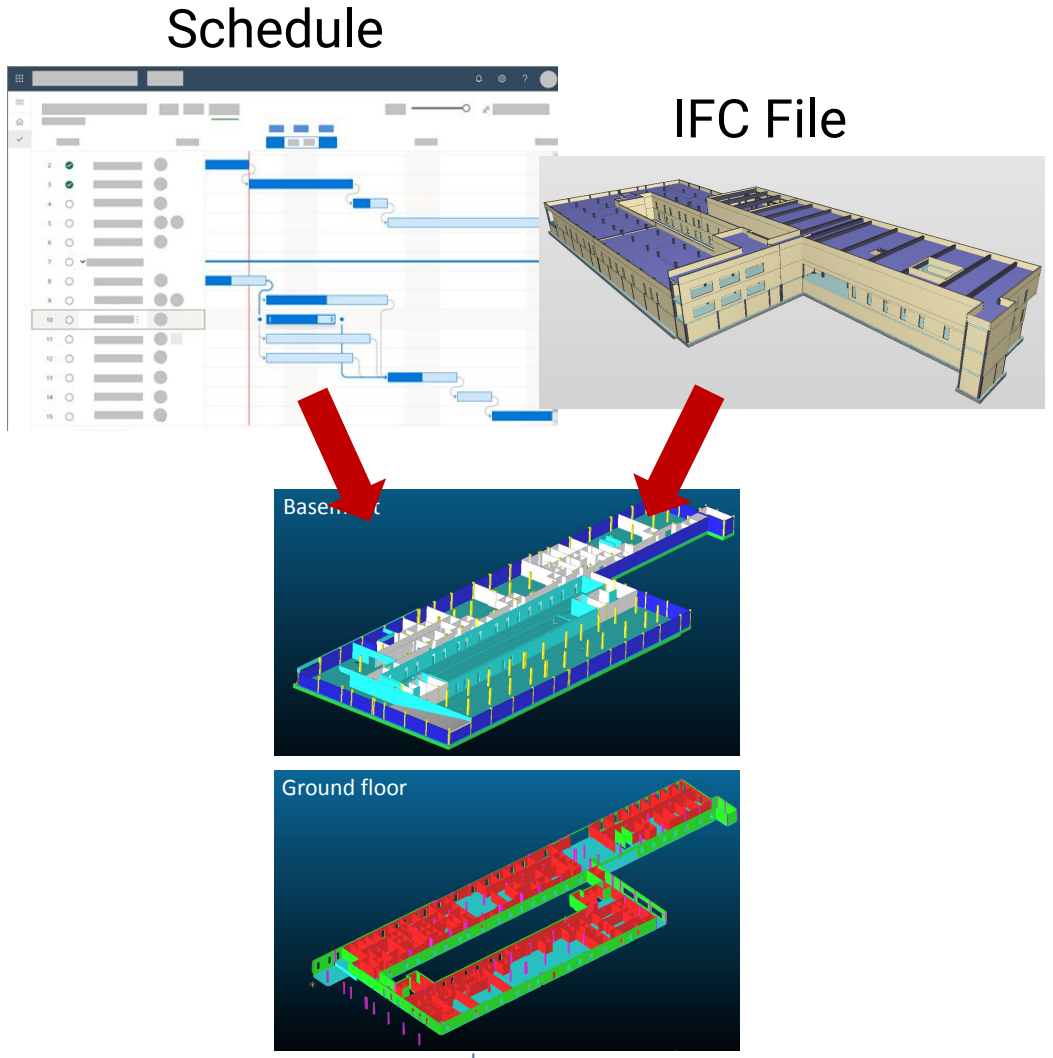
- Representation of key components of a digital twin of the construction phase
- Separation between project intent and status
- Process-oriented



Published online:
https://dtc-ontology.cms.ed.tum.de/ontology

Platform Setup

1. Pre-processing of IFC files
2. Convert IFC (IFC2LBD converter) + geometry converter
3. Convert schedule
4. Link schedule and IFC (semi-automated)

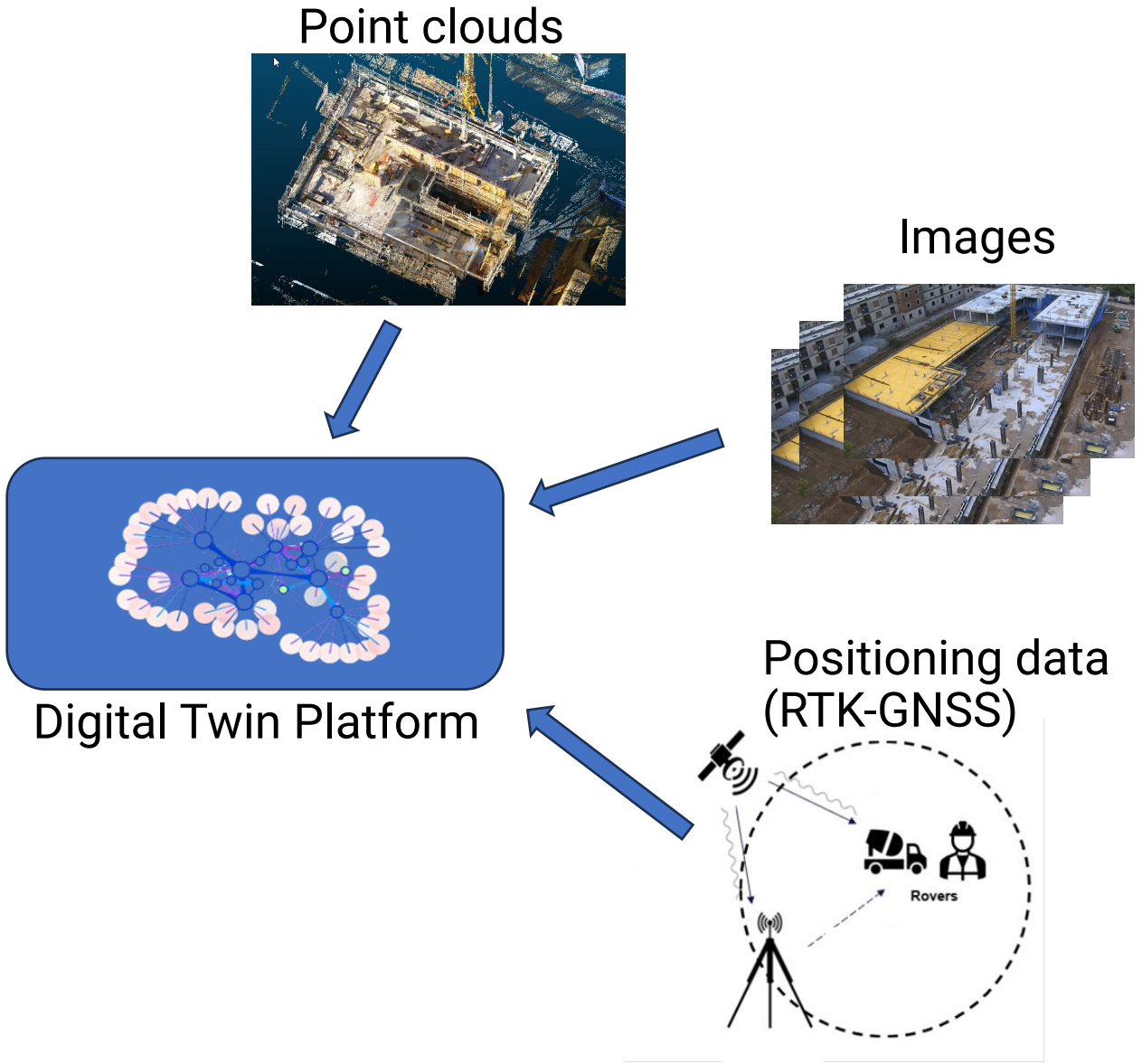


Pilot Sites

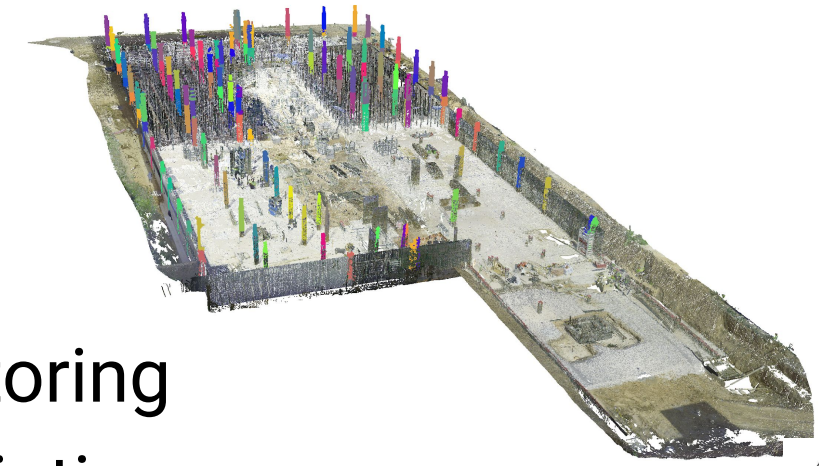
Several pilot sites in:

- Finland
- France
- Spain

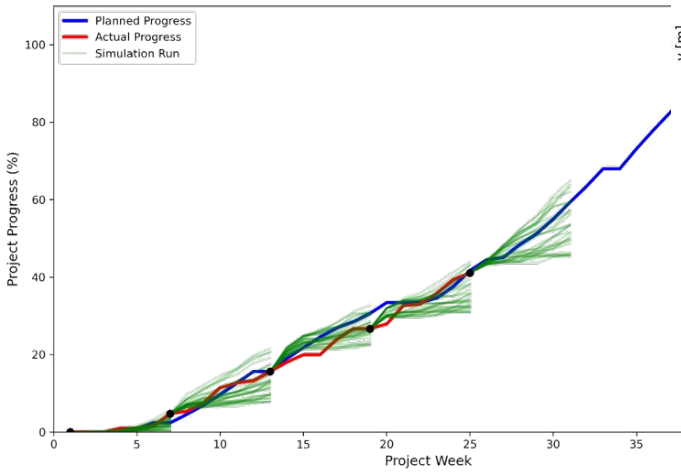
+ open-source datasets

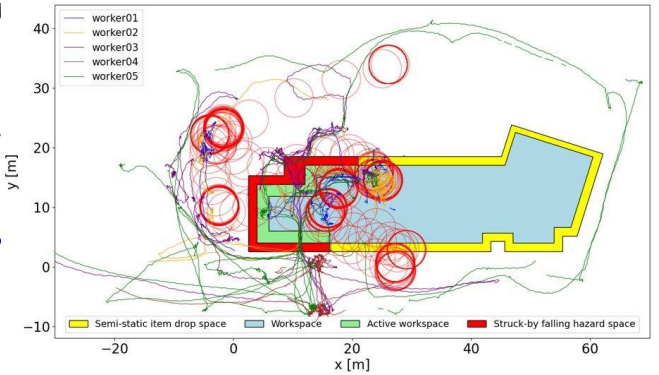


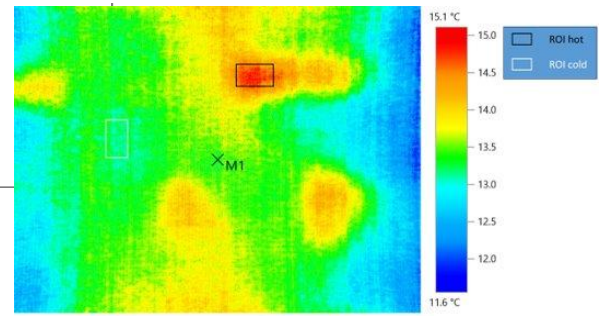
Use Cases



- PC-based progress monitoring
- Detection of element deviations
- Detection of surface defects
- Equipment optimization
- Proactive safety
- Alternative planning







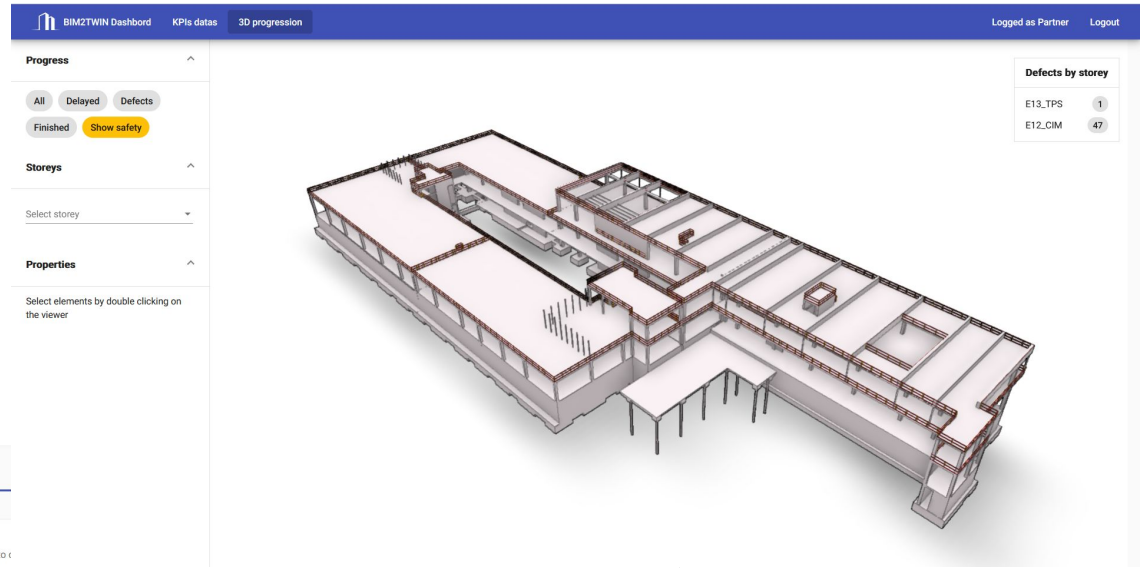
BIM2TWIN Dashboard

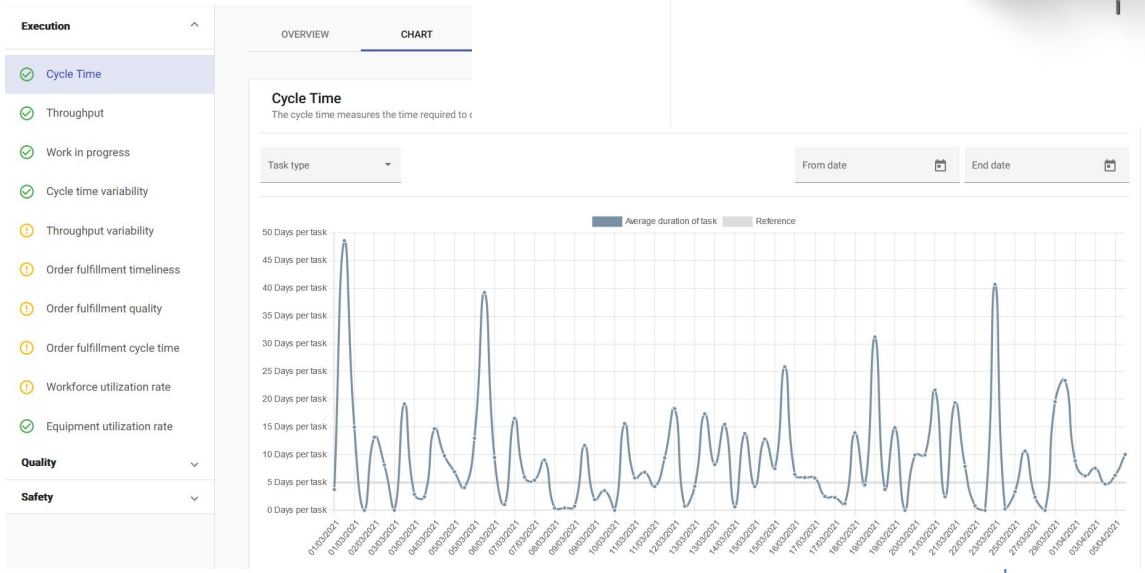
3D Viewer:

- Overall progress
- Defects
- Safety equipment

KPI Viewer:

- Execution excellency
- Quality
- Safety





Challenges

Construction companies:

- Large variety of planning methodologies (no standard for schedule exchange)
- Involvement of subcontractors
- Varying expertise and digital twin use cases

Flexibility as key requirement of Digital Twin Platform

SUSTAINABLE PLACES 2024

Thank you for your attention!

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TUM Chair of Computational Modeling and Simulation

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BIM TWIN