



Facilitating Digital Twins for the Built Environment with Linked Data

Jakob Beetz

La captation de cette conférence est disponible sur Culture Sciences de l'Ingénieur à partir du lien suivant : https://eduscol.education.fr/sti/si-ens-paris-saclay/ressources_pedagogiques/edubim-2021-facilitating-digital-twins-for-the-built-environment-with-linked-data



Facilitating Digital Twins for the Built Environment with Linked Data

eduBIM 2021, Paris, Dec. 1st

Jakob Beetz
RWTH Aachen University

RWTH, Department of Architecture, DC Team

RWTH

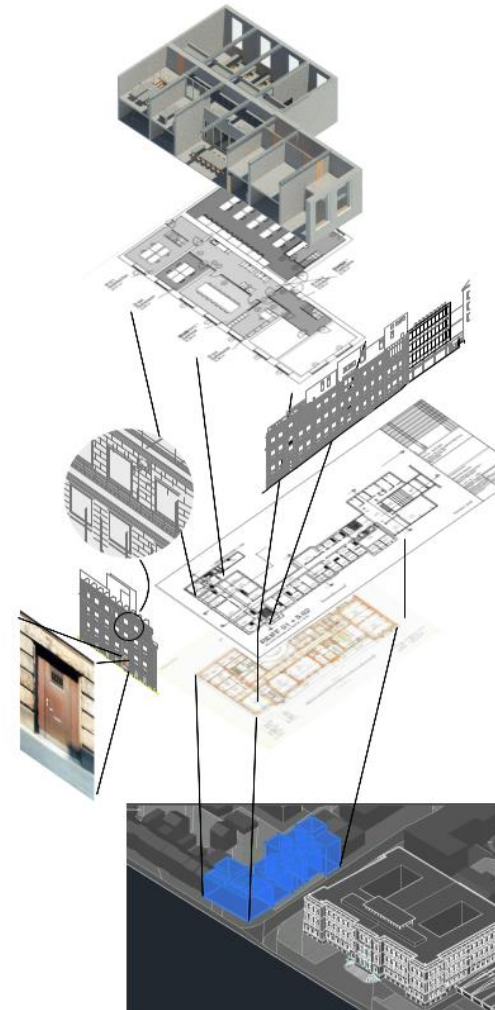
- Since 1870
- 47.173 Students, 10k staff, 550 profs.
- “excellent”

Dept. of Architecture

- 1800 students, 22 chairs
- ~ 280 students BA per year
- MSc tracks: Architecture, Urban Planning, Construction Robotics, Transforming City Regions

Design Computation

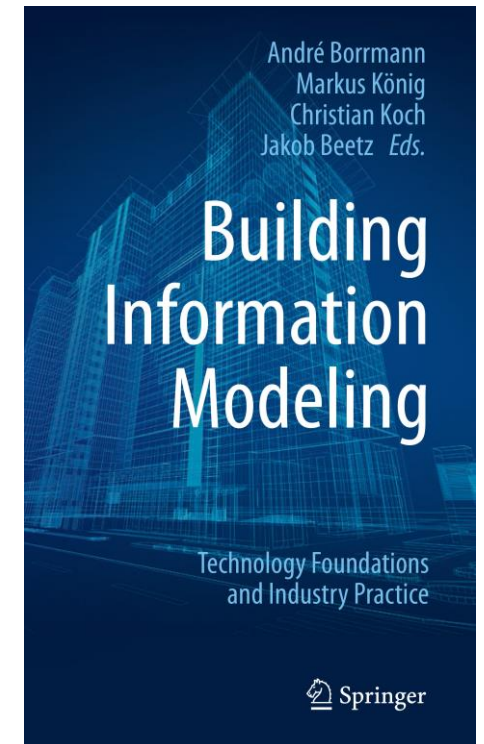
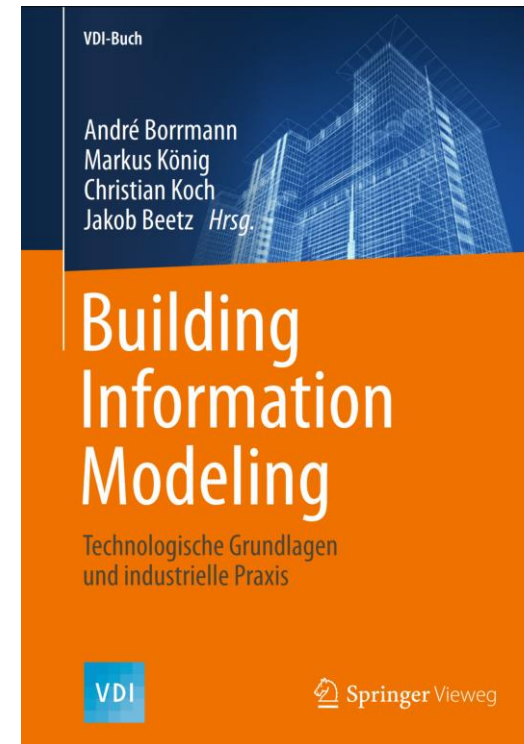
- 1,5 permanent lecturer & research staff
- 4 researchers funded by projects
- 3 PhD students via scholarships (DAAD, CRC)
- 2 industry lecturers with 3 ECTS
- 4 ~ 7 student assistants





Prof. Dr. Jakob Beetz
chair

- > 15 years BIM in research, development and standardization, e.g. bimserver.org, ifcOWL
- EU-projects Intelgrid; DURRARK (Long term preservation BIM), BIM4Ren (BIM for existing buildings)
- DIN, CEN, ISO, bSI Technical Board, Board buildingSMART DACH
- CIB W78 Co-Chair. Board EG-ICE, ECPPM,
- Co-editor and -autor BIM books



Overview

The Challenges

- The Built Environment
- The Construction Sector

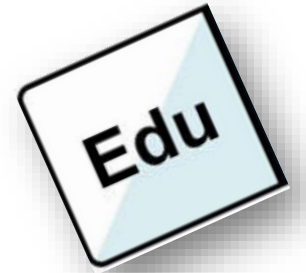
Digital Twin topics by example

- Data Acquisition / Reality Capturing
- Micro: Sensors
- Meso: Bridges
- Macro: System of Systems: Road Networks

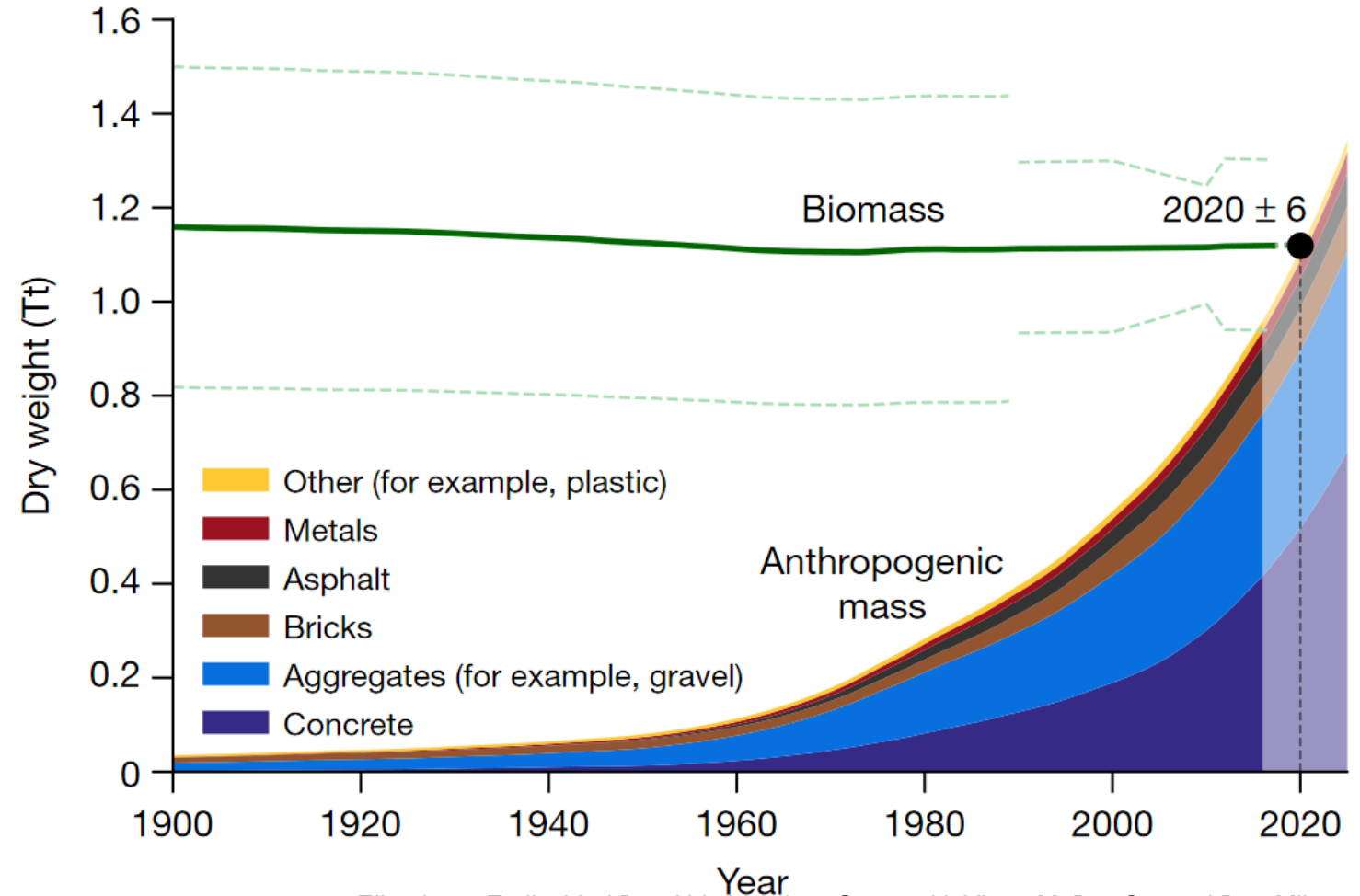
Academic Teaching

- Some tools
- IfcOpenShell-Jupyter-Notebooks

Some opinions & recommendations



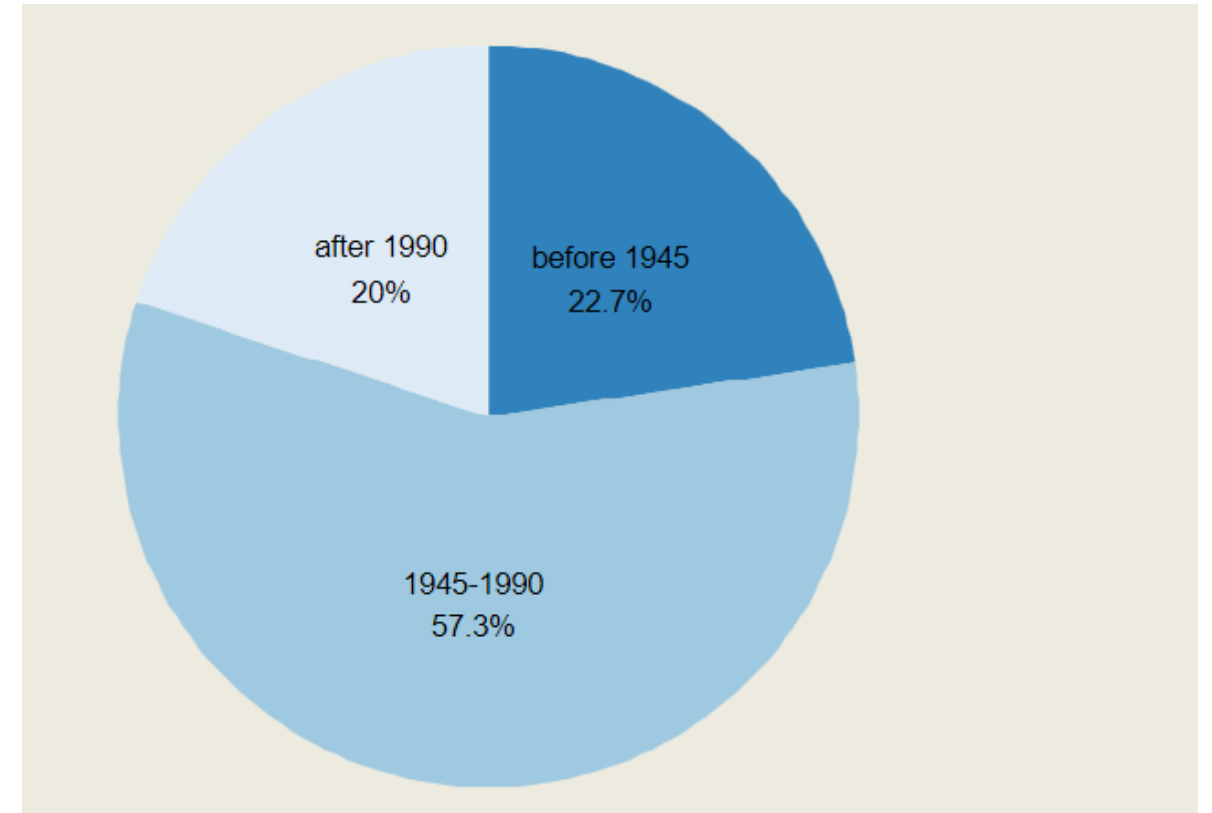
The Built Environment : Scale and impact



Elhacham, Emily, Liad Ben-Uri, Jonathan Grozovski, Yinon M. Bar-On, and Ron Milo. "Global Human-Made Mass Exceeds All Living Biomass." *Nature* 588, no. 7838 (December 2020): 442–44. <https://doi.org/10.1038/s41586-020-3010-5>.

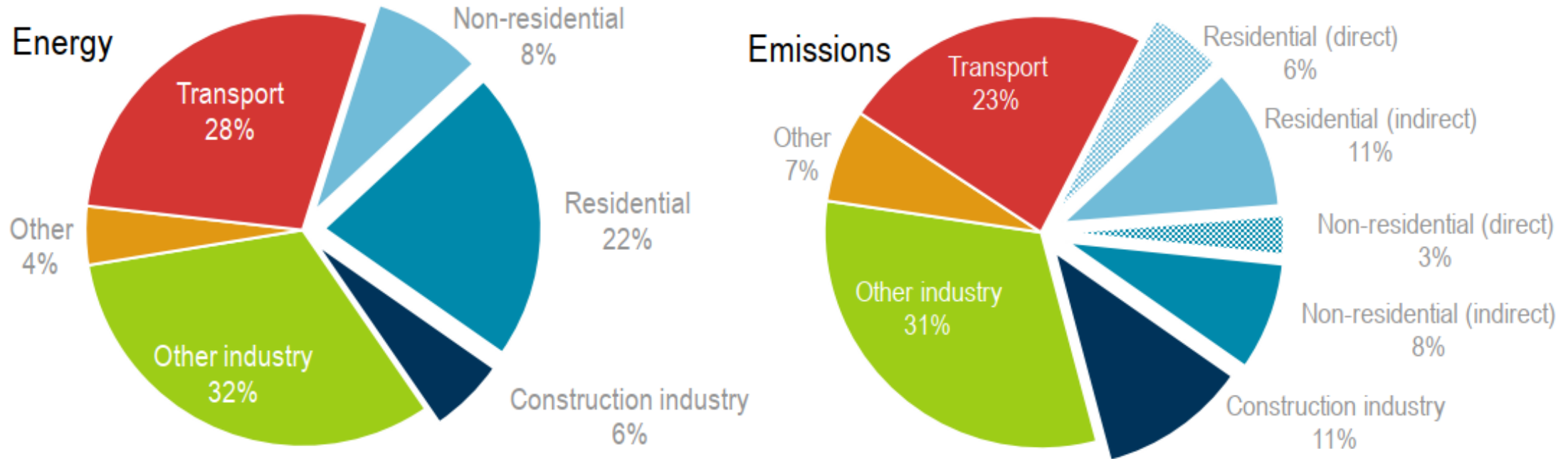
The Built Environment : State of the Products

- About 80% built before 1990



The Built Environment : Scale and impact

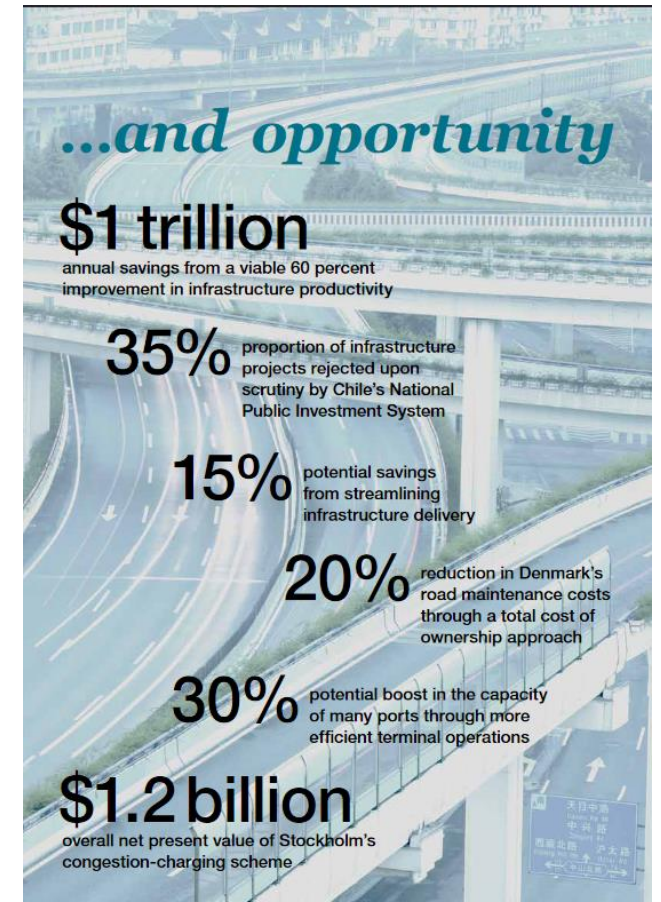
Figure 2 • Global share of buildings and construction final energy and emissions, 2018



IEA (2019). All rights reserved.

United Nations Environment Programme with International Energy Agency IEA. (2019). 2019 Global Status Report for Buildings and Construction. ISBN 978-92-807-3768-4

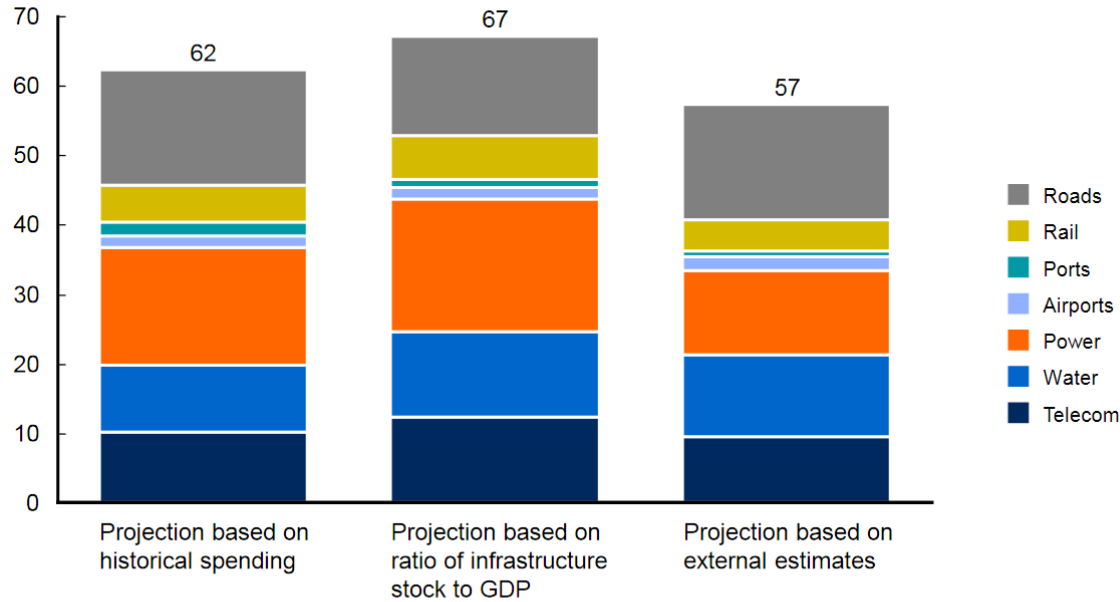
The Built Environment : Scale and impact



Dobbs, Richard, H Pohl, D Lin, J Mischke, N Garemo, J Hexter, S Matzinger, R Palter, and R Nanavatty. “Infrastructure Productivity: How to Save \$1 Trillion a Year. McKinsey Global Institute.” *McKinsey Co* January, 2013.

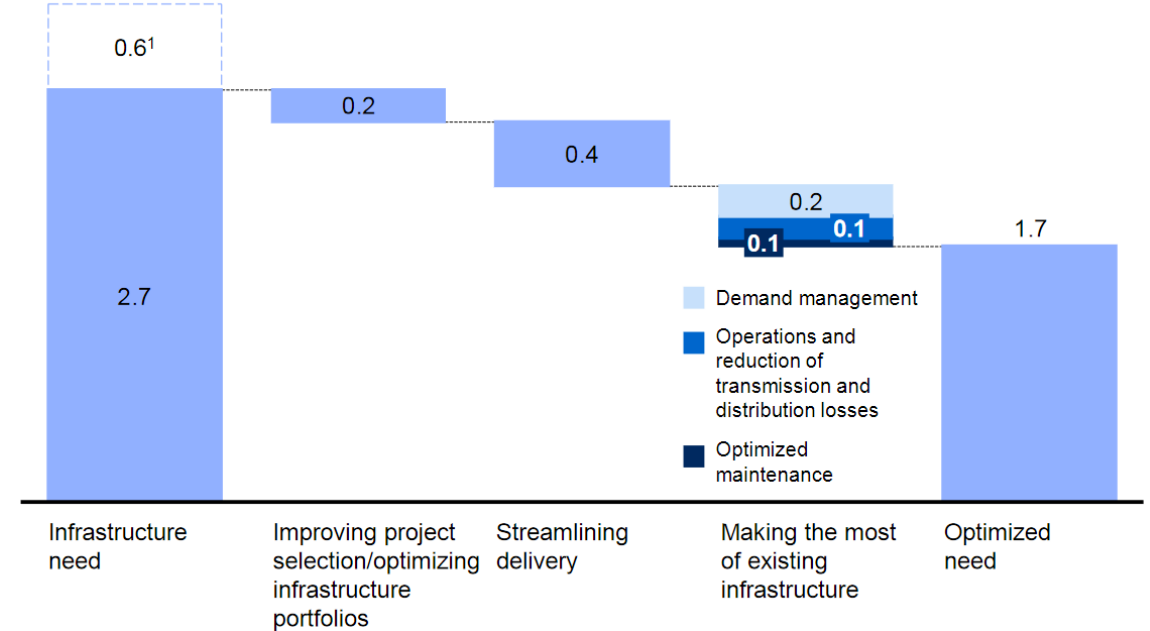
The Built Environment : Scale and impact

Estimates of needed infrastructure investments, 2013–30
\$ trillion, constant 2010 dollars



SOURCE: Organisation for Economic Co-operation and Development (OECD); International Energy Agency (IEA), 2011; International Transport Forum (ITF); Global Water Intelligence (GWI); McKinsey Global Institute analysis

The \$1 trillion-a-year infrastructure productivity opportunity
Global infrastructure investment need and how it could be reduced
Yearly average, 2013–30
\$ trillion, constant 2010 dollars



Dobbs, Richard, H Pohl, D Lin, J Mischke, N Garemo, J Hexter, S Matzinger, R Palter, and R Nanavatty. "Infrastructure Productivity: How to Save \$1 Trillion a Year. McKinsey Global Institute." *McKinsey Co* January, 2013.

The Construction Sector: !Innovation

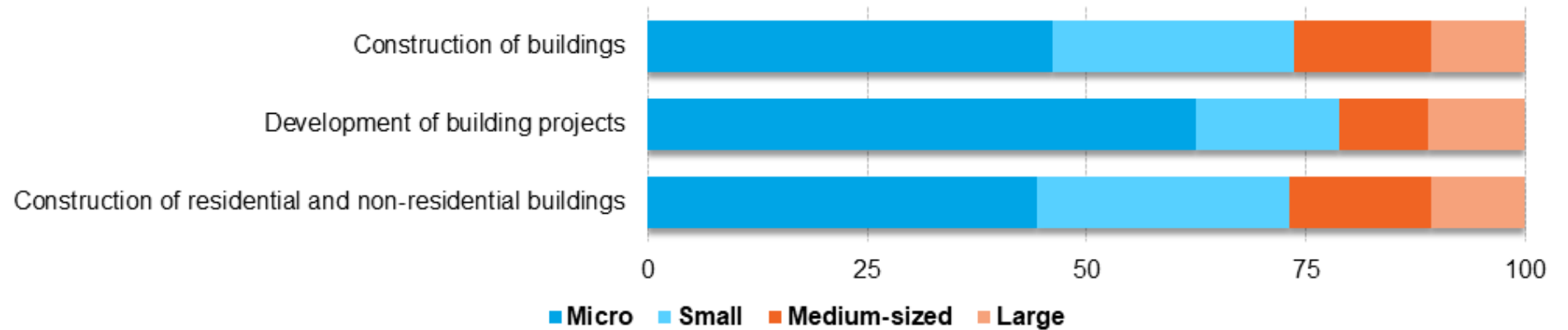
Welcome to the building industry!



idea: A. Kiviniemi. Image Sources:
[Dailymail 2015], [Protocars 2015] [Uregiana 2015]

Sectoral analysis of employment by enterprise size class, Construction of buildings (NACE Division 41), EU-27, 2017

(% share of sectoral employment)

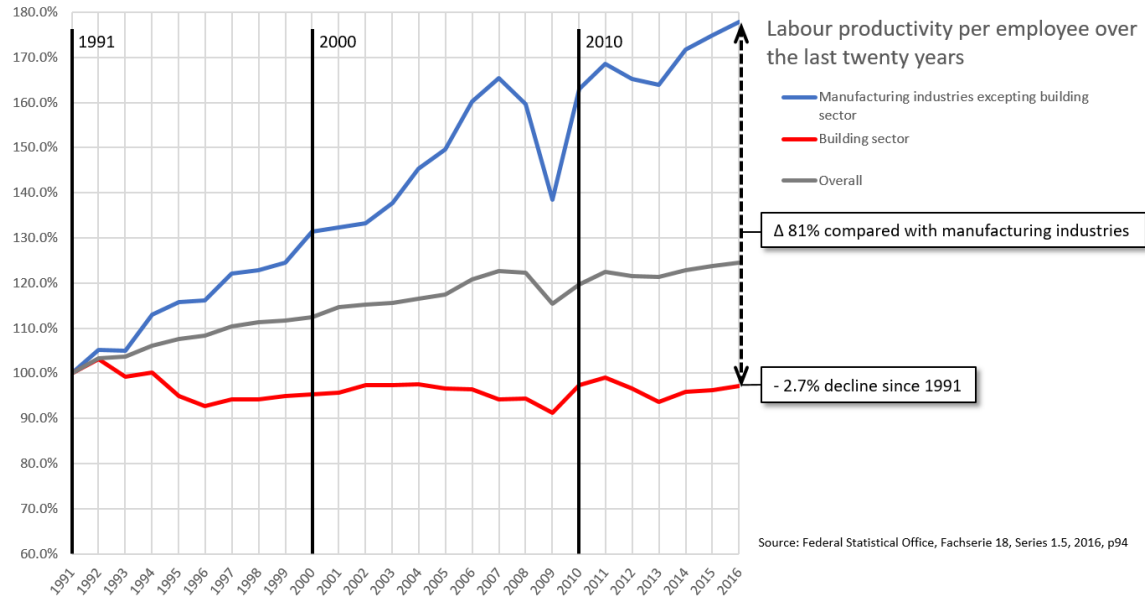


Note: Activities which are not shown are incomplete. For the purpose of the article some percentages have been calculated for confidential data, which causes a lower reliability.

Source: Eurostat (online data code: sbs_sc_con_r2)

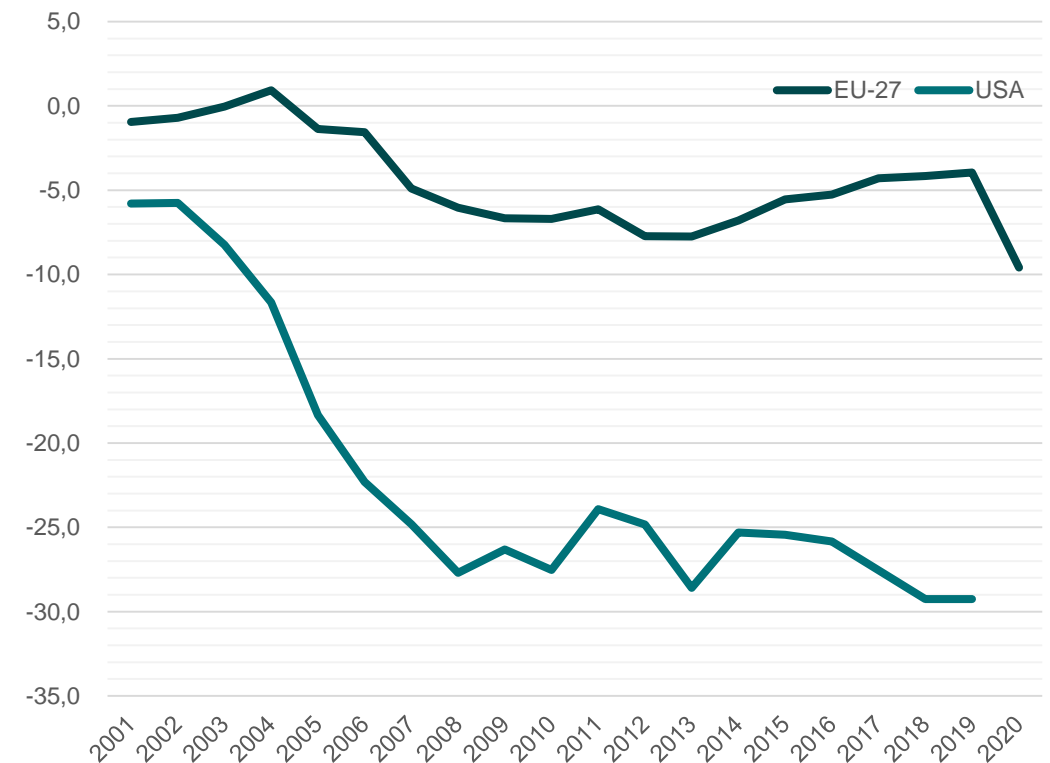
eurostat 

The Construction Sector: Productivity



Source: OECD (2021), "Productivity and unit labour cost by industry, ISIC Rev. 4", *OECD Productivity Statistics* (database), <https://doi.org/10.1787/data-00687-en>

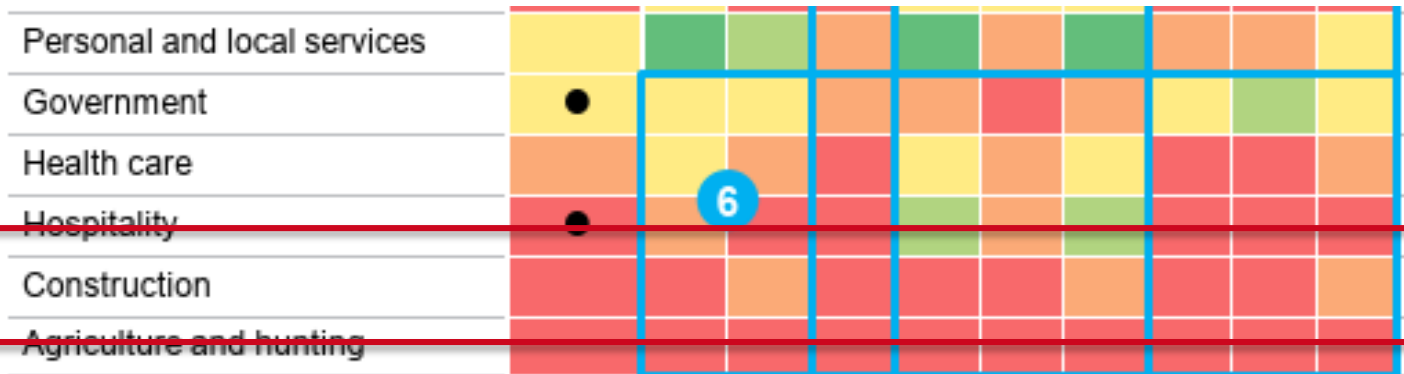
Construction sector: Gross value added per person employed, constant prices (cumulative)



The Construction Sector: Digitalization



Source: unknown. Cobie Man "Lyle" from [Bill East presentation](#)



The MGI Industry Digitization Index

2015 or latest available data

Relatively low digitization Relatively high digitization

● Digital leaders within relatively undigitized sectors


Sector	Over-all digitization ¹	Assets		Usage			Labor			GDP share %	Em-ploy-ment share %	Produc-tivity growth, 2005-14 ²
		Digital spending	Digital asset stock	Transactions	Interactions	Business processes	Market making	Digital spending on workers	Digital capital deepening			
ICT										5	3	4.6
Media										2	1	3.6
Professional services		1								9	6	0.3
Finance and insurance										8	4	1.6
Wholesale trade										5	4	0.2
Advanced manufacturing						4				3	2	2.6
Oil and gas										2	0.1	2.9
Utilities		2								2	0.4	1.3
Chemicals and pharmaceuticals										2	1	1.8
Basic goods manufacturing										5	5	1.2
Mining										1	0.4	0.5
Real estate	●									5	1	2.3
Transportation and warehousing	●									3	3	1.4
Education	●									2	2	-0.5
Retail trade	●									5	11	-1.1
Entertainment and recreation										1	1	0.9
Personal and local services										6	11	0.5
Government	●									16	15	0.2
Health care										10	13	-0.1
Hospitality	●									4	8	-0.9
Construction		6								3	5	-1.4
Agriculture and hunting										1	1	-0.9

- 1 Knowledge-intensive sectors that are highly digitized across most dimensions
- 2 Capital-intensive sectors with the potential to further digitize their physical assets
- 3 Service sectors with long tail of small firms having room to digitize customer transactions
- 4 B2B sectors with the potential to digitally engage and interact with their customers
- 5 Labor-intensive sectors with the potential to provide digital tools to their workforce
- 6 Quasi-public and/or highly localized sectors that lag across most dimensions

Manyika, et al ,2015 "Digital America: A Tale of the Haves and Have-Mores."

The Construction Sector: Building Performance Gaps

- Multiple gaps between what is designed / simulated / "twinned" and how it actually performs!



450026: Estover Community College
Sector: Education
Benchmark category: Schools and seasonal public buildings

	Design data	Actual data
	37.9 kg CO ₂ /m ² /yr	60.4 kg CO ₂ /m ² /yr

[more project details](#)

Building/project type: New build Building use: Single Use

Tenancy: Owner Occupied

Project summary: The project has created a combined campus consisting of 7 form entry secondary school, a 1 form entry primary school and an integrated special school. The secondary school is a specialist Visual Arts college. The campus also provides fully accessible community facilities including public library, theatre and sports provision

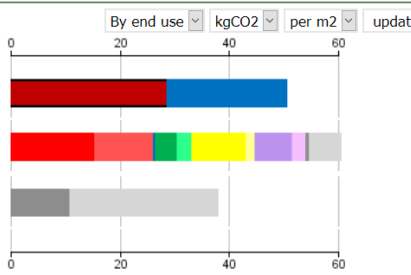
Project records

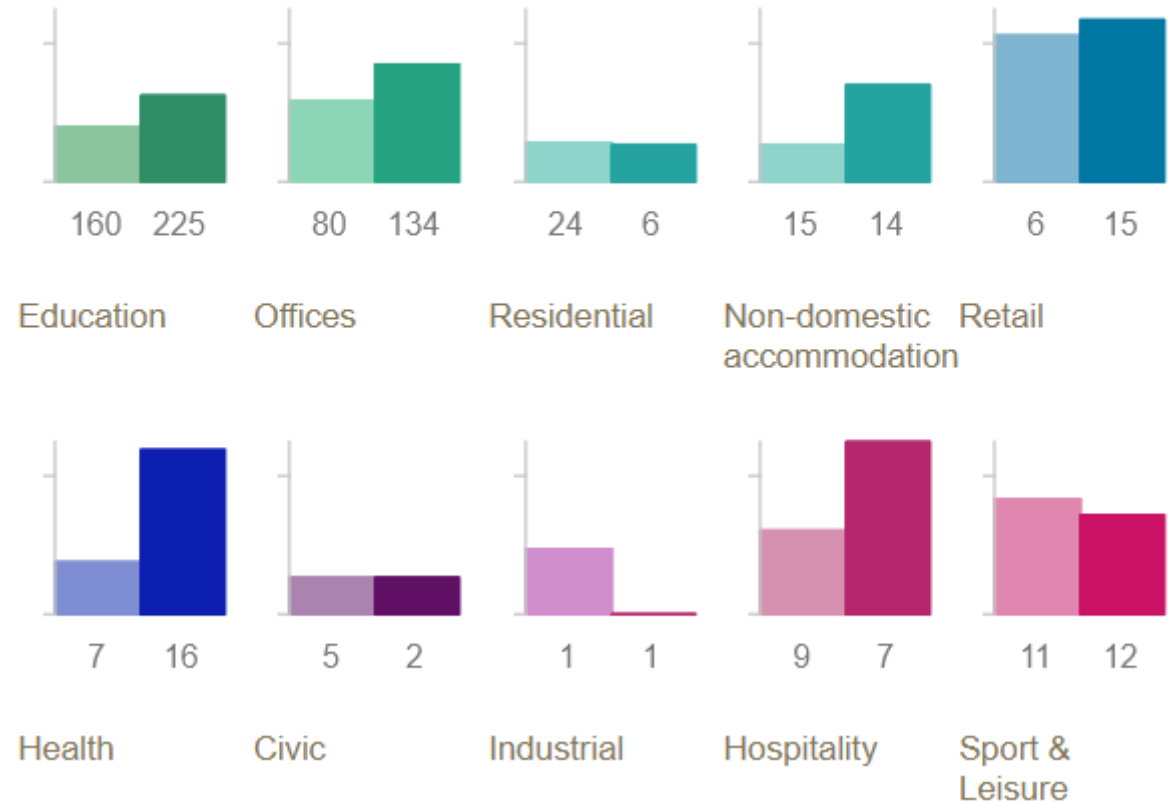
CIBSE TM46 Benchmark

TM22 In Use (Unadjusted) - TM22 spreadsheet (3/11/2014)

EPC - Blocks A, B, F & G - EPC as designed (25/7/2014)

By end use | kgCO₂ | per m² | update





source:carbonbuzz.org

The Construction Sector: Corruption

Engineering and construction sector
analysis of PwC's 2014 Global Economic
Crime Survey

Fighting corruption and bribery in the construction industry



49%

Nearly half of respondents reporting economic crime say it includes bribery and corruption. That's the highest level of any industry.

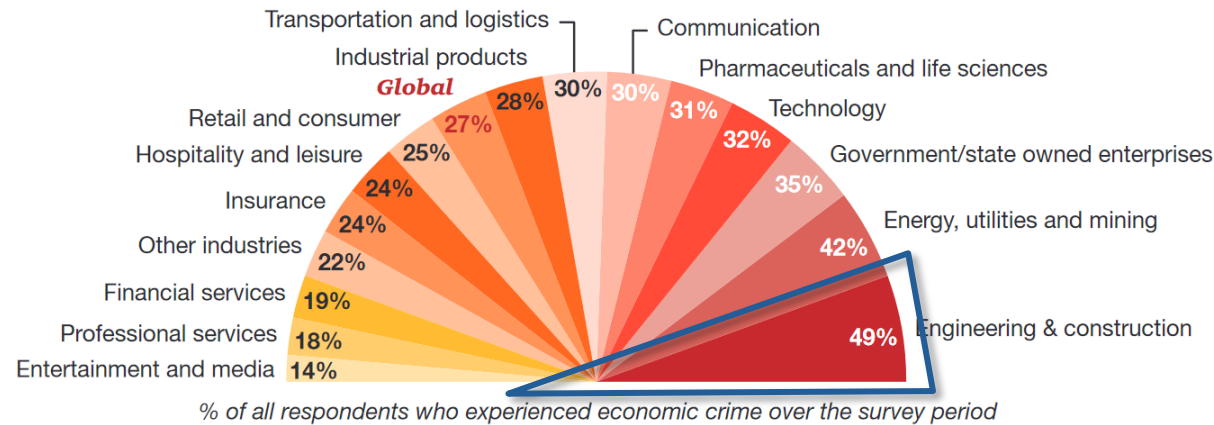
76%

Asset misappropriation tops the list of types of economic crime experienced by engineering & construction respondents.

70%

Seven out of ten of the most serious economic crimes suffered by engineering & construction companies were perpetrated by insiders.

Figure 2: Reported bribery and corruption, by industry



How can Semantic Digital Twins for the BE help?

- 1. What is what: Acquisition** of information from static model to **"living" Twin for the existing environment**
 - inventory: what do we have, what is it made of?
 - different models at different levels of scale,
 - with design intent (not just "what we see")
- 2. how are things?** status monitoring
 - by the minute
 - by the day
 - by the year
 - throughout an ownership lifecycle
 - across generations (!)
- 3. who else is out there?**
 - Connect, align, map
 - orchestrate systems of systems
- 4. Planning**
 - informed decision making based on the above

Semantic Digital Twins in the Built Environment

buildingSMART

- Positioning Paper "Enabling an Ecosystems of Digital Twins", 2020

- Jakob Beetz, Aachen University
- Léon van Berlo, buildingSMART International
- André Borrmann, The Technical University of Munich
- Mark Enzer, Mott MacDonald/the Centre for Digital Built Britain
- Christian Frey, Siemens
- Ulrich Hartmann, Oracle
- Wolfgang Hass, Siemens
- Aidan Mercer, buildingSMART International
- Frank Weiß, Oracle
- Natalie Weiß, Oracle

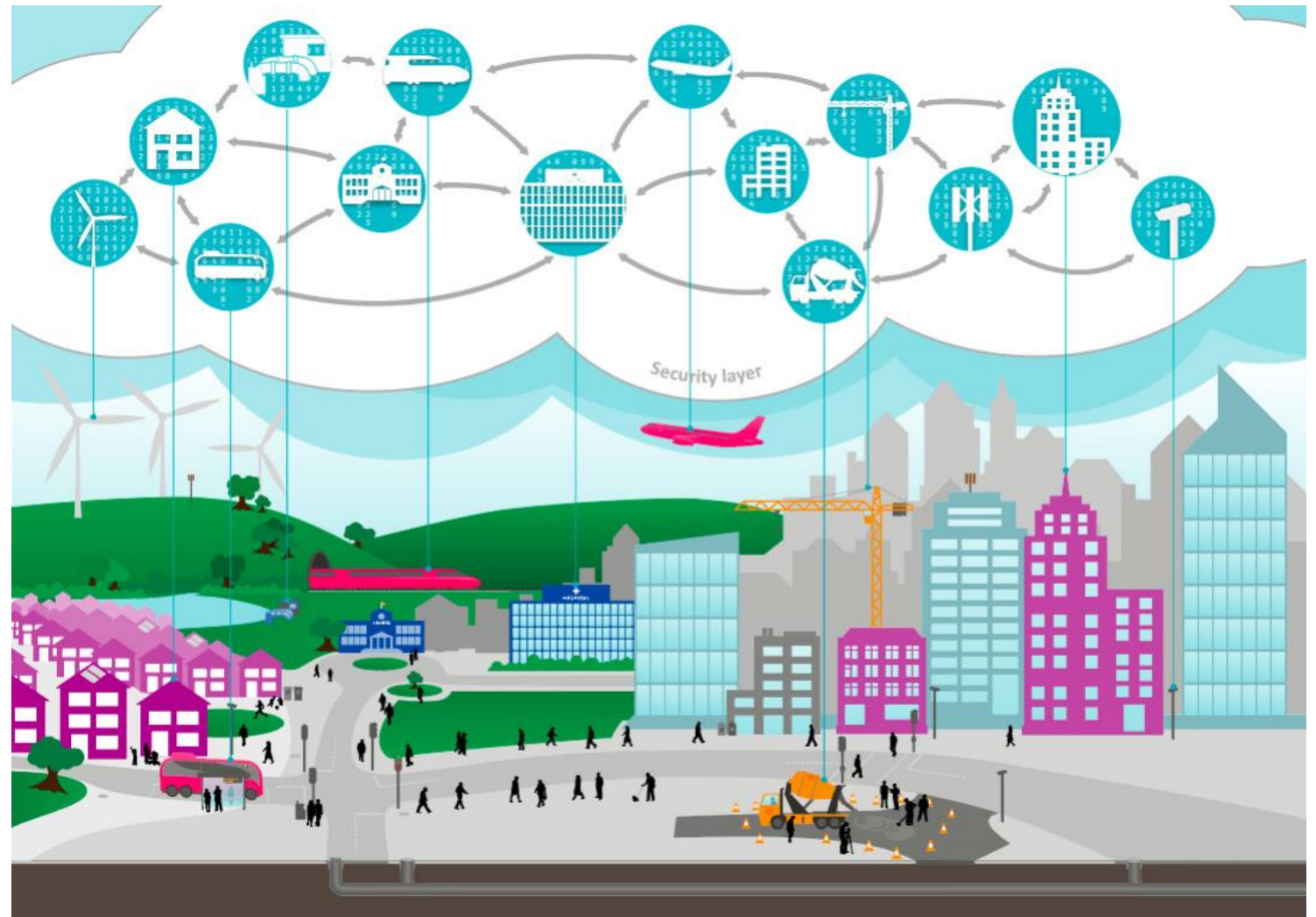


illustration: David McNamara, Oracle

Semantic Digital Twins in the Built Environment

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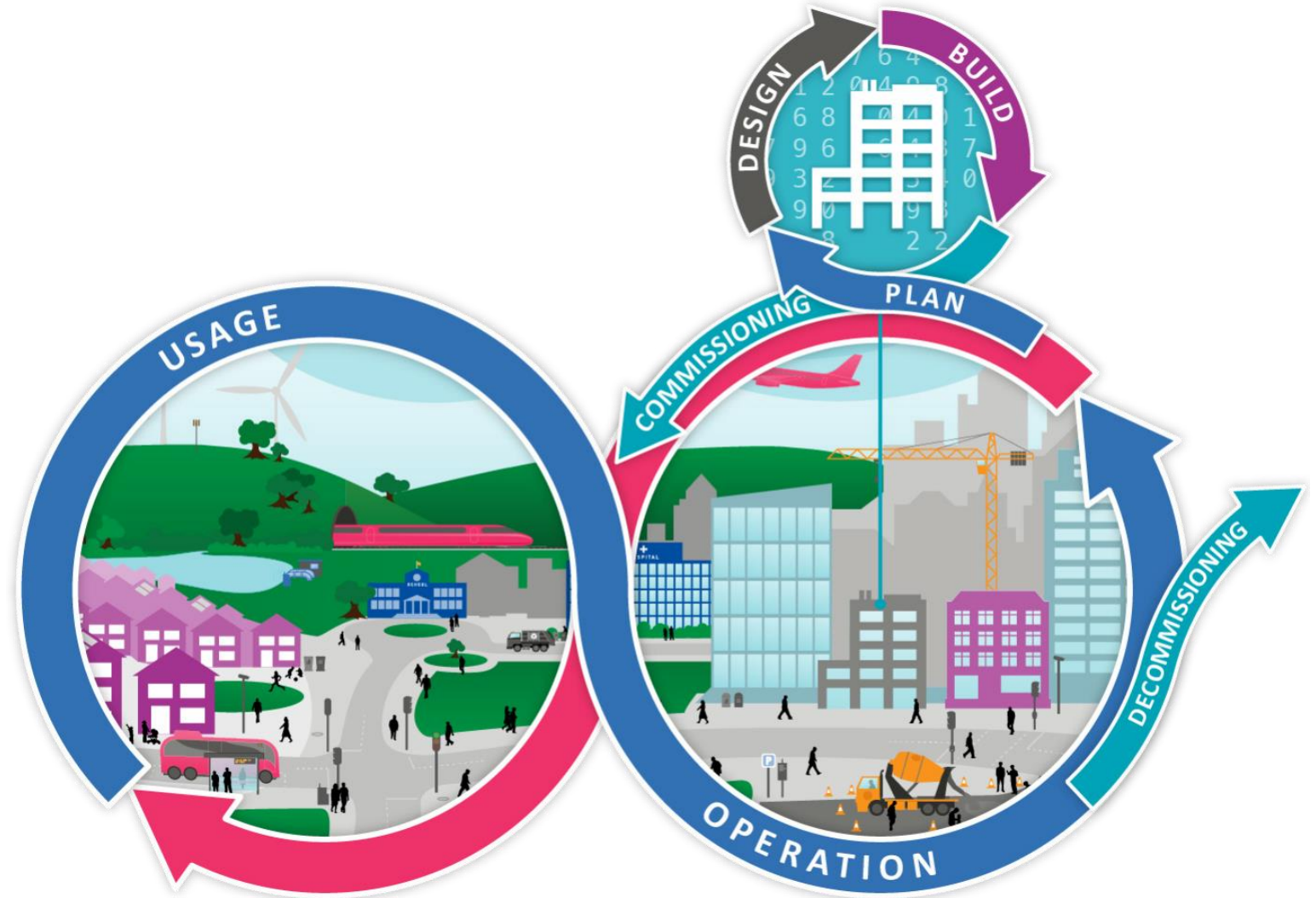
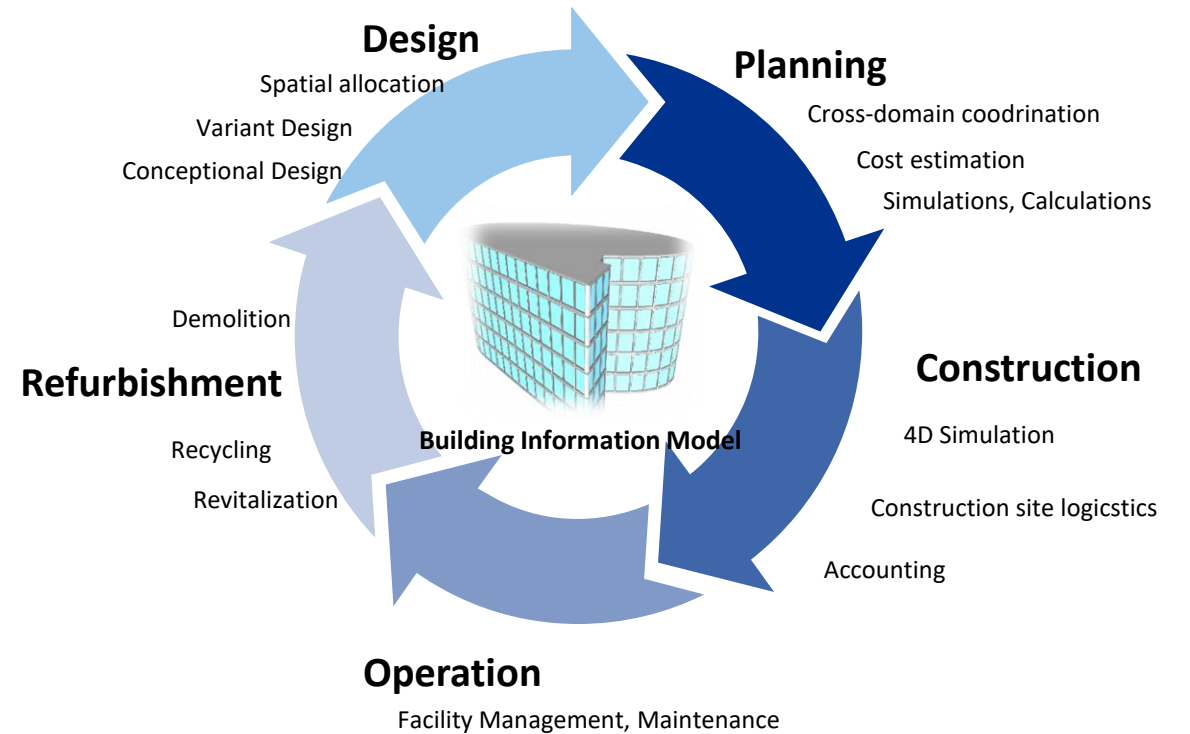
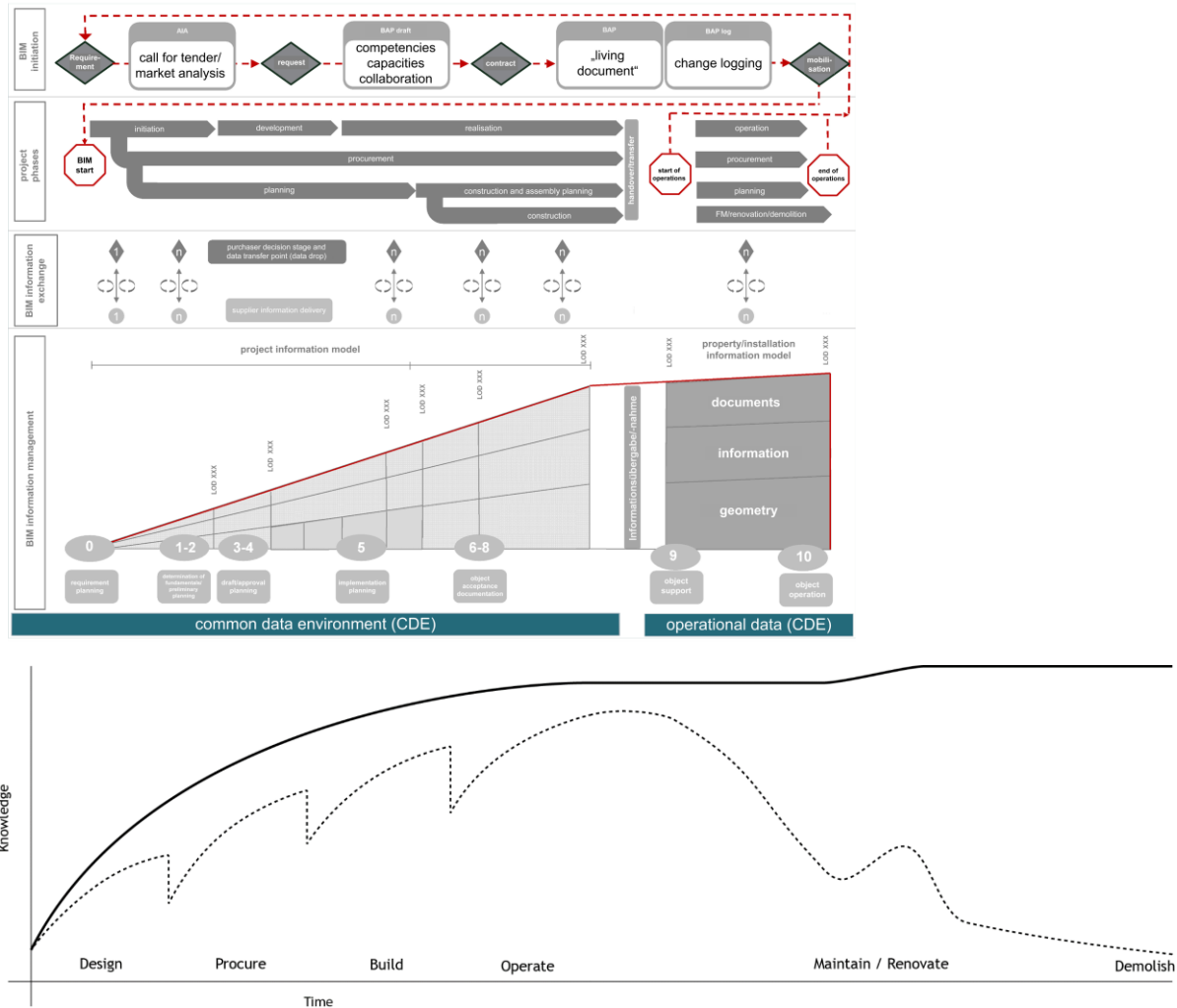


illustration: David McNamara, Oracle

Digital Twins for the built environment: Lifecycle concepts



Source: Bormann, König, Koch, Beetz 2015

Linked, heterogeneous Building Information Modelling – BIM

Interoperability buildingSMART IFC and beyond

4 Ruimtelijk Programma van Eisen

4.1 Samenvatting benodigde ruimtelijke voorkeuzingen

A 89109.24
Erasmus MC te Rotterdam, afbouw wandbesten A, A1 en B1. PLAFOND- EN WANDSYSTEMEN 44

44.01.21.c **SYSTEEMWAND, BEPLATING OP SKELET METALEN, WANDPROFIEL, GIPSPLAAT (vervalst)**

1. METALEN WANDPROFIEL

Fabrikant: BFB.

- koudgewalste stalen profielen met een dikte van ten minste 0,6 mm. Oppervlaktelabelling: secundair verzinkt
- Profielen:
 - zijn en regels: standaard profielen
 - vereenvoudigingen aanbrengen naar de wand opgenomen knooppunten, en waar en ergens nodig voor een stabiele uitvoering, zoals bij vrije wand-afsluitingen, bij aan de wand bevestigde zware lantaarn, vaste scharnier en dergelijke.
 - bij een WOBDO-waarde van 30 of 60 minuten (door-koeler-wand) aan weerszijden van zijden deze en/of aansluitingen een verankerd (voering-voering) profiel aanbrengen (van vloer tot bovenliggende vloerconstructie) aanbrengen met een wanddikte van 2,5 mm aanbrengen, bij niet-voering-voering knooppunten eenzelfde profiel aanbrengen boven het knooppunt, gekoppeld aan de verankelde zijden
 - knooppunten aanbrengen in de wanden ter plaatse van de aansluitingen op de brandwerende bakkele gangen (volgens tekening en TNO-rapport knooppunt 06.4, zie detail 1.2.20) opklemsen (o.v.).
 - knooppunten boven gangen (zie detail 4057-01.7).
- Toelichting:
 - berekeningsovername
 - afsluitingsmaatwerk zoals o.a. lantaarn, lantaarnkroon en dergelijke, zoals aangegeven op tekening en/of voorgeschreven door de leverancier.

Fabrikant: BFB

Type:

- niet betegeld oppervlak: GKZ standaard beplating
- betegeld oppervlak: GKZ 70-plaat met verankerde waterpasgips
- gipsplaat en waar aangegeven: Thermap

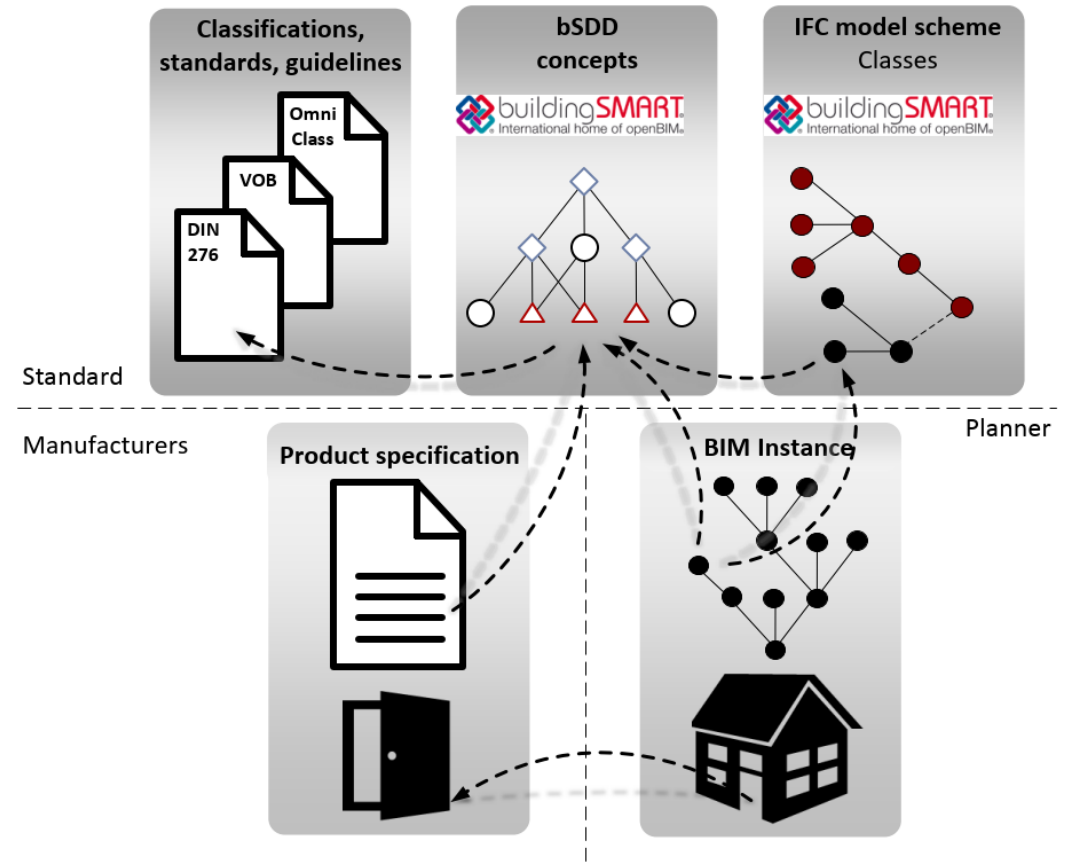
 Materiaal: gipsgevoerd spijkstaal.
 Aansluitingen: volgens tekening.
 Fabrikant: BFB

2. GIPS-KARTONPLAAT (BBI 1009-w99)

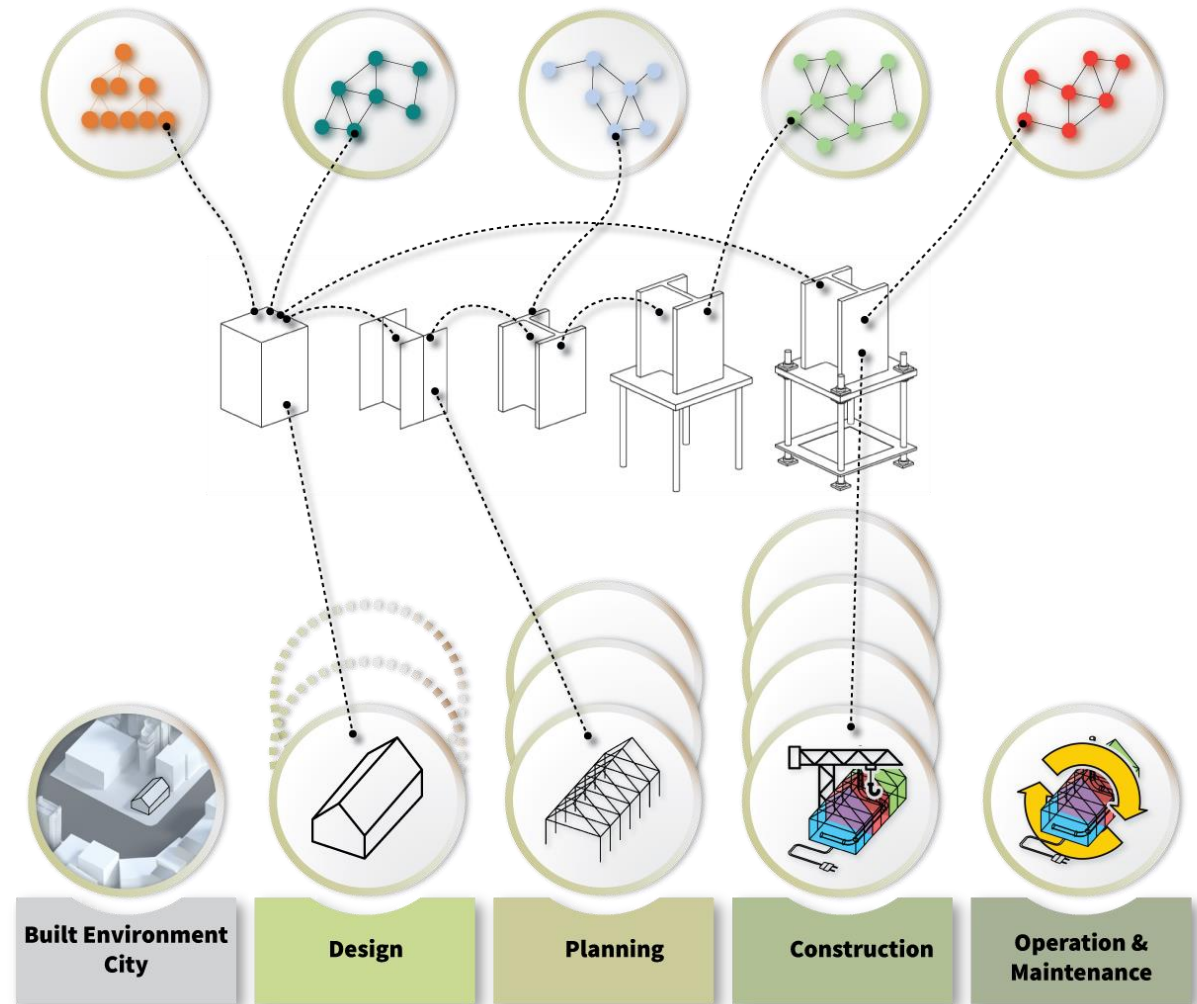
Type:

- niet betegeld oppervlak: GKZ standaard beplating
- betegeld oppervlak: GKZ 70-plaat met verankerde waterpasgips
- gipsplaat en waar aangegeven: Thermap

 Materiaal: gipsgevoerd spijkstaal.
 Aansluitingen: volgens tekening.
 Fabrikant: BFB

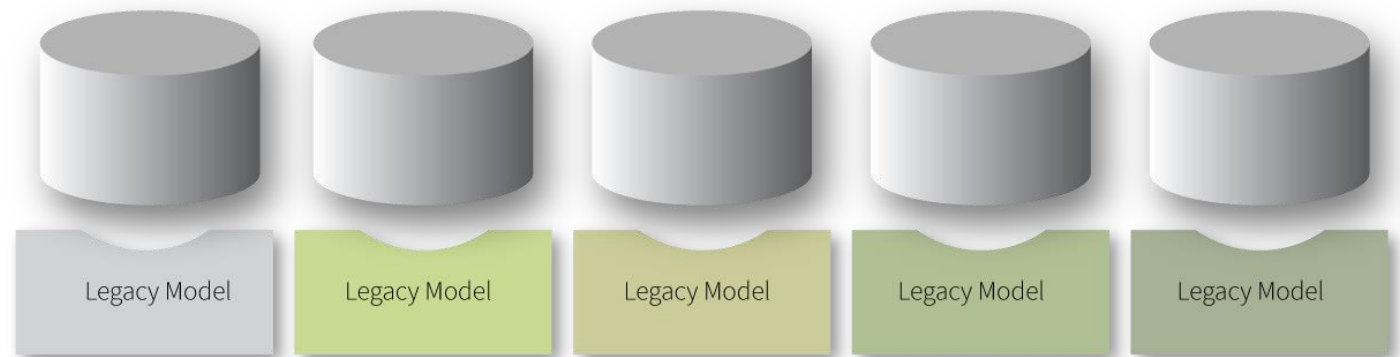
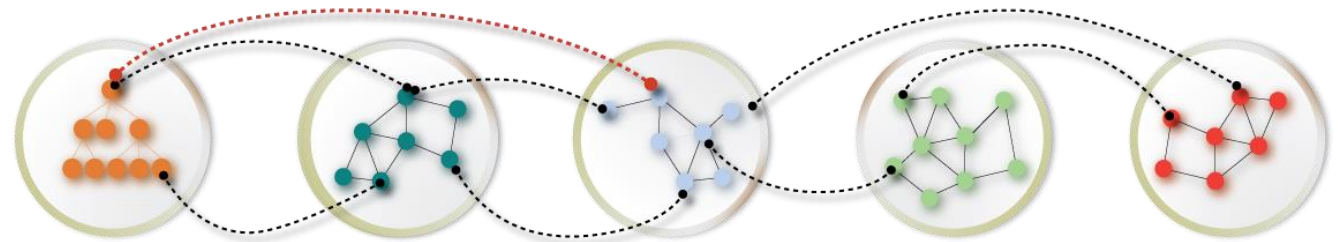
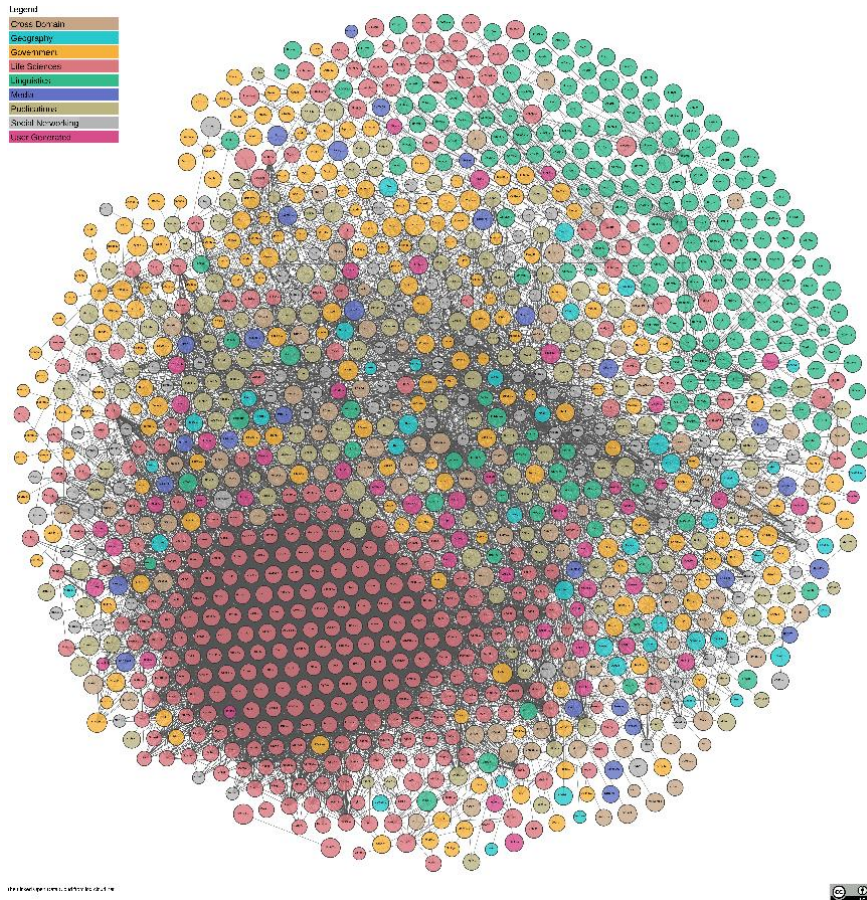


Semantic DTs: interlinked, interoperable information : W3C Linked Data for DT

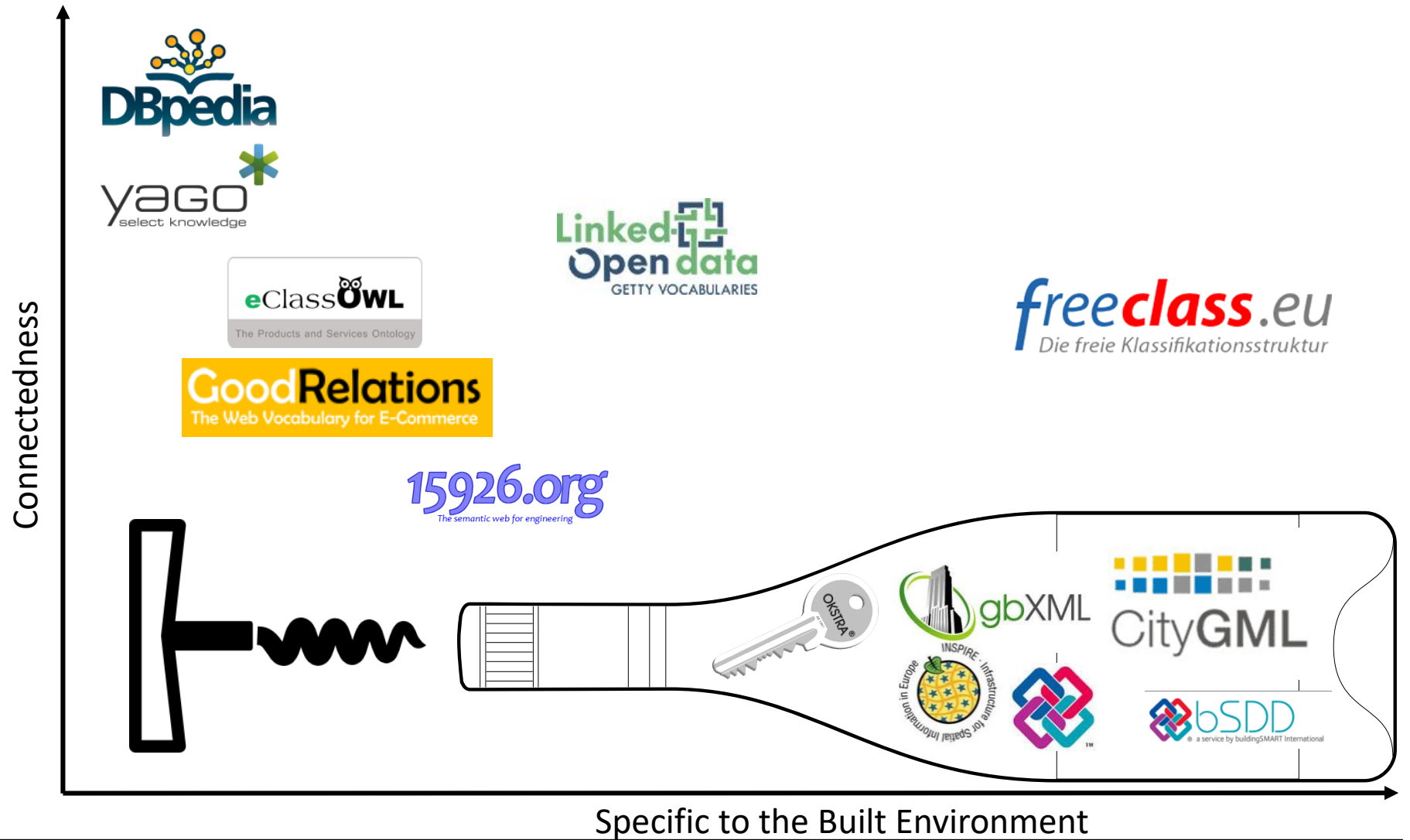


Semantic DTs: interlinked, interoperable information : W3C Linked Data for DT

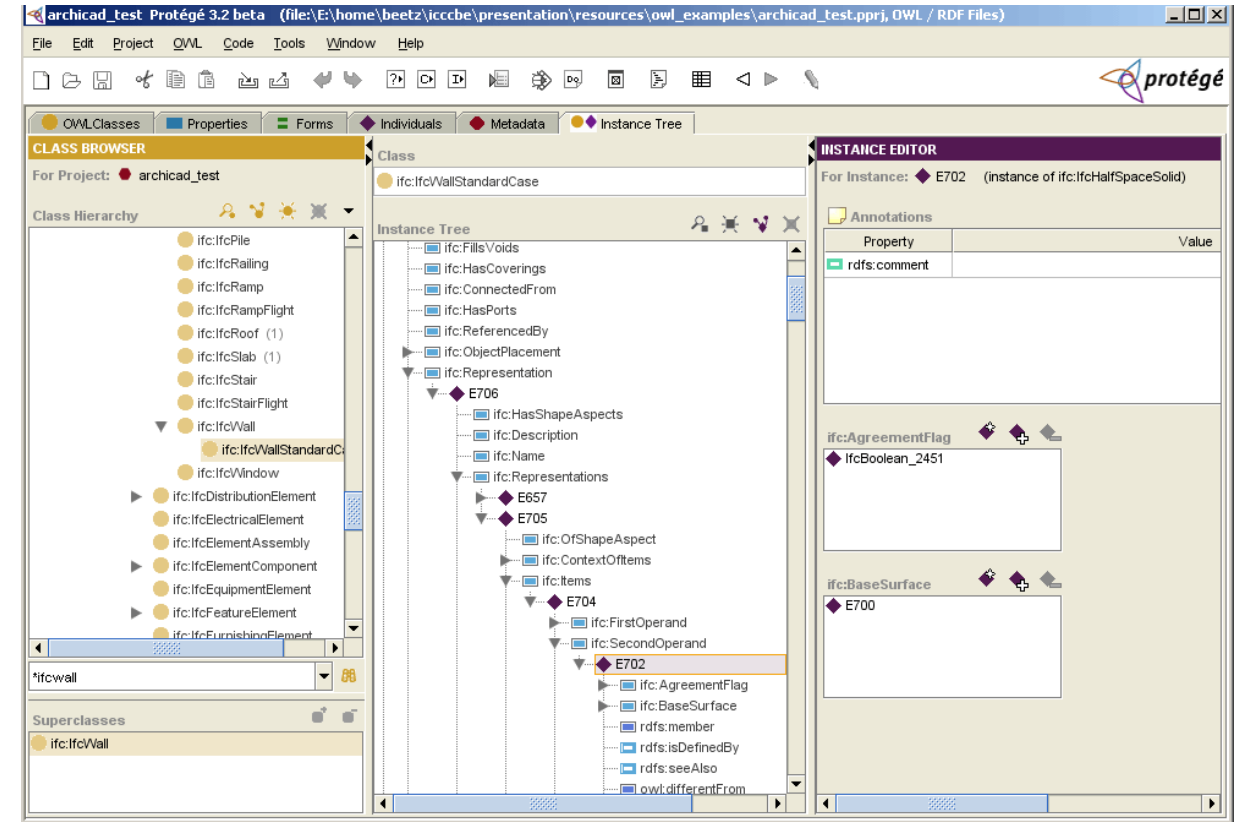
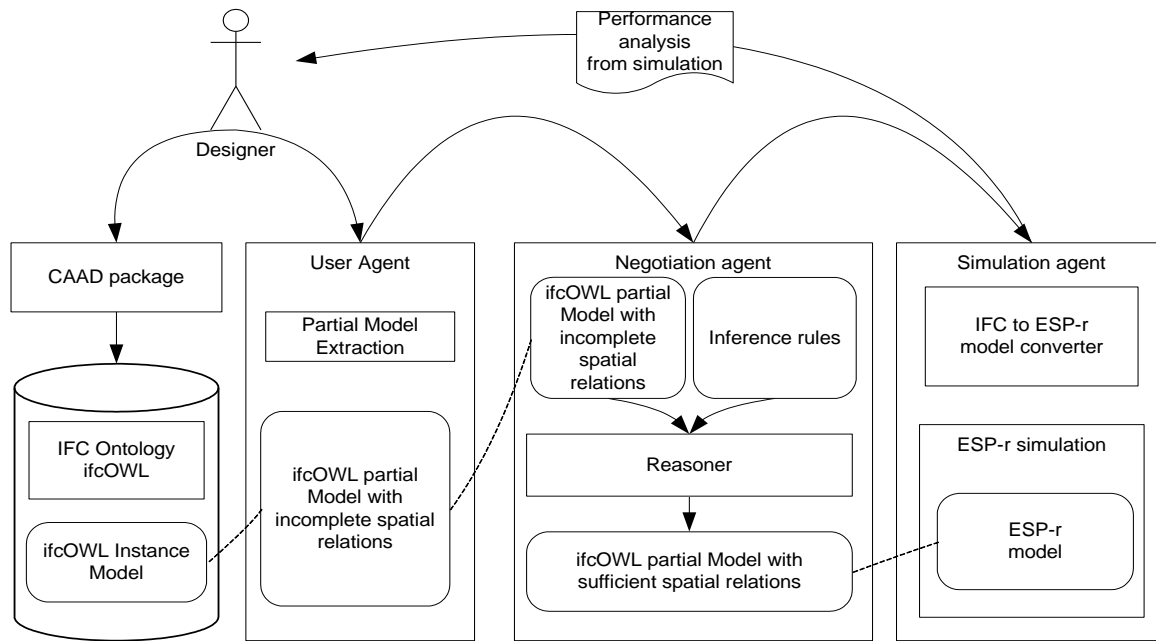
Breaking out of the silos...



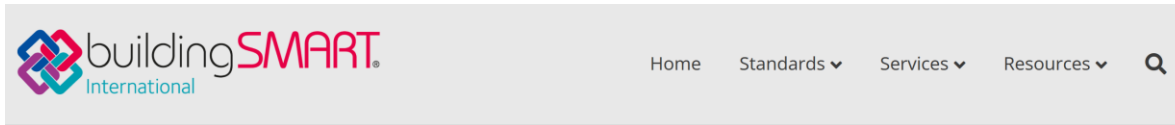
Linked Data and legacy Building Information Models



Greetings from the past : Reasoning with Linked Data | Semantic Web [Beetz 2006]



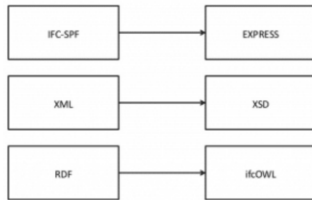
ifcOWL official buildingSMART standard



ifcOWL

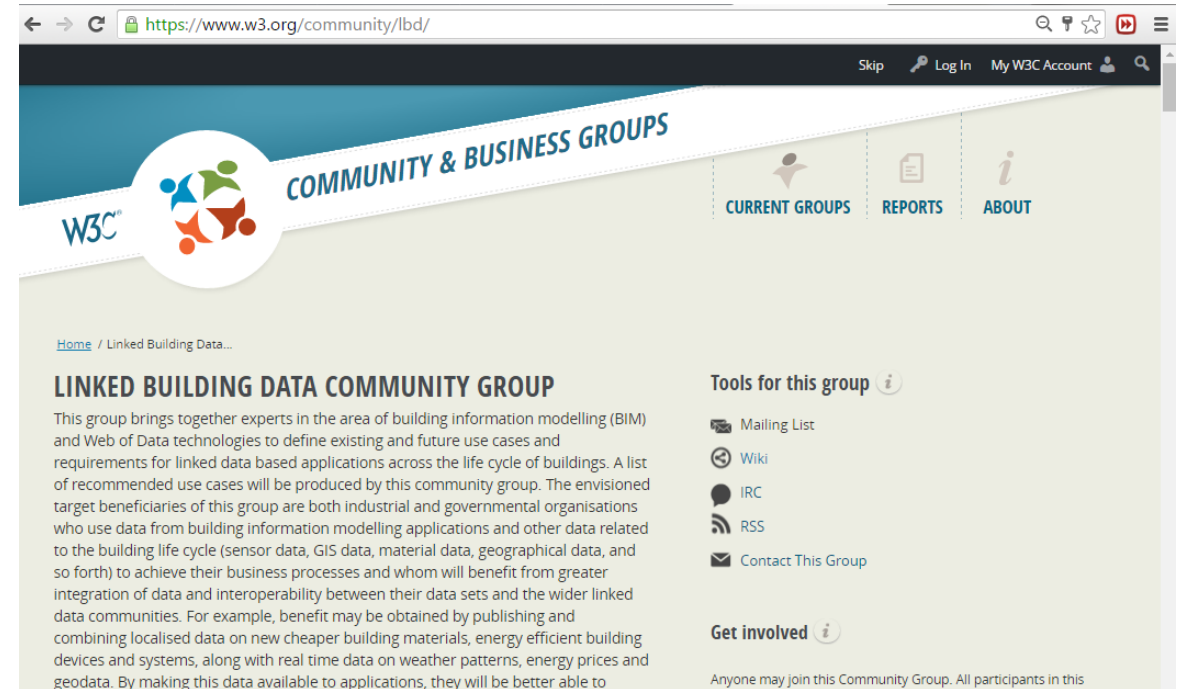
What is ifcOWL?

ifcOWL provides a Web Ontology Language (OWL) representation of the Industry Foundation Classes (IFC) schema. IFC is the open standard for representing building and construction data (see BuildingSMART). The ifcOWL ontology has the same status as the EXPRESS and XSD schemas of IFC.



What is it good for?

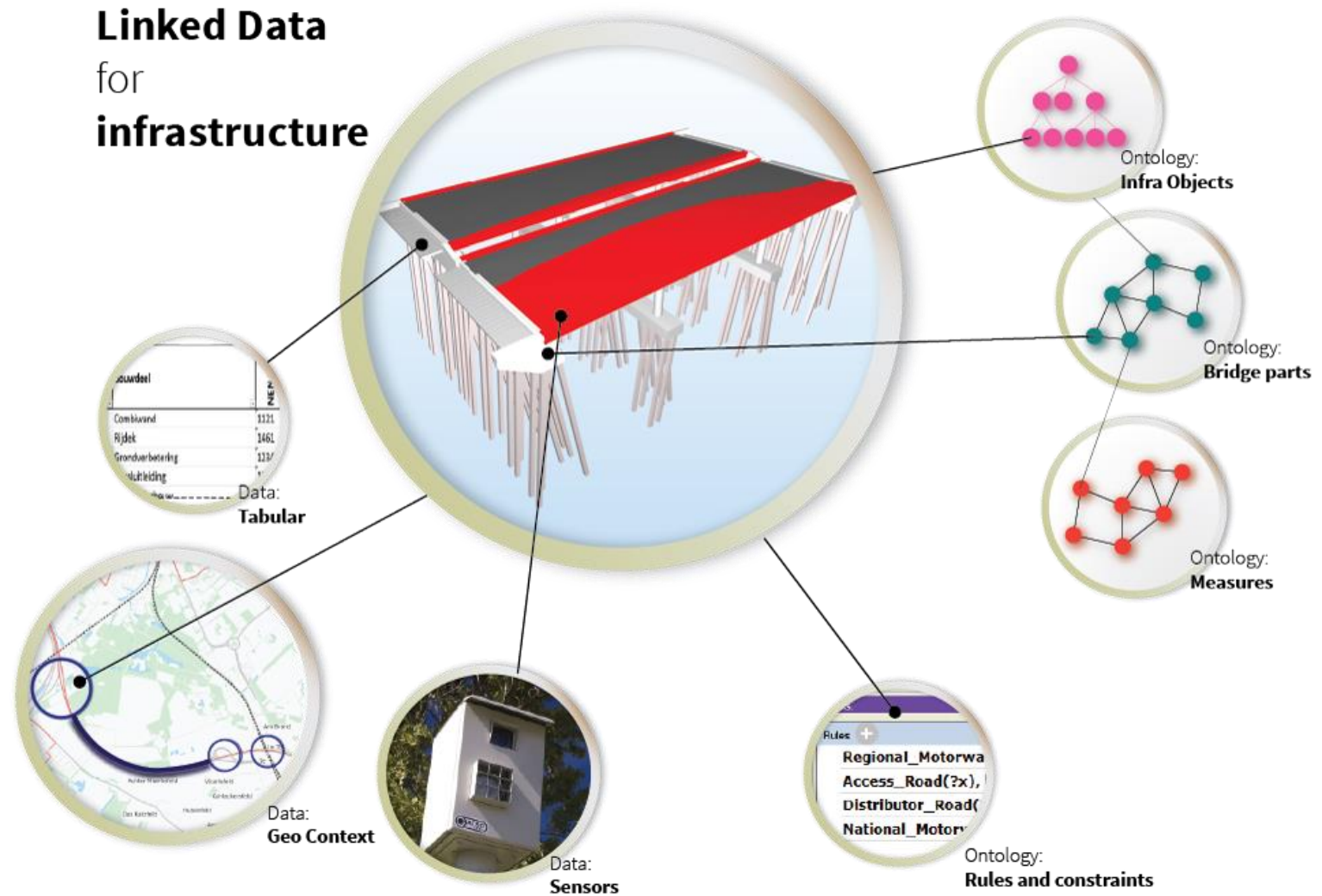
Using the ifcOWL ontology, one can represent building data using state of the art web technologies (semantic web and linked data technologies). IFC data thus becomes available in directed labelled graphs (RDF). This graph model and the underlying web technology stack allows building data to be easily linked to material data, GIS data, product manufacturer data, sensor data, classification schemas, social data, and so forth. The result is a web of linked building data that brings major opportunities for data management and exchange in the construction industry and beyond.



Validation of pre-alignments by experts/crowds

The screenshot displays the Interlink web application interface. At the top left, there is a 'User' login form with fields for 'Username' and 'Password', and buttons for 'Close', 'Register', and 'Login'. A red circled '3' is next to the form. The main area shows a network of RDF class alignments. A central node is labeled 'owl:sameAs' with a red circled '1' and a checkmark. Below it, a node for 'http://dbpedia.org/resource/Category:Potassium' is highlighted in blue. This node is connected to several other nodes via 'skos:broader' and 'owl:sameAs' relationships. A box labeled '100 URIs' lists several URIs, including 'bsdd:3PSPsABR0Htm00025QrESV', 'bsdd:2zRVm0BR0Htm00025QrESV', and 'bsdd:34bGeABR0Htm00025QrESV'. A box labeled '29 URIs' lists URIs from dbpedia.org and wikidata.org. A box labeled '27 URIs' is also present. On the right, a 'Settings' panel (red circled '4') shows configuration options for 'Languages' (en), 'Predicates', and 'Prefixes'. The URL 'http://bw-dssv19.bwk.tue.nl/interlink/' is highlighted in purple at the bottom.

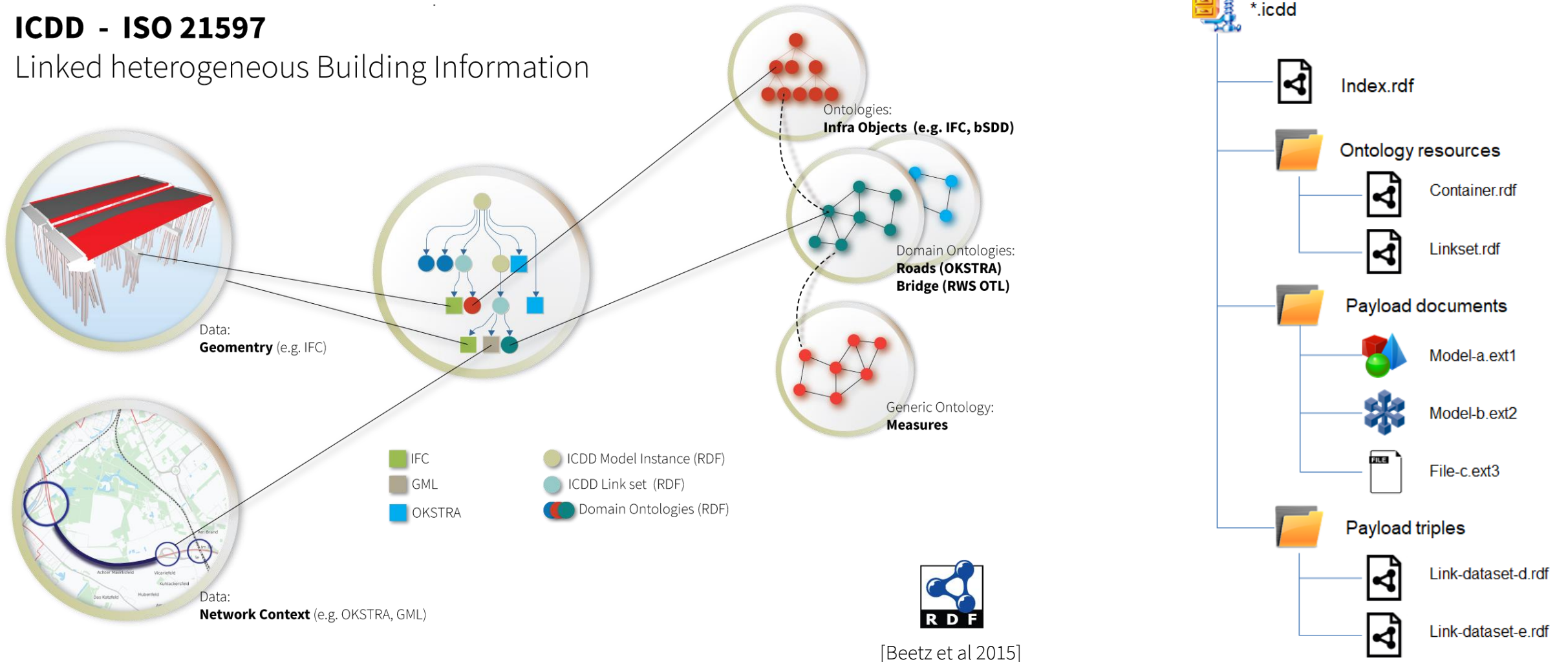
Linked DT Data Breaking out of the silos...



Future: Linked DT Data Information Container Document Delivery – ISO 21597

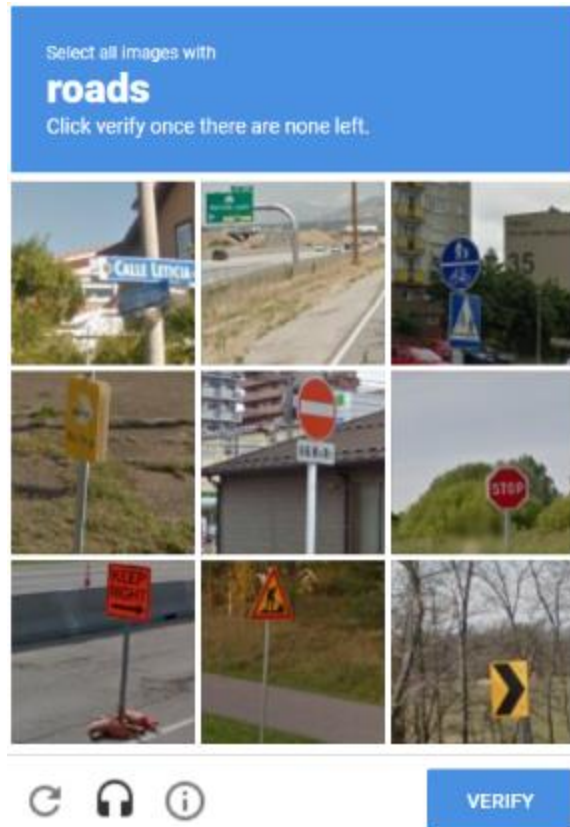
ICDD - ISO 21597

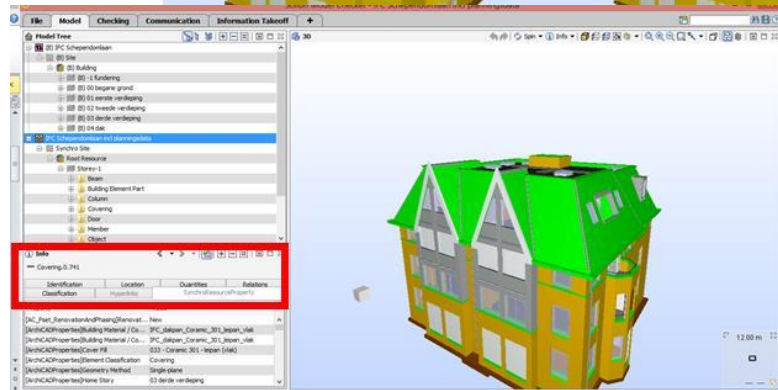
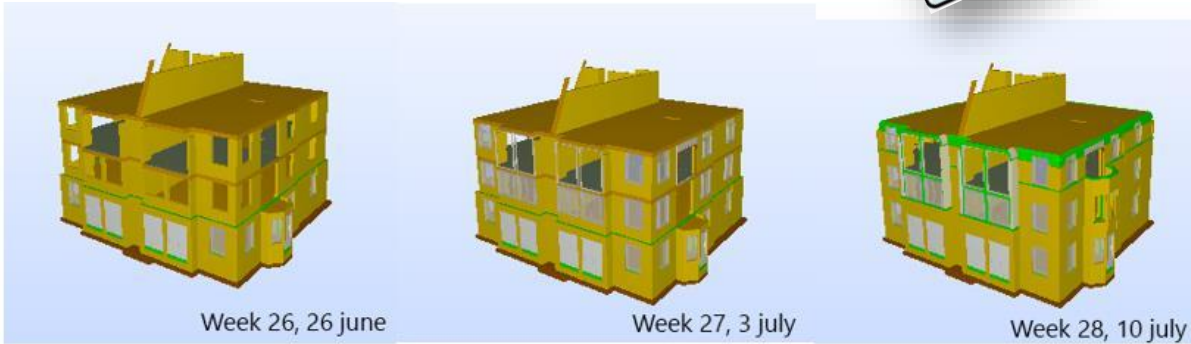
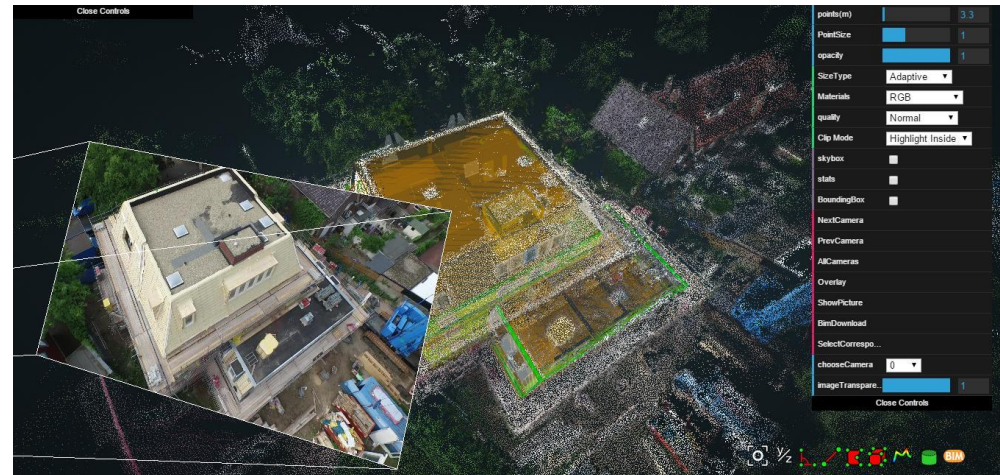
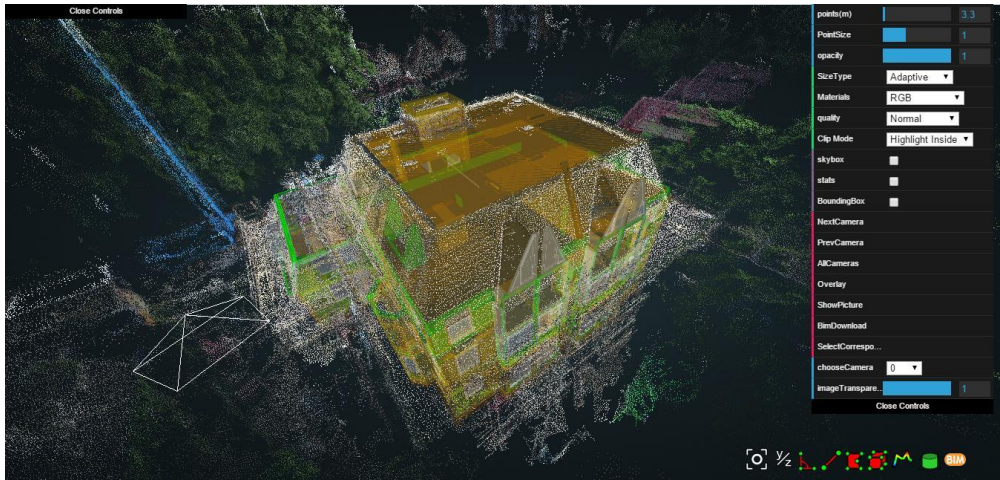
Linked heterogeneous Building Information



Digital Twins Reality Capturing: Why we need more annotated data

Source: [Fisher et al 2018] BDD100K: A Diverse Driving Video Database with Scalable Annotation Tooling





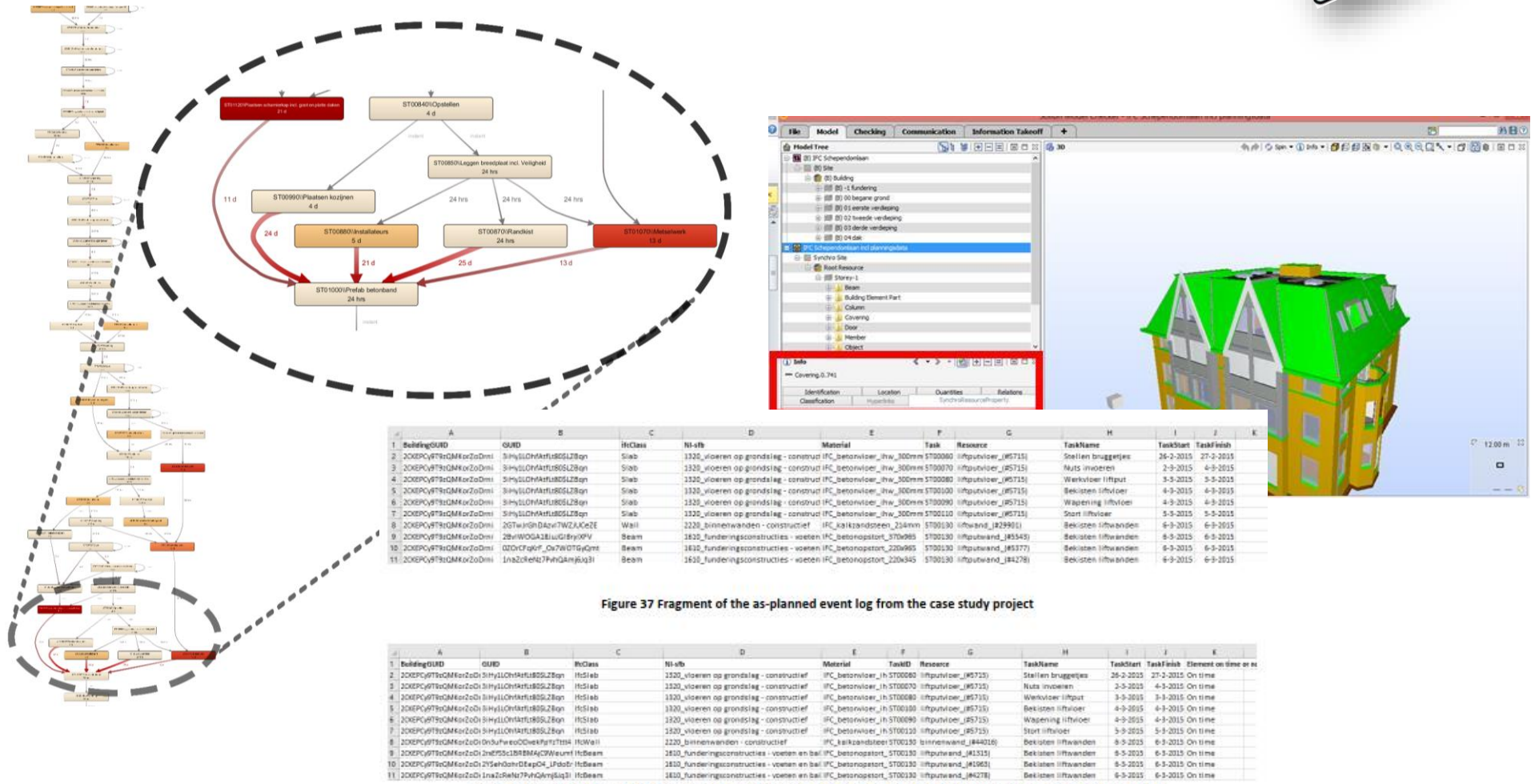
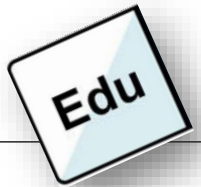
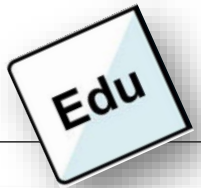


Figure 37 Fragment of the as-planned event log from the case study project

Figure 38 Fragment of the as-built event log from the case study project. This log differs from the log in figure 37 with the parameter 'Element on time or not'

Publicly available dataset Schependomlaan



Search or jump to... Pull requests Issues Marketplace Explore

openBIMstandards / DataSetSchependomlaan

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Code Issues 2 Pull requests 1 Actions Projects 0 Security Insights

No description, website, or topics provided.

50 commits 1 branch 0 packages 2 releases 4 contributors View license

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DOI 10.17605/OSF.IO/NE2YU

Dataset Schependomlaan

All data owners have given permission to use the data for scientific and academic purposes. The data is gathered during the master thesis project of Stijn van Schaijk at the [Information Systems for the Built Environment \(ISBE\) group](#) of the [TU Eindhoven](#). In collaboration with Hendriks Bouw en Ontwikkeling[1], ROOT[2], TNO[3] and RAAMAC[4] the data is collected. General information about the project can be found at the website <http://www.schependomlaan.nl/>.



Please pay attention: Do not download separate files, they will give errors. Download the full dataset please use [the zip](#) from [the release section](#)

The dataset contains the following elements:

- Design model in .IFC and .PLA (Archicad)
- Issues (collision / clash detection) in BCF (.bzzip) and in Tekla BIMsight Package.
- Subcontractor models in .IFC and .DWG - Flooring - Walls - Stairs - Fencing - Steel - Roofs - Prefab
- Coordination models in .TBP (Tekla BIMsight Package)
- Schedule/Planning in .pdf and .xml
- As-planned models in .IFC and Synchro file format.
- As-built models in point cloud formats .ASCII and .PLY
- Results comparison as-planned and as-built models in .xls
- As-planned Event log in .xlsx and .csv
- As-built Event log in .xlsx and .csv
- Event log with actors in .xlsx and .csv
- Download link to drone images and videos

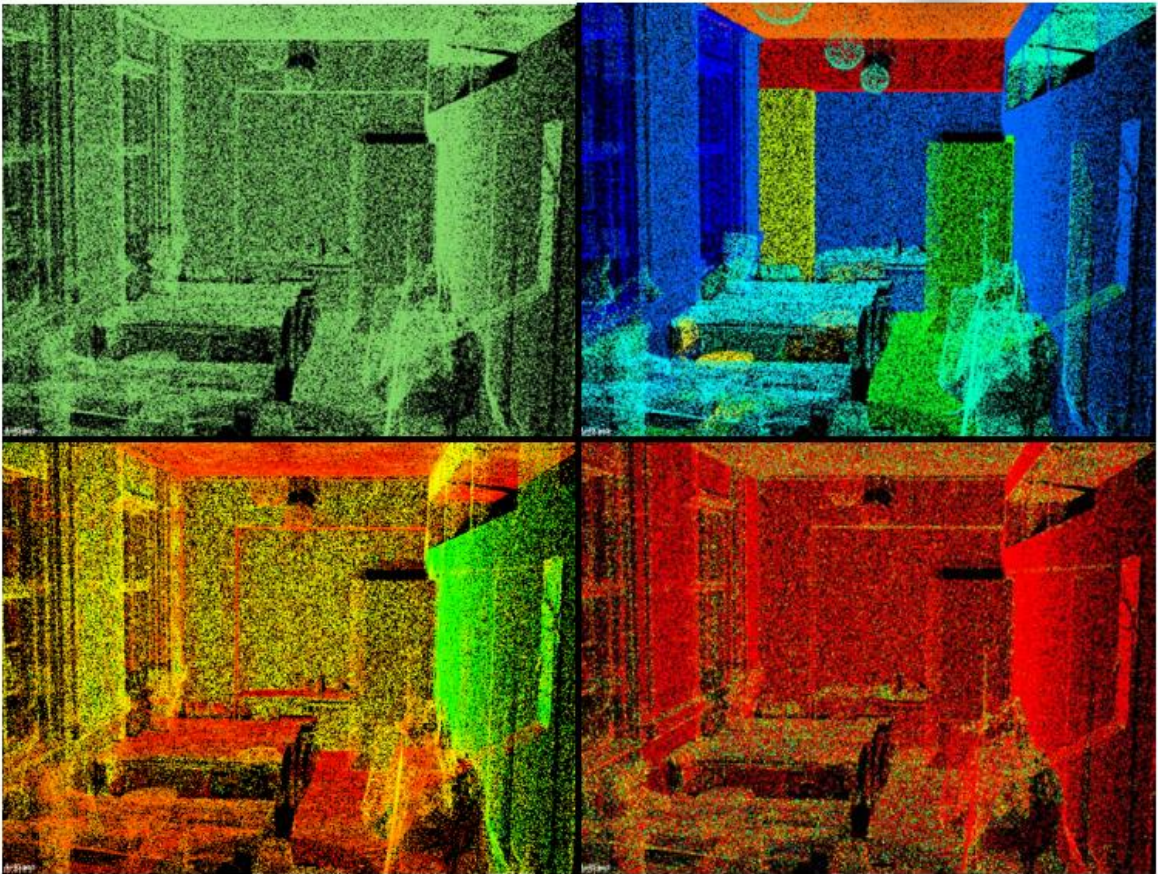
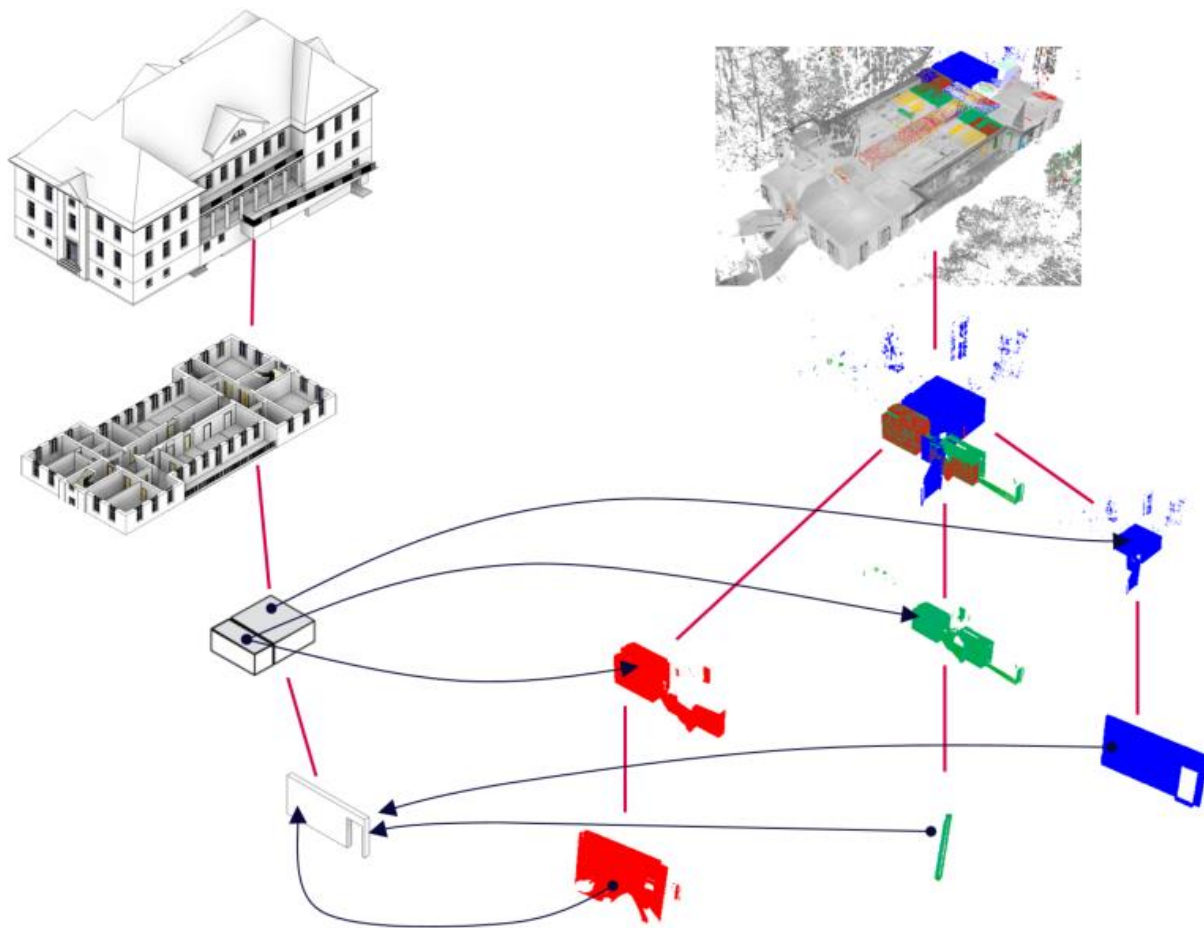
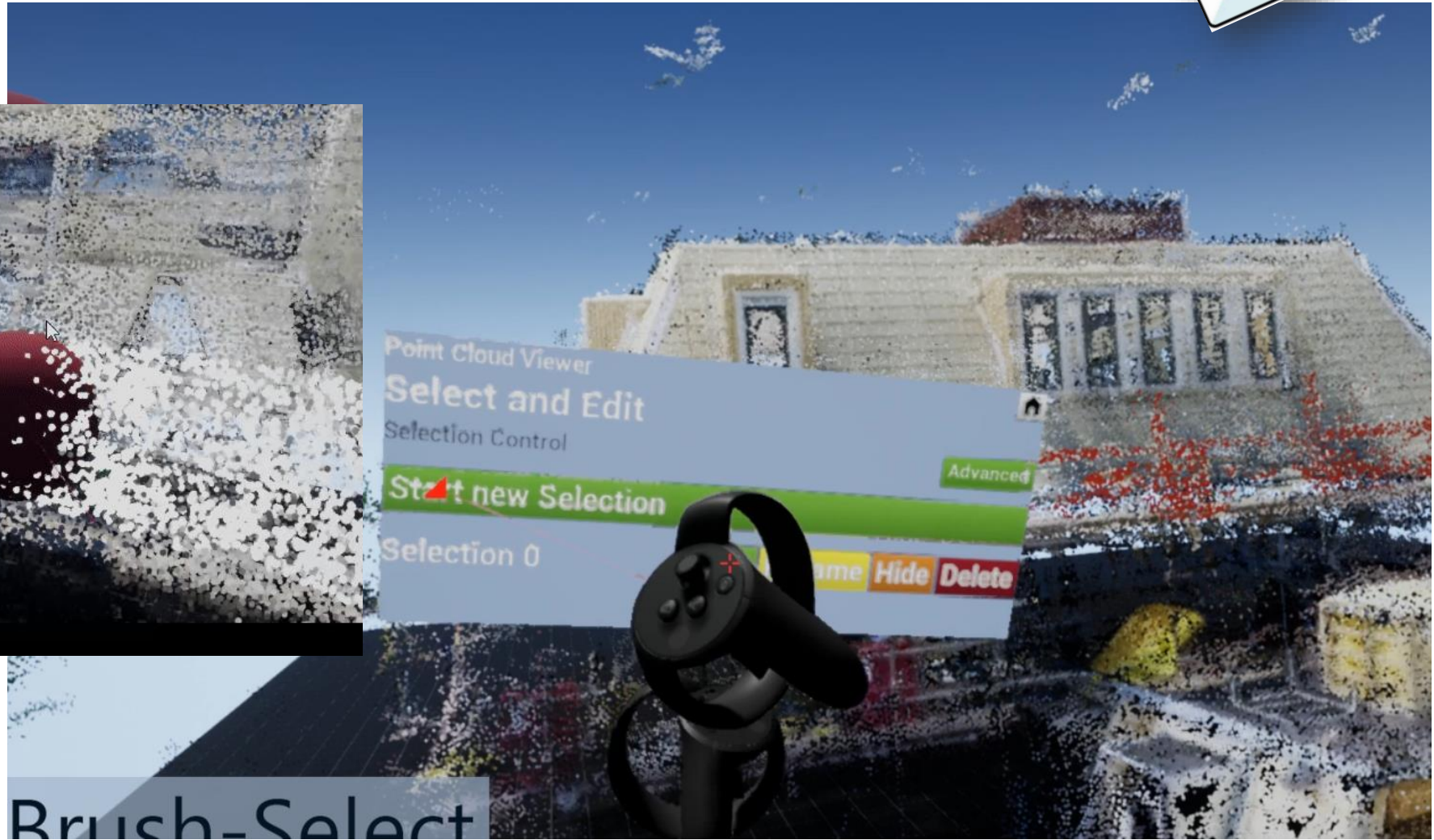
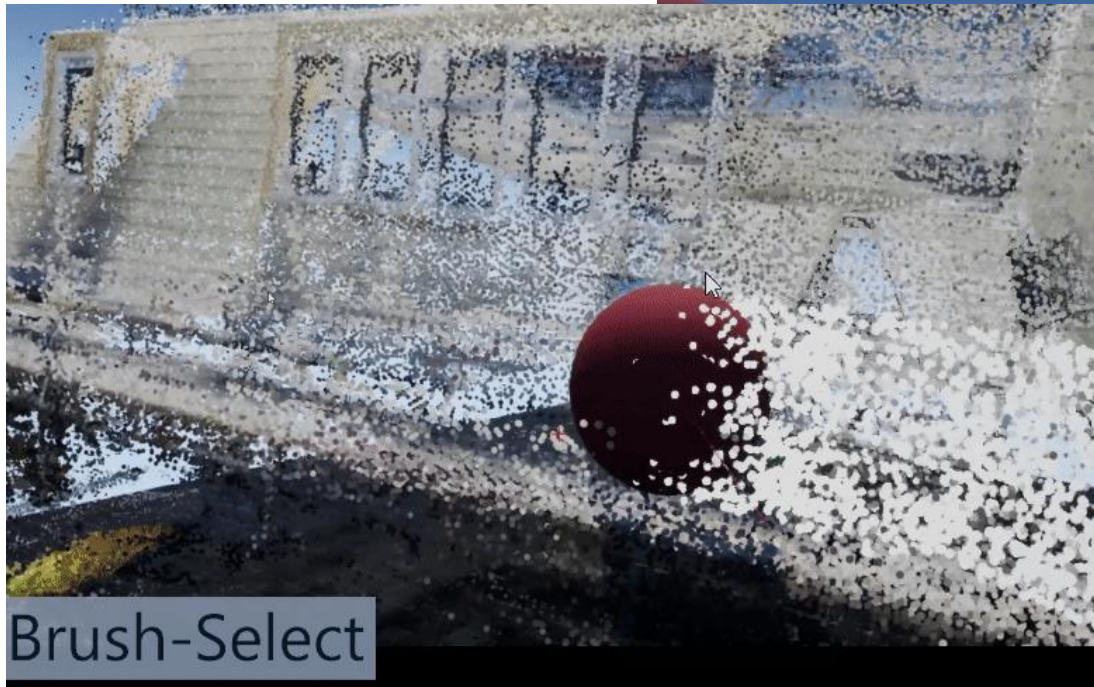
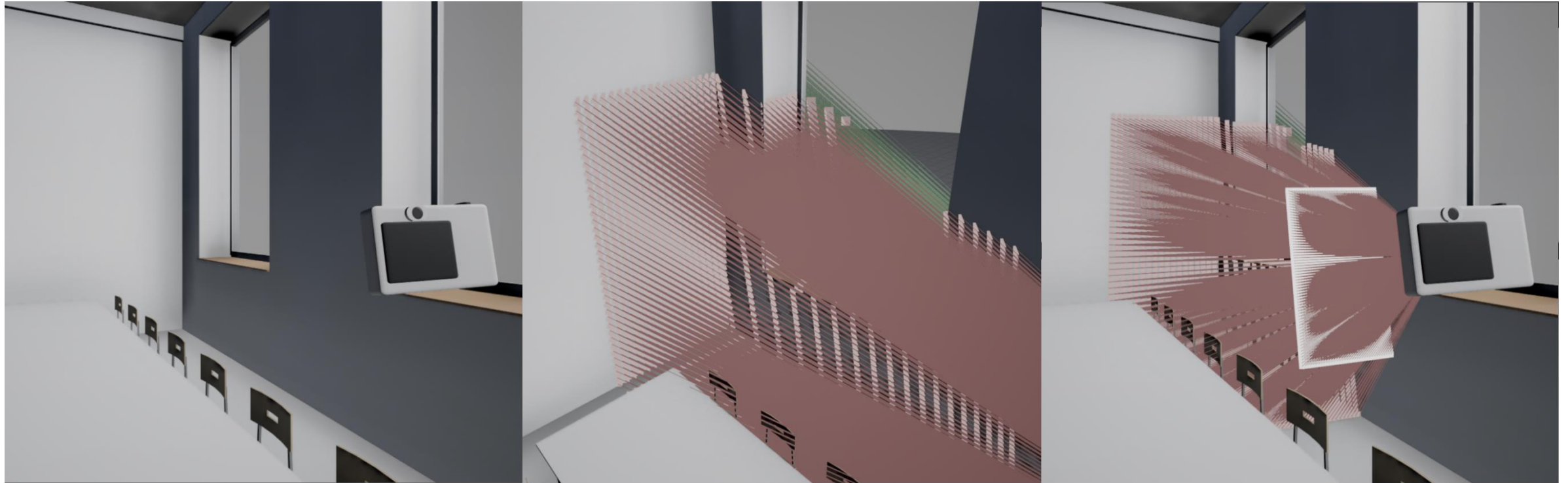


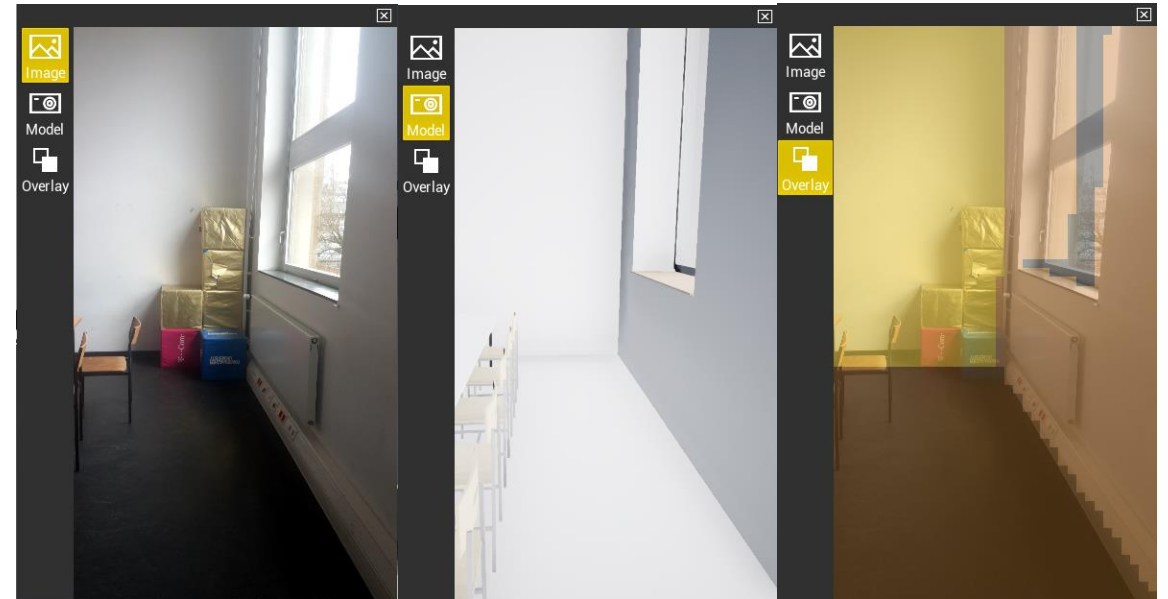
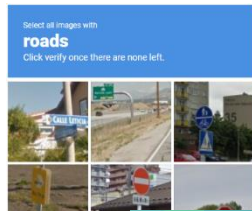
Figure 27: Scene from the pre-processed Byg72 point cloud dataset; (1) un-classified view, (2) classified point cloud data, (3) FPFH descriptor and (4) curvature



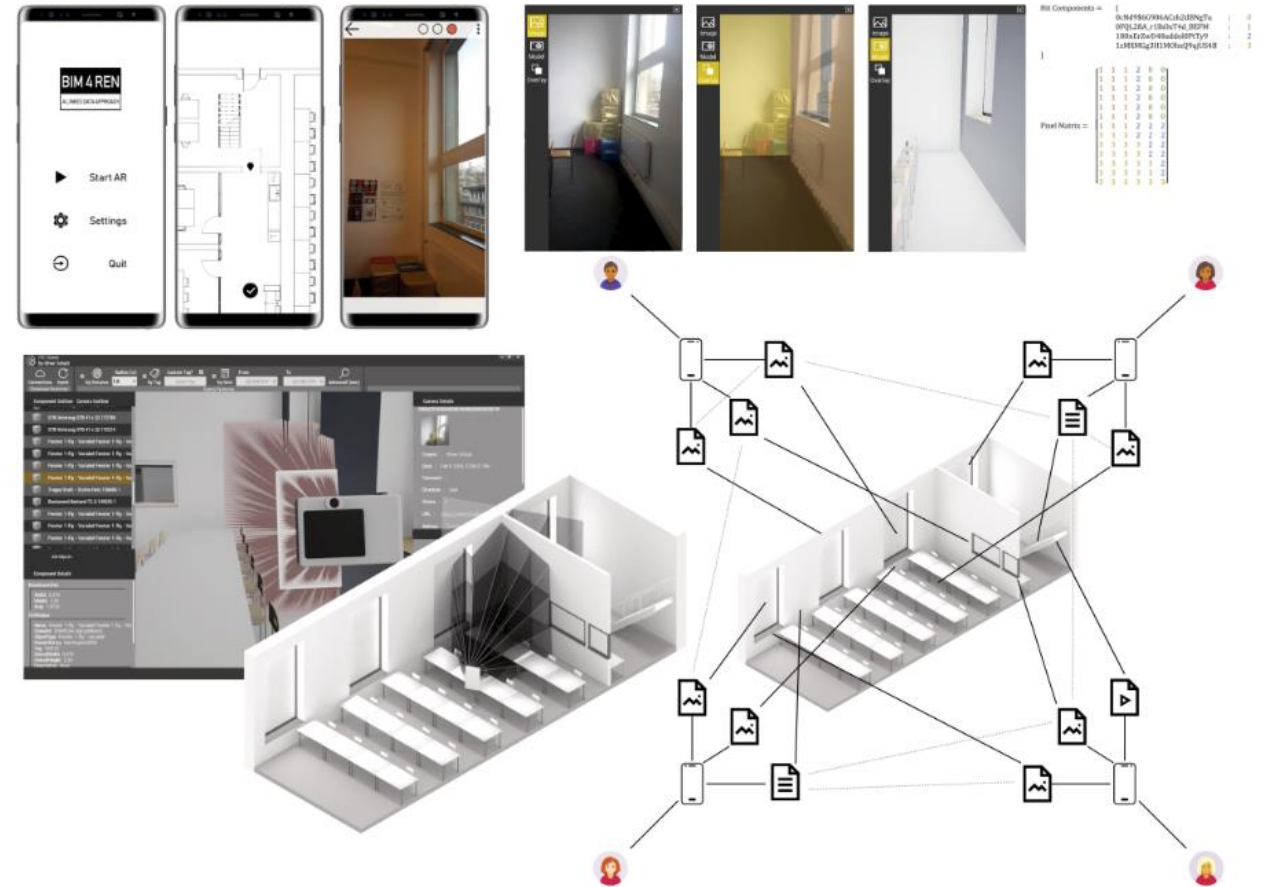
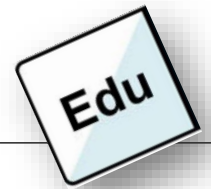
[Vermeulen, 2019]



[Schulz 2019], [Schulz & Beetz]

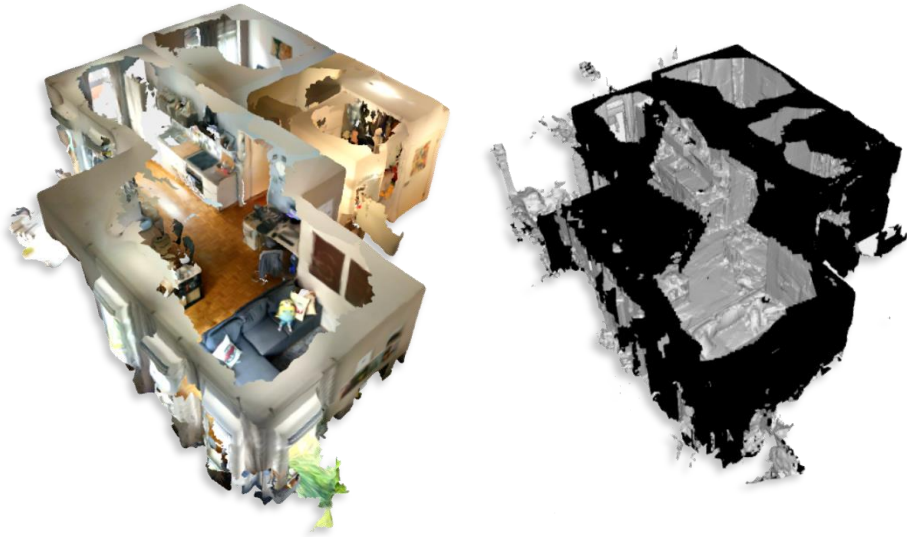


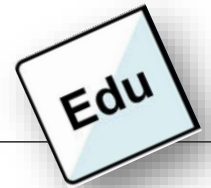
CAIA: Image Acquisition for existing buildings



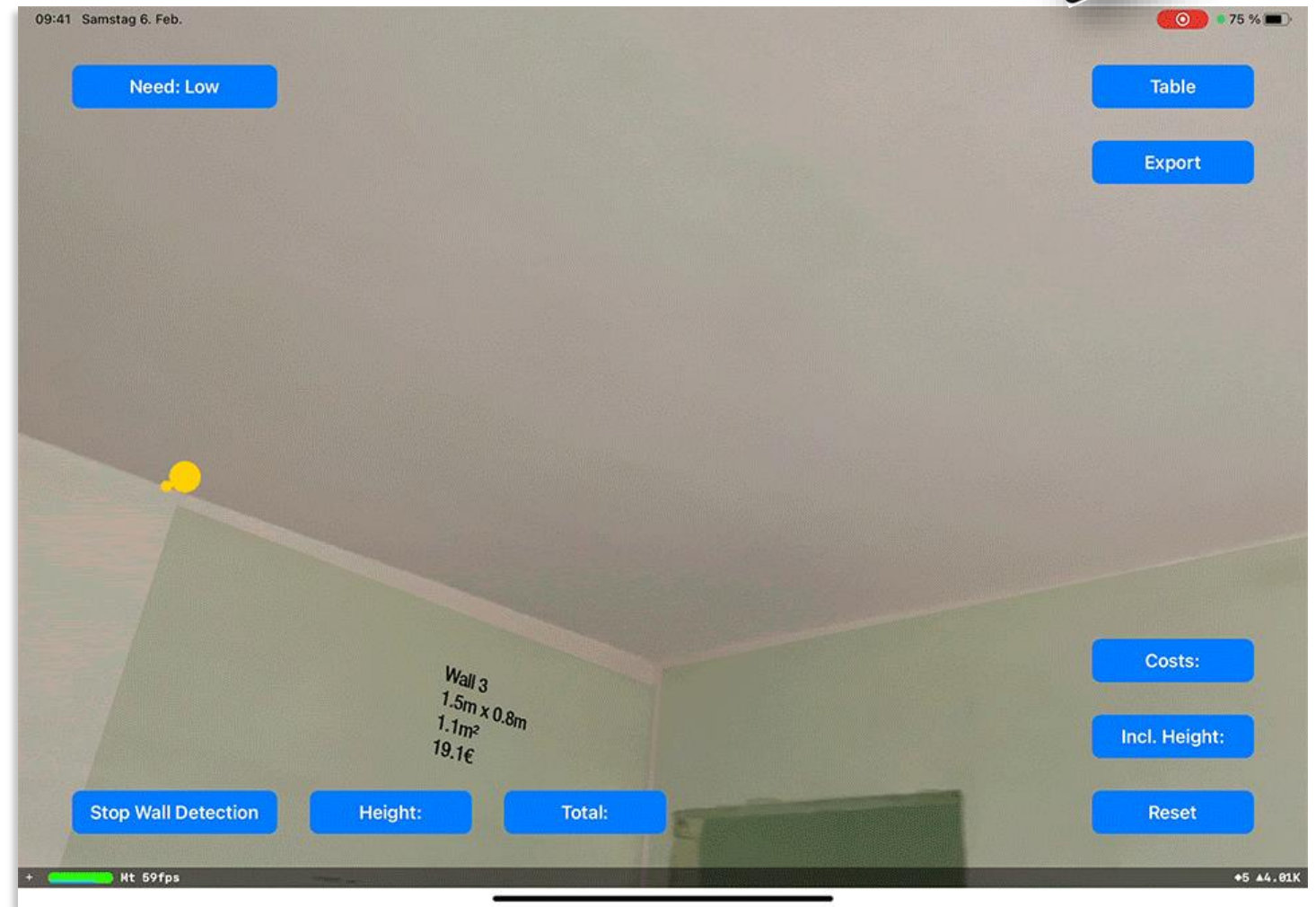
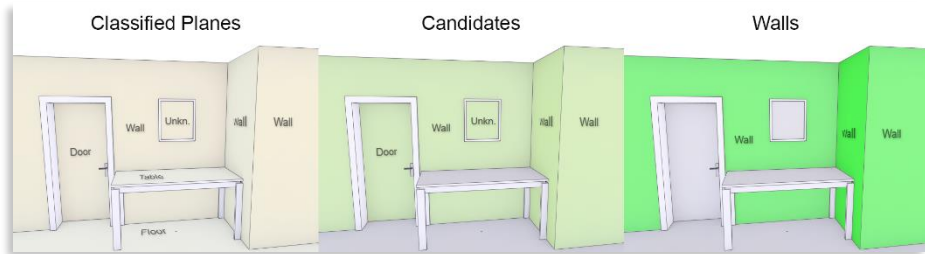
Schulz, O. & Beetz, J. (2019) *Context-Aware Image Acquisition Approaches for Renovation Building Process Using AR and Linked Data* 7th Regional International Symposium on Education and Research in Computer Aided Architectural Design in Europe

Cost estimation using AR on Tablet

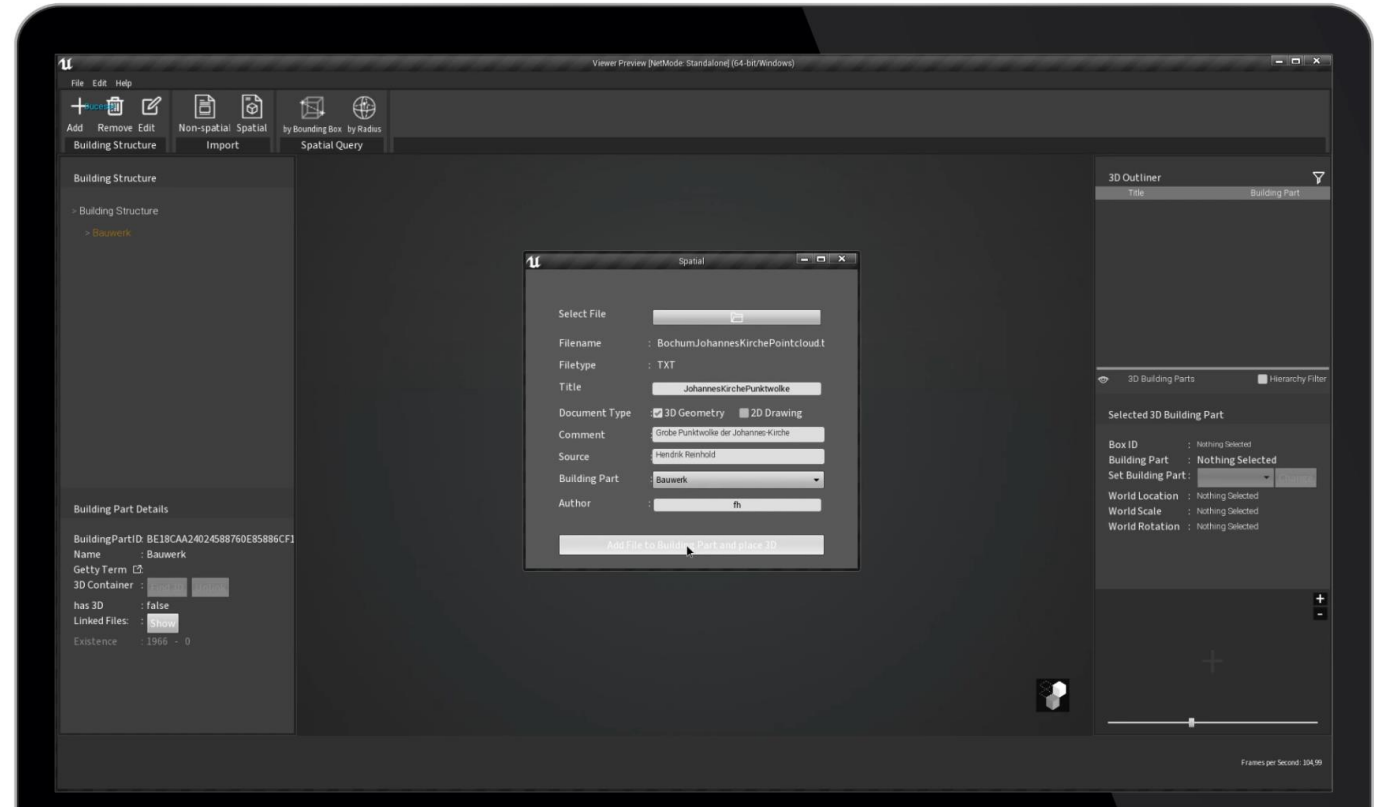
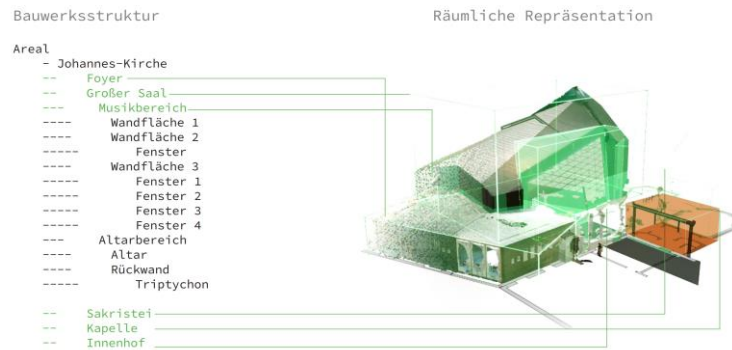




Cost estimation using AR on Tablet



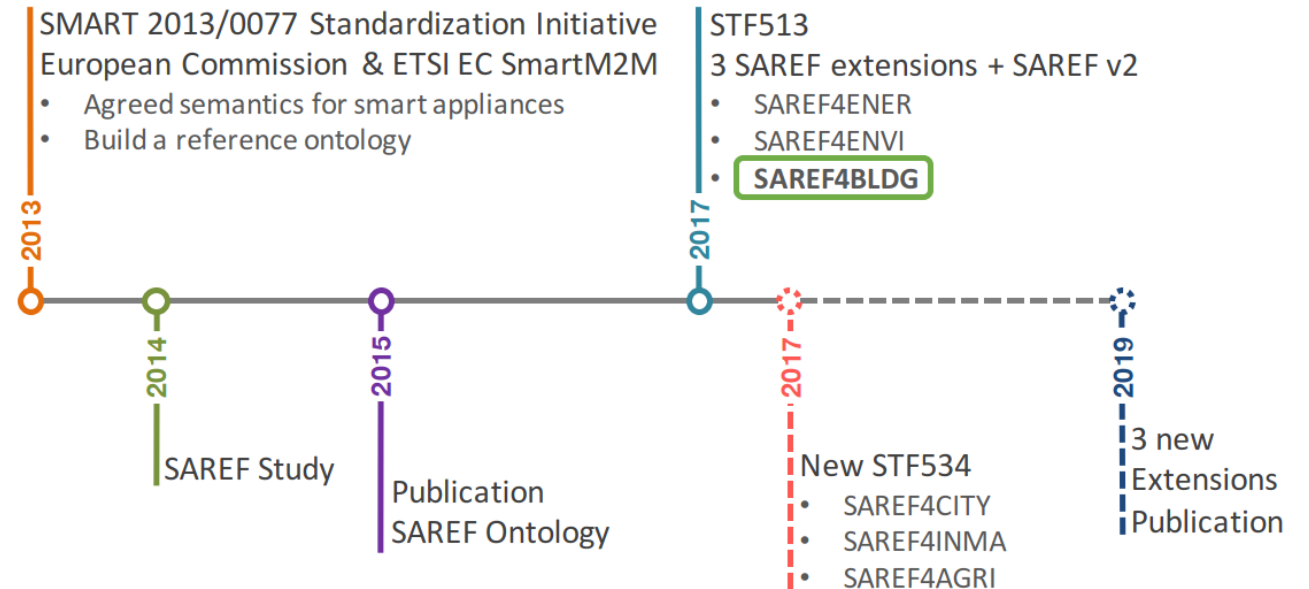
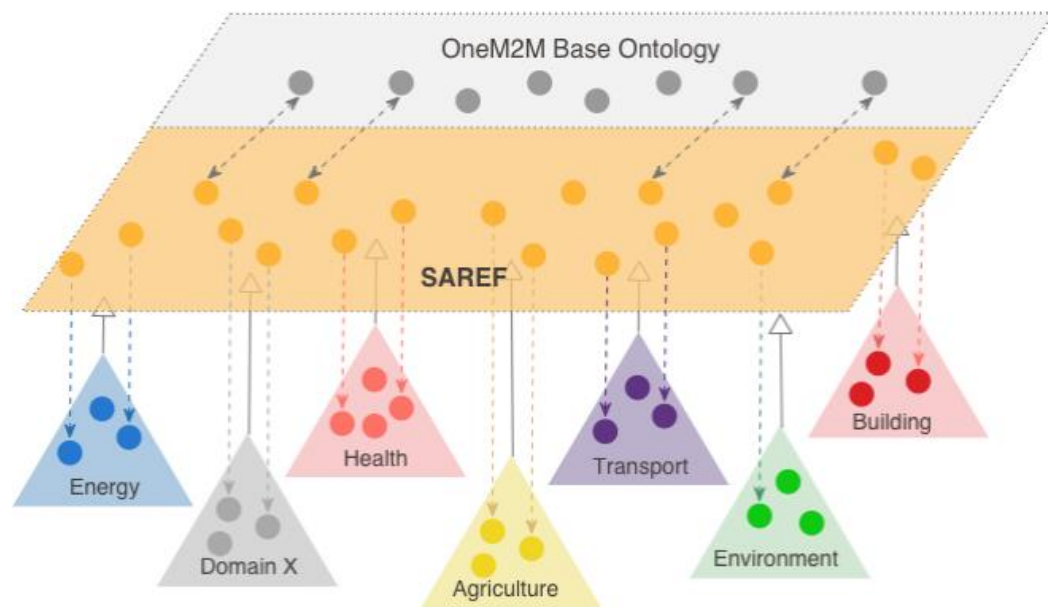
- Integration of existing heritage data structures



Future: Linked DT Data – SAREF [Poveda 2019]

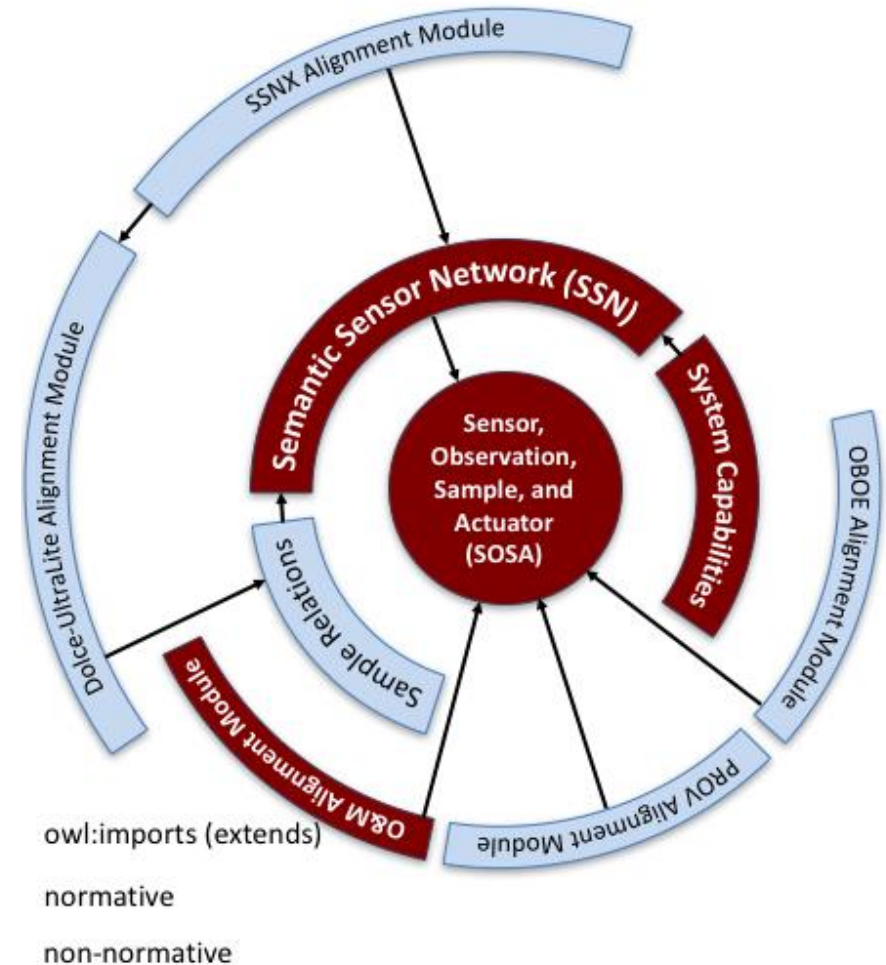
- Legacy sensor integration
- RDF transformation sensor DB into SAREF
- Interlinking into ifcOWL model SPARQL queries
- [source <http://www.oeg-upm.net/>]

This material is partially based on “Extending the SAREF ontology for building devices and topology” by María Poveda Villalón and Raúl García Castro”

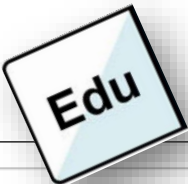


Future: Linked DT Data – SSN Semantic Sensor Network Ontology

- Semantic Sensor Network Ontology
- W3C Recommendation 19 October 2017
- self-contained core ontology called SOSA (Sensor, Observation, Sample, and Actuator)
- Has PROV-O alignment to capture provenance

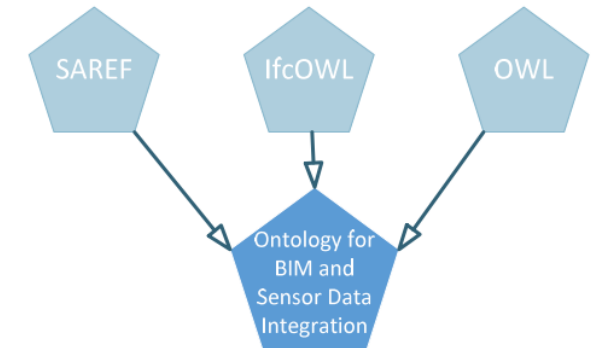
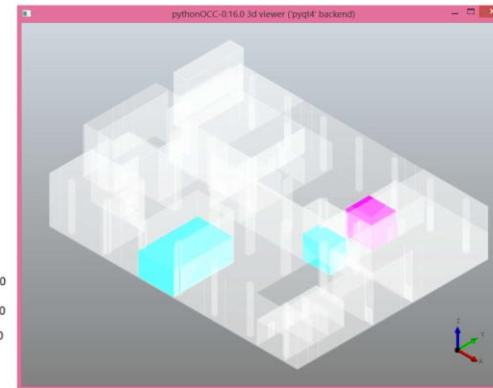
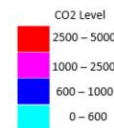
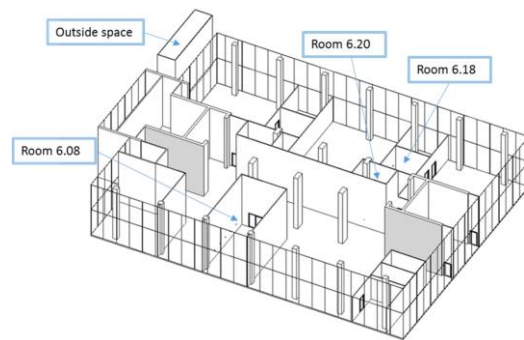


Future: Linked DT Data – SAREF case study [Yu 2016]

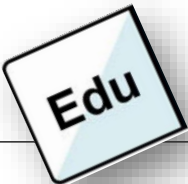


- Integration of 48 legacy sensors
- RDF transformation sensor DB into SAREF
- Interlinking into ifcOWL model
- SPARQL queries over many parameters

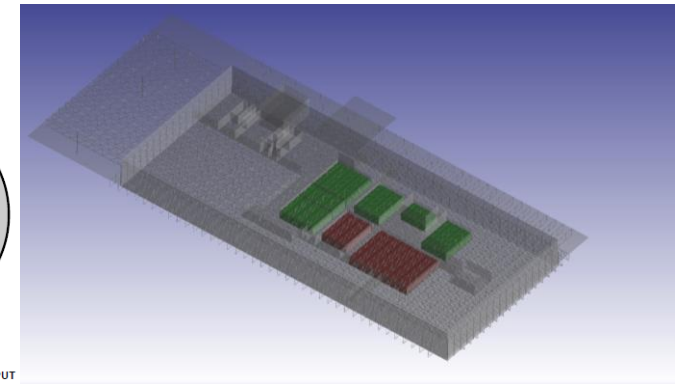
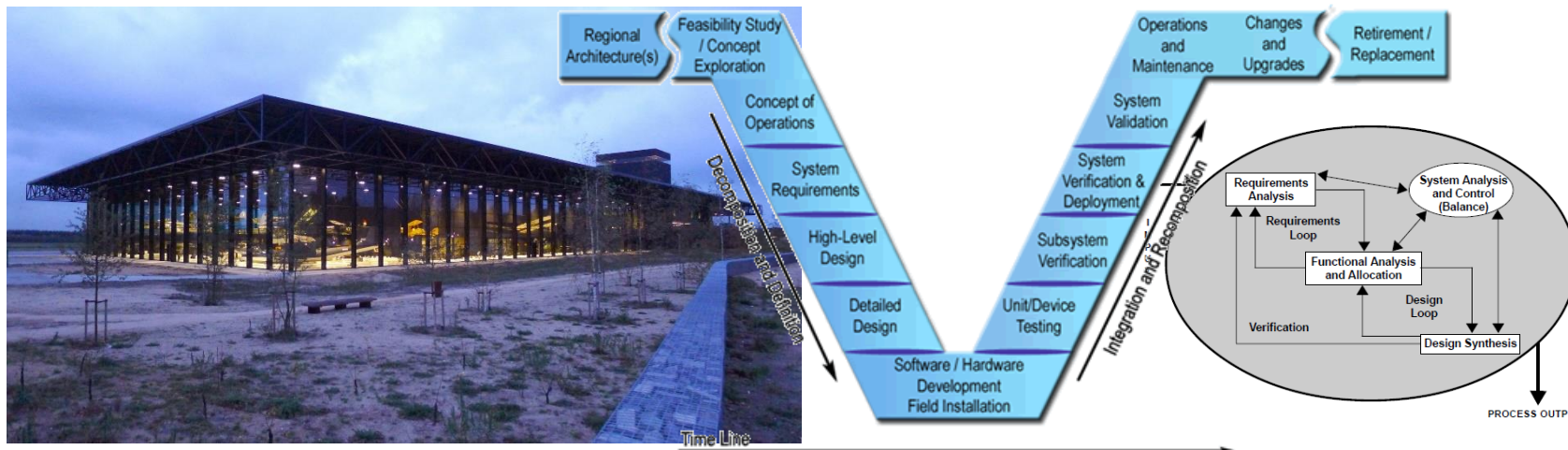
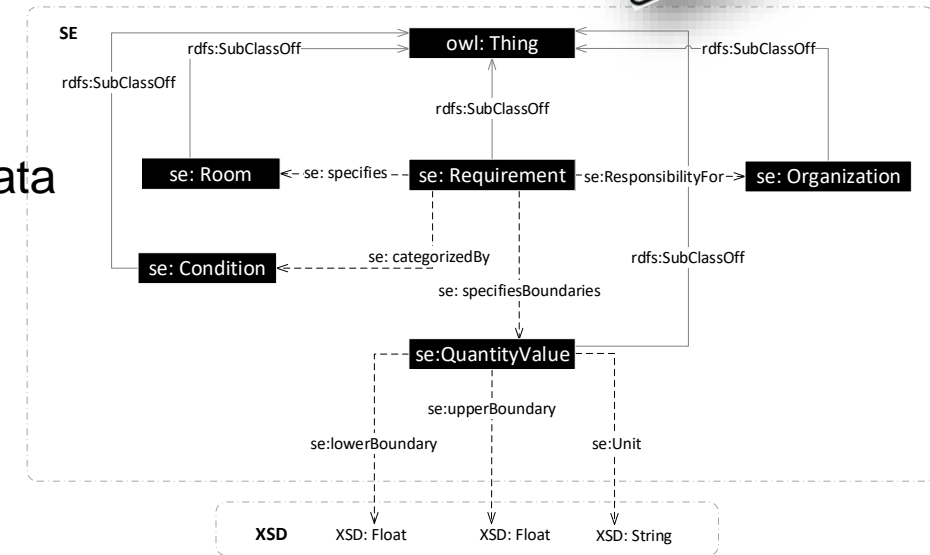
Sensor Name	Log Interval	Unit	Description	Measurement Range	Location	Height	Log Schedule
DT03	00:00:01	m/s	Air speed at 1.1 m		Room 6.08	1.1m	ComfortStatief
DT06	00:00:01	°C	Air temperature at 1.1 m	-30.0 - 65.0	Room 6.08	1.1m	ComfortStatief
DT07	00:00:01	°C	Temperature black globe at 0.6 m	-30.0 - 65.0	Room 6.08	0.6m	ComfortStatief
DT08	00:00:01	%	Relative Humidity at 0.6 m	0.0 - 100.0	Room 6.08	0.6m	ComfortStatief
M03	00:10:00	ppm	CO2	0 - 5000	Room 6.08		Modbus
M38	00:10:00	°C	Temperature	5 - 45	Room 6.18	0.75m	Modbus
M39	00:10:00	%	Relative humidity	0.0 - 100.0	Room 6.18		Modbus
M40	00:10:00	ppm	CO2	0 - 5000	Room 6.18		Modbus
M51	00:10:00	°C	Temperature	-30.0 - 65.0	Room 6.20	0.75m	Modbus
M52	00:10:00	%	Relative humidity	0.0 - 100.0	Room 6.20		Modbus
M53	00:10:00	ppm	CO2	0 - 5000	Room 6.20		Modbus
T_amb_avg	00:01:00	°C	Outside temperature		Vertigo roof		DL_SMS_Mete



Future: Linked DT Data – SSN case study [Kalpoe 2016]

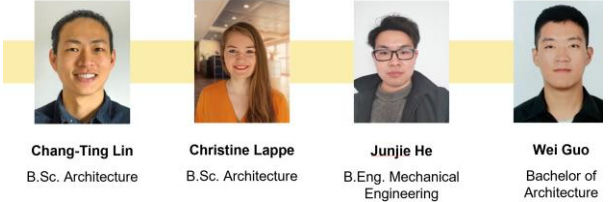
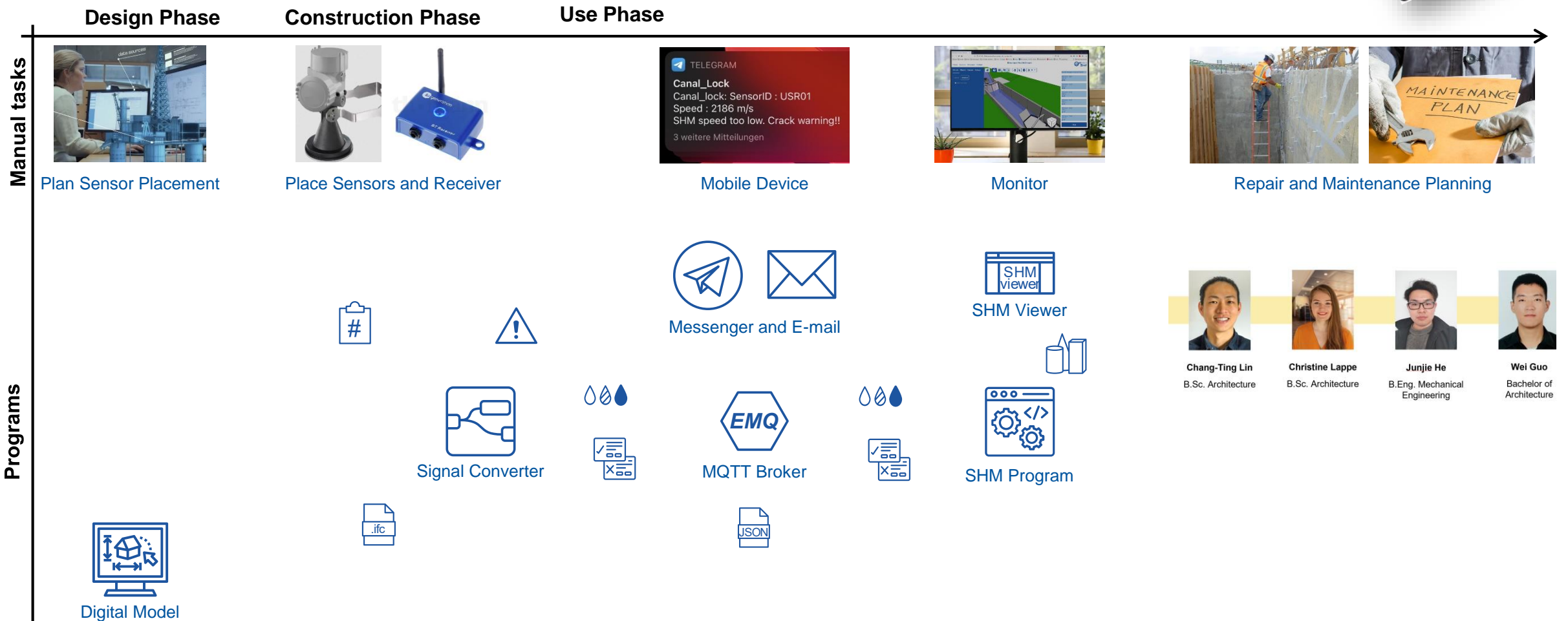
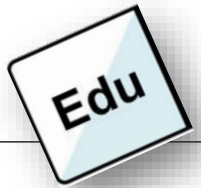


- Kalpoe, Rakesh (2016): The integration of domain-specific building data using linked data. MSc Thesis (prospective)
- Scheduled compliance checks in performance-based (DBFMO) contracts.
- Example: Room sensor data for National Military Museum, Soest
- Use of **DUL**, **SSN**, **QUDT** ontologies augmented with custom Requirements ontology





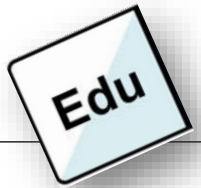
The Concept



Figures: (in read direction) 5, 6, 7, 8, 9, 10, 11



Demonstration

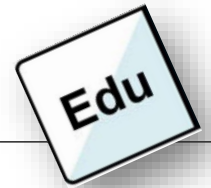


The screenshot displays a Node-RED workflow. On the left, an 'inject' node feeds into a 'delay 12s' node. This is followed by a series of 'delay' nodes (4s, 8s, 12s, 10s, 20s, 24s, 28s, 32s, 30s, 40s, 44s, 48s, 52s) each connected to a corresponding sensor node (R001-R003, USL01-USL07, USR01-USR07). These sensors feed into 'Waterlevel' and 'Concret Senzor Speed' nodes. The 'Waterlevel' node connects to a 'Check Height' node, which then branches into 'set msg height' nodes. The 'Concret Senzor Speed' node connects to an 'Add unit' node, which then feeds into a 'Speed report' node. Both 'set msg height' and 'Speed report' nodes have multiple outgoing paths to various message formatting nodes like 'Detail good', 'Detail too low', 'Warning', 'Color good', 'Color bad', 'Message', and 'Mail warning'. These nodes connect to 'msg.payload' and 'msg.height' nodes, which then connect to 'NoNode' and 'Telegram sender' nodes. The 'Telegram sender' nodes are connected to a Telegram chat window on the right, which shows a notification: 'You have created a group. Groups can have: • Up to 200,000 members • Persistent chat history • Public links such as t.me/title • Admins with different rights'. Below the notification is a red banner with the text 'Keine älteren Mitteilungen'.

Viewer: https://christine-lappe.github.io/christine-lappe.github.io/embeddedDemos/assign_color_to_object.html



User Surface and Interaction



WLAN Entsperrt 38 %

SHM report
Sensor : USR04
Return speed : 4286 m/s
3 weitere Mitteilungen

TELEGRAM
Canal_Lock
Canal_lock: SensorID : USR01
Speed : 2186 m/s
SHM speed too low. Crack warning!!
3 weitere Mitteilungen

GMAIL
Message from Node-RED
SensorID : USR01 Speed : 2186 m/s SHM speed too low. Crack warning!!
3 weitere Mitteilungen

SHM Object-Viewer - OnePiece

127.0.0.1:5500/embeddedDemos/assign_color_to_object.html

Sport Rezepte E-Mail Bewerbung DE SHM Water Infrastruct... Skills Google YouTube sciebo RWTHmoodle RWTHonline Aachener Bank Pinterest CoRo Google Maps Weitere Lesezeichen

Home Sensors Overview Contact

Structural Health Viewer

NEPIECE SHM

Models Objects Classes Storeys

Load all Unload all

WaterLock Design

Recent changes of Sensor USR06

2021-2-21 18:24	4.50 m	good
2021-2-21 18:25	5.00 m	good
2021-2-21 18:25	5.05 m	good
2021-2-21 18:27	5.05 m	good
2021-2-21 18:27	5.10 m	good
2021-2-21 18:28	5.10 m	good

clear

Use cases: Predictive maintenance

SIB-Bauwerke

Stadt Bad-Breisig SIB-BAUWERKE Übersichtsblatt

Bauwerksnummer **061001** 1 Interne Bwnr: **06-1-001** Bad Breisig

Name: Zufahrt Industriegebiet Goldene Meile/Überführungsbauwerk

Bemerkung:

Art: Plattenbrücke

Konstrukt.: Schlaffbewehrte Stahlbetonplatte

Stadium: Neubau fertig gestellt, nicht unter Verkehr

Stat. Sys. L: Mehrfeldrig mit Durchlaufwirkung

Stat. Sys. Q: Echte Platte quer biegesteif, Flächentragwerk

Am: Stadt Bad-Breisig

SM:

Zustand: 1,6 HP: 25.11.2013 2013 EP: . . . 0

BrKl: LM1 MLC RJK: Baupjhr: 2013

NR-Stufe: 0 NR-Klasse: NR-Nutzungsdauer bis: 0

Bst. Ubb.: Stahlbeton

Q UBB: Einstegiger Überbau als Vollquerschnitt

Q HTW: Einteiliger Vollquerschnitt

Felder: 2 Sbr: 15.42 - 12.48 m

Ges. Länge: 27,90 m
Breite: 10,35 m
Br Fläche: 320 m²
Winkel: 1,70 - Links gon
U/UA: U/UA bei Gemeinde
Baulast: Gemeinde

Lager	Straße	Von-Nr.	Nach-Nr.	Nahbereich absehb.	Station Mitte [m]	KM	Min B [m]	Min H [m]	Schilder StV/Menge
O:	G						6,35		
U:	G						8,00	7,20	

U: Gleis der DB, elektrifiziert DB-Strecke 2630 Köln-Koblenz

Buttons: Tabelle, Suchen, Zurück, Zustand, Druck / PDF, Bilder, Zeichnungen, Dokumente

Bundesland Landesbetrieb für Straßenbau SIB-BAUWERKE

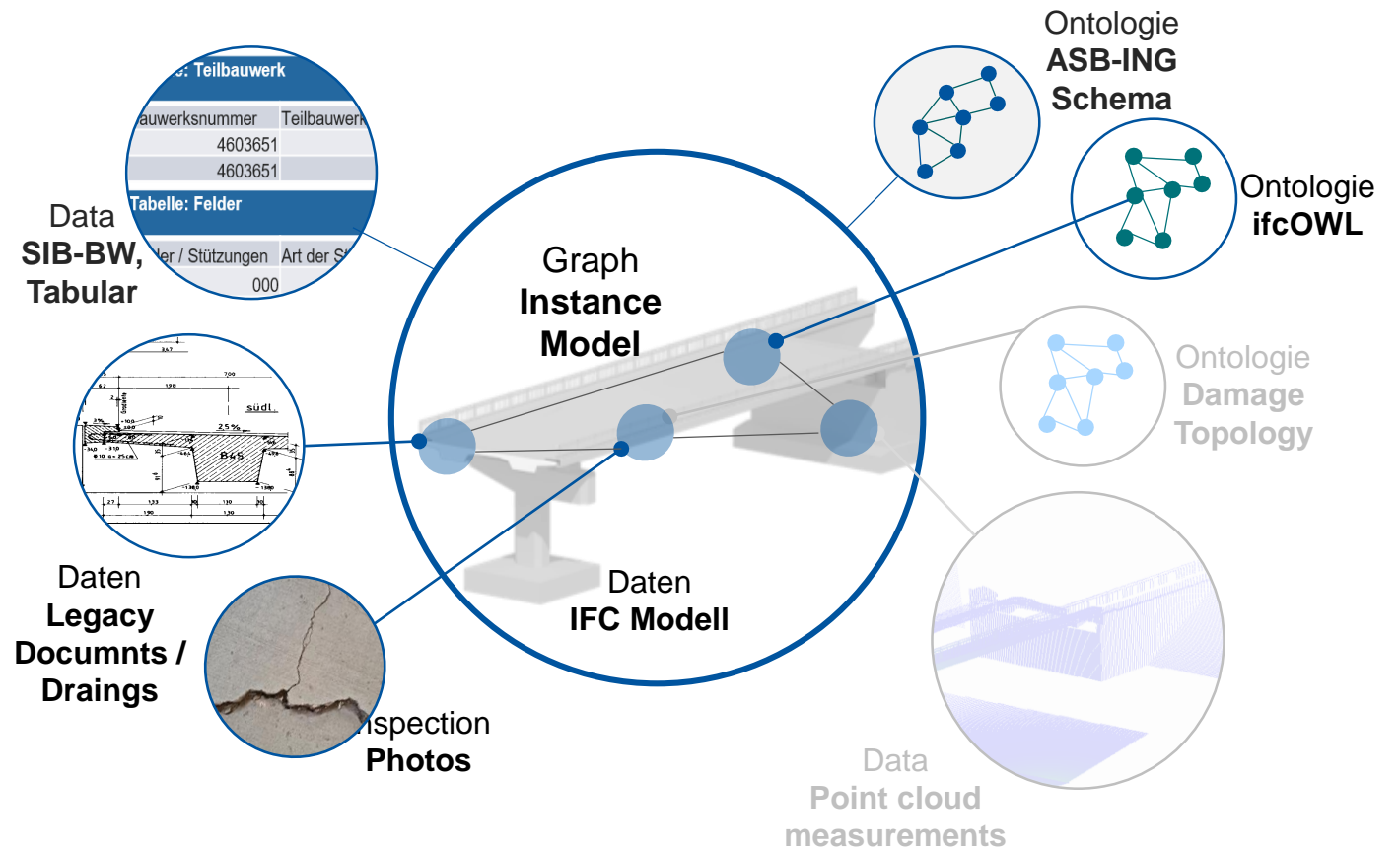
Buttons: Zu den Bauwerken, Übersicht, BW-Daten ausgeben, BW-Daten einlesen, Auswertung, Administration / Einstellungen, Ende, Bedienungsanleitung, Info, Dokumentation

Zentrale Datenbank

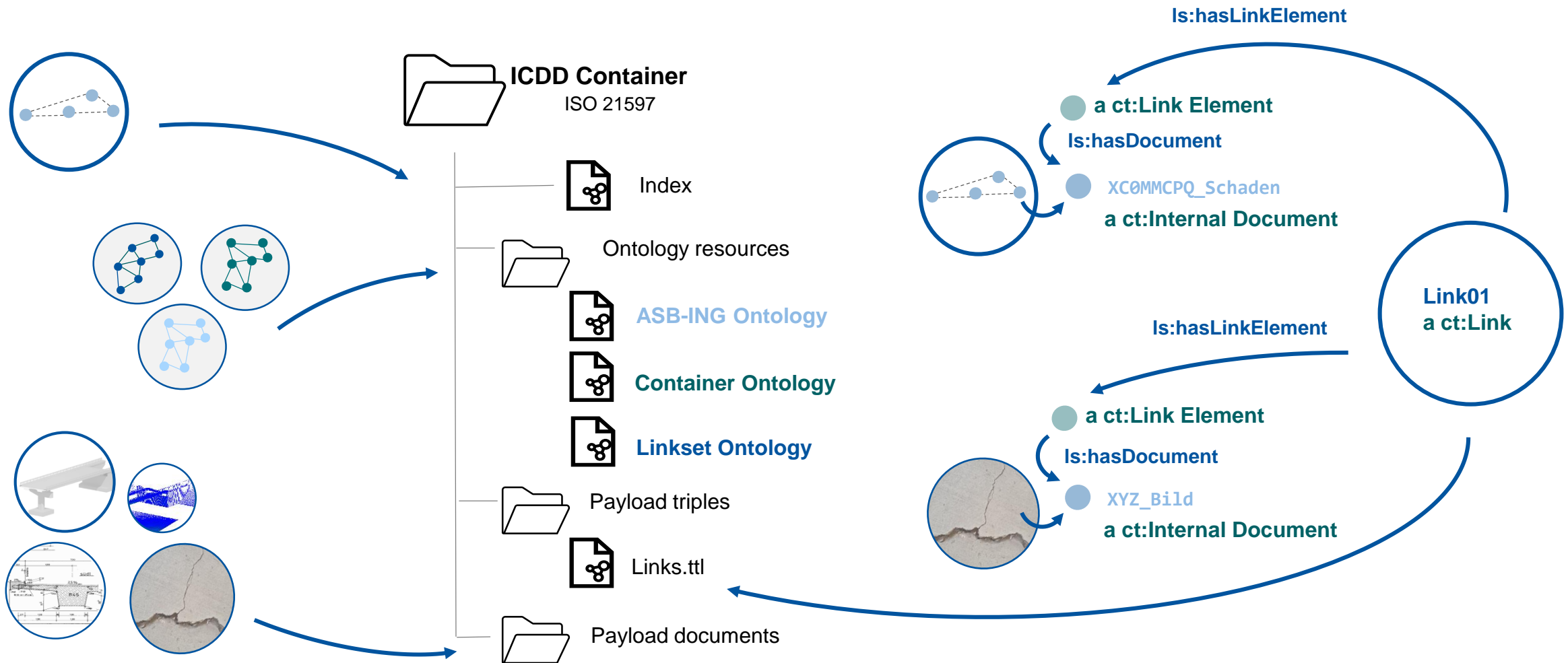
Buttons: CLOSE X

Linking and long-term DT for SIB-BW graph with IFC Model, Pictures, Plans

- ✔ Convert IFC Model to LBD Graph (IFC OWL, BOT,...)
- ✔ Mapping of IFC (Bridge) Ontology to ASB-ING Ontology
- ✔ Linking of building elements instances between SIB-BW and IFC OWL graph
- ✔ Creating ICDD Structure for SIB-BW Data, Model, Pictures, Damages..
- ✔ Linking Damage Pictures to building elements
- ✔ Locate damages in the model, Link between damages and elements

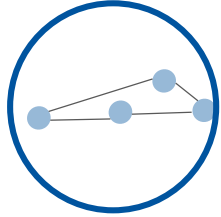


ICDD Container Structure



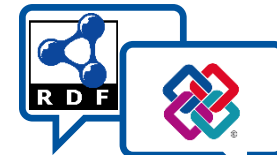
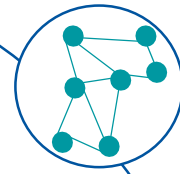
Linking SIB-BW Graph with IFC Model

SIB-BW Graph

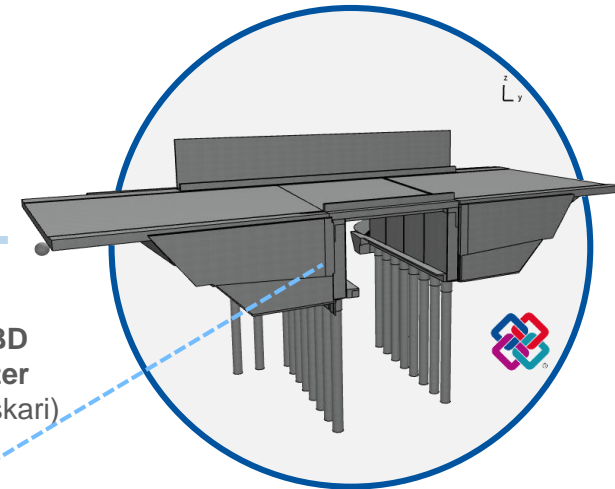


```
inst:wall_4e99b1ef-d1cf-4df6-824b-1b26b5836045
  a                               bot:Element ;
  props:baustoff_simple           "Stahlbeton" ;
  props:bauteilklassifikation_simple
    "N_WDL_SA" ;
  props:betonguete_simple         "C30/37" ;
  props:betonstahl_simple         "B500B" ;
  props:bewehrungsgrad_simple     "149.74"^^xsd:double ;
  props:bezeichnung_simple        "Widerlager" ;
  props:einheit_simple            "m\\X2\\00B3\\X0\\" ;
  props:expositionsclassen_simple
    "XC4 XD2 XF2 WA" ;
  props:globalIdIfcRoot_attribute_simple
    "1EcR7lqSzDze9B6oQrWs15" ;
  props:ifcBauteilkategorie_simple "IfcWall" ;
  props:klassifikation_simple     "Widerlager" ;
  props:LOD_simple                "400."^^xsd:double ;
  props:lebensphase_simple        "Neubau" ;
  props:modellelement_simple     "N_WDL_SA_01" ;
  props:nameIfcRoot_attribute_simple
    "Widerlager" ;
  props:objektname_simple         "Wand" ;
  props:richtzeichnung_simple     "F1\\X2\\00FC\\X0\\ 1, Bild 1" ;
  props:standardleistungsnummer_simple
    "12.914.2/110 09 08 05 01 TA" ;
  props:volumen_simple            "436.72"^^xsd:double ;
  owl:sameAs                    inst:IfcWall_48304
```

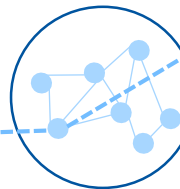
LBD Graph



IFCtoLBD Converter
(Jyrki Oraskari)

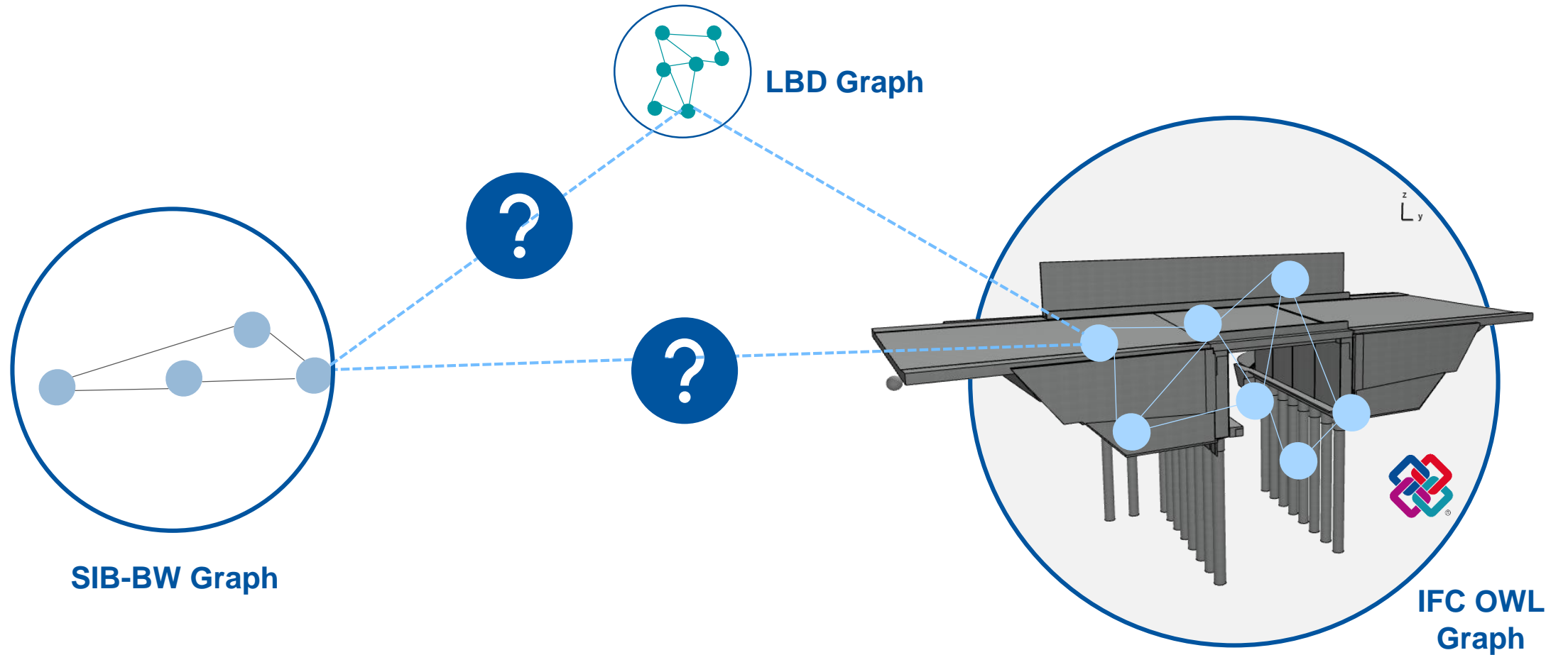


IFC Model



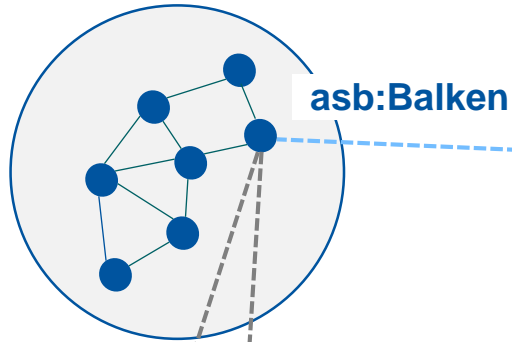
ifcOWL Graph

Linking SIB-BW Graph with IFC Model

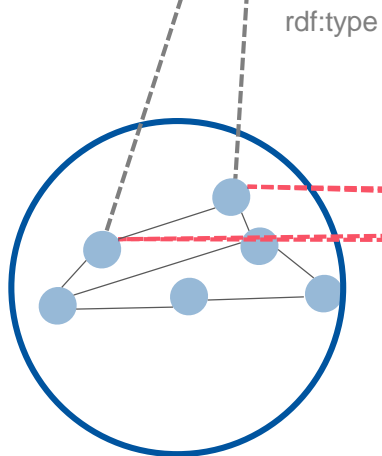
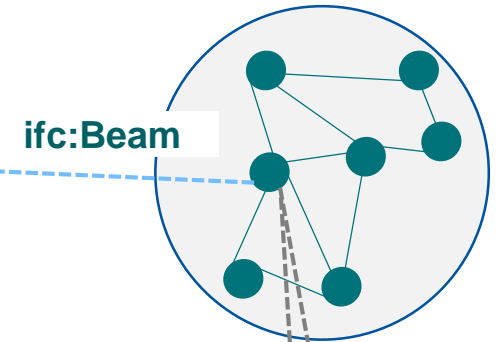


Linking SIB-BW Graph with IFC Model – Mapping of classes and elements

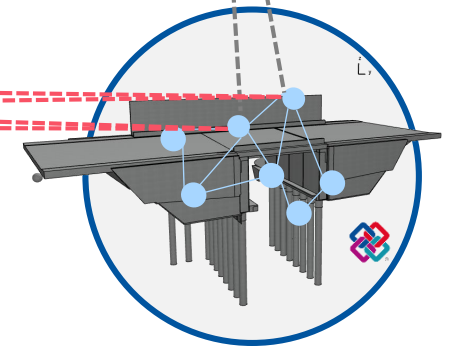
ASB-ING Ontology



IFC (Bridge) Schema / ifcOWL Ontology



SIB-BW Graph (Instance)



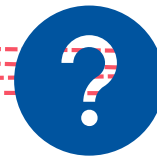
IFC OWL Graph (Instance)

owl:SameAs

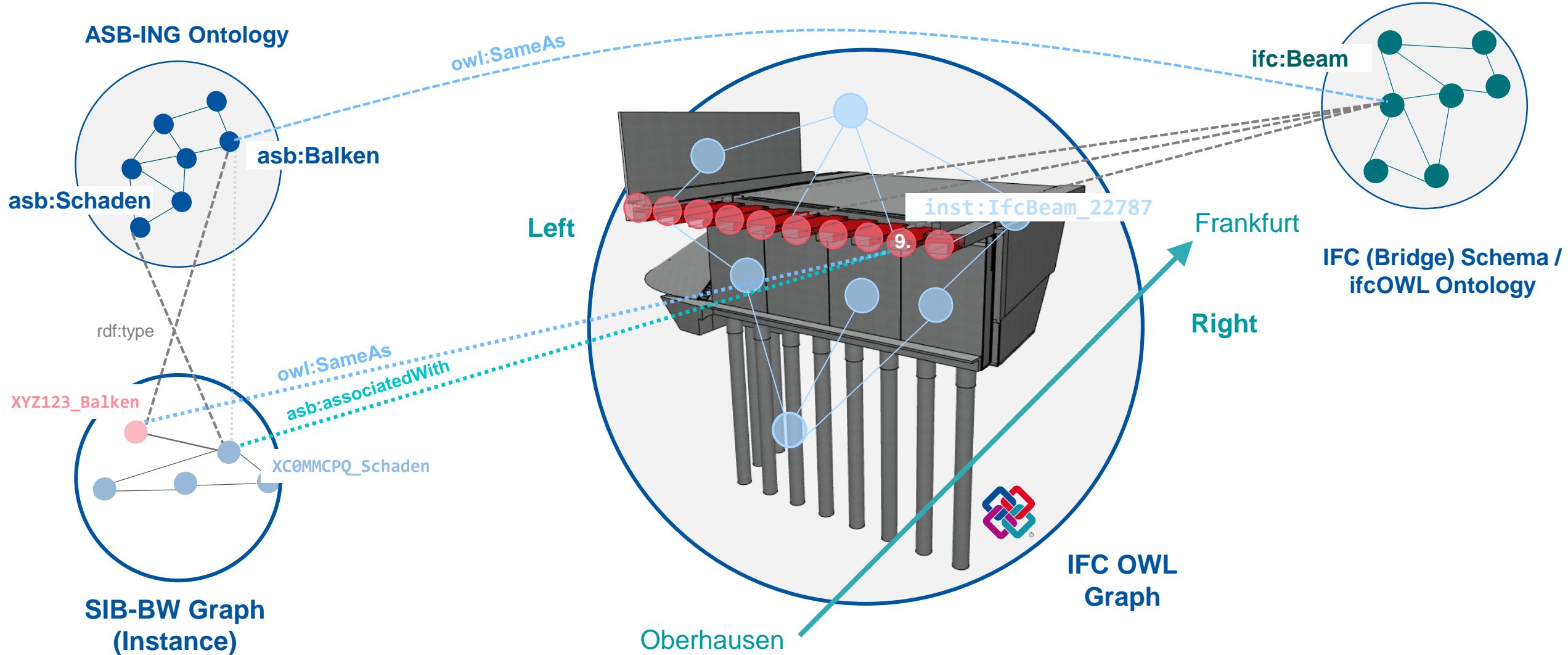
ifc:Beam

rdf:type

rdf:type



Linking SIB-BW Graph with IFC Model – Mapping of classes and elements





Use cases: Linked Road information models

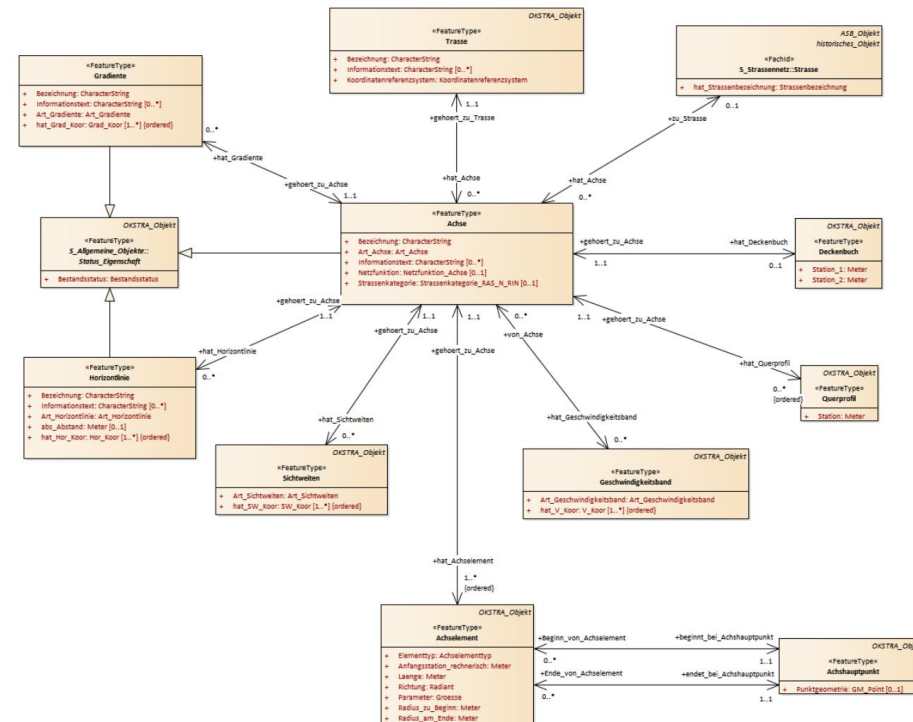
Example use cases:

- Find a route for a heavy freight transport **across different countries**
- Query traffic cameras **along international roads** → traffic forecast
- Orchestrate construction and maintenance work **across major transportation axes in Europe**



[Beetz & Borrmann 2018]

- German Road Data Model
- Very comprehensive data model
- More than 3,800 entities, 14,000 attributes
- Covers design, condition, maintenance, equipment, traffic, accidents, etc.
- Mandatory in public projects
- Implemented in commercial products
- Modelled in UML, mapped to XML-Schema
- Geometry: GML
- German denominators



Paket S_Administration
Paket S_Allgemeine_Geometrieobjekte
Paket S_Allgemeine_Mengenberechnung
Paket S_Allgemeine_Objekte
Paket S_Arbeitsstelle_an_Straßen
Paket S_Bauliche_Strasseneigenschaften
Paket S_Bauwerke
Paket S_Dynamische_Beschilderung
Paket S_Dynamische_Verkehrsdaten
Paket S_Entwurf
Paket S_Flaechenmodell
Paket S_Grunderwerb
Paket S_Hausnummern
Paket S_Historisierung
Paket S_Kataster
Paket S_Kostenmanagement
Paket S_Kreuzungen
Paket S_Landschaftsplanung
Paket S_Lichtsignalanlage
Paket S_Liegenschaftsverwaltung
Paket S_Netzaenderungsprotokoll
Paket S_Oekologie
Paket S_Organisation
Paket S_Projektressourcen
Paket S_Pruefdaten
Paket S_REB_22013
Paket S_Schwertransport
Paket S_Statische_Beschilderung
Paket S_Strassenausstattungen
Paket S_Strassennetz
Paket S_Strassenverzeichnis
Paket S_Strassenzustandsdaten
Paket S_Topografie
Paket S_Umfeldmessstelle
Paket S_Unfall
Paket S_Verkehr
Paket S_Vermessungspunkt

Rijkswaterstaat Object Type Library (RWS-OTL)

- Ontology of the Dutch Ministry of Transport
 - Multiple domains, including roads
- Part of the Dutch BIM for Roads practice
- Defined in OWL
- Describes network, roadway, layers
- Geometry outsourced to common GML format and linked in containers
- Linked to national “upper ontology” Concept Library CB-NL

The screenshot shows the Rijkswaterstaat Object Type Library (RWS-OTL) website. The header includes the logo of the Rijkswaterstaat Ministry of Infrastructure and the Environment. The main content area displays the 'WEGMENT' (Road Segment) ontology page. The page is structured with a navigation menu at the top, a taxonomy tree on the left, and a detailed view of the 'WEGMENT' class on the right. The detailed view includes a description, meta-information, and diagrams illustrating the road segment types.

WEGMENT
IN00029

View: Alles

Taxonomie

- FunctionalRoleType
- Configuratietype
- Weglink
 - Wegment

WEGMENT

IN00029

Info

u0-1.0 3 jaar geleden gewijzigd Functionaalroltype

— Model: OTL Conceptueel model

Definitie

Verbinding tussen twee Intersecties, bestaande uit een van moment tot moment mogelijk wisselend aantal en in de tijd daardoor toenemend aantal Wegvakken.

Meta informatie

Description Een Wegment wordt gedurende zijn hele levensduur begrensd door precies dezelfde twee Intersecties.

Name in EN Road Segment

Inwinstuctie-Aanvullende RWS-eisen

In een gerelateerd document dient de ontwerpbeschrijving van de WOL, zijnde het horizontaal en het verticaal alignment, opgenomen te worden. De LineString (GML-string) van het gehele wegsegment of een gedeelte daarvan (vanaf een raakvlakjunctie/projectgrens) dient te bestaan uit lijnstukken van maximaal 10 meter met in het horizontaal en verticaal alignment. De Z-waarde van de LineString dient 0 te zijn. De LineString kan worden afgeleid van de theoretische as. (Overgang is het punt waar het alig een overgangsbog of naar een boog). In een gerelateerd document dient de ontwerpbeschrijving van de WOL, zijnde het horizontaal en het verticaal alignment, opgenomen te worden. WOL: De Weg Oriëntatie Lijn (WOL) bepaalt het verloop van de weg en kan gezien worden als de hoofdas van de weg. Deze hoofdas heeft een 3D-verloop door de combinatie van het Alignment van de weg.

Op een weg met een even aantal hoofdrijbanen bevindt de wol zich in de middenberm.

Op een weg met een oneven aantal hoofdrijbanen bevindt de wol zich op de (middelste) hoofdrijbaan.

Noot: Er kunnen uitzonderingen zijn doordat b.v. de linker- en de rechterbaan van een Rijksweg volledig gescheiden zijn en ieder hun eigen horizontaal- en verticaal alignment, los van elkaar, hebben.

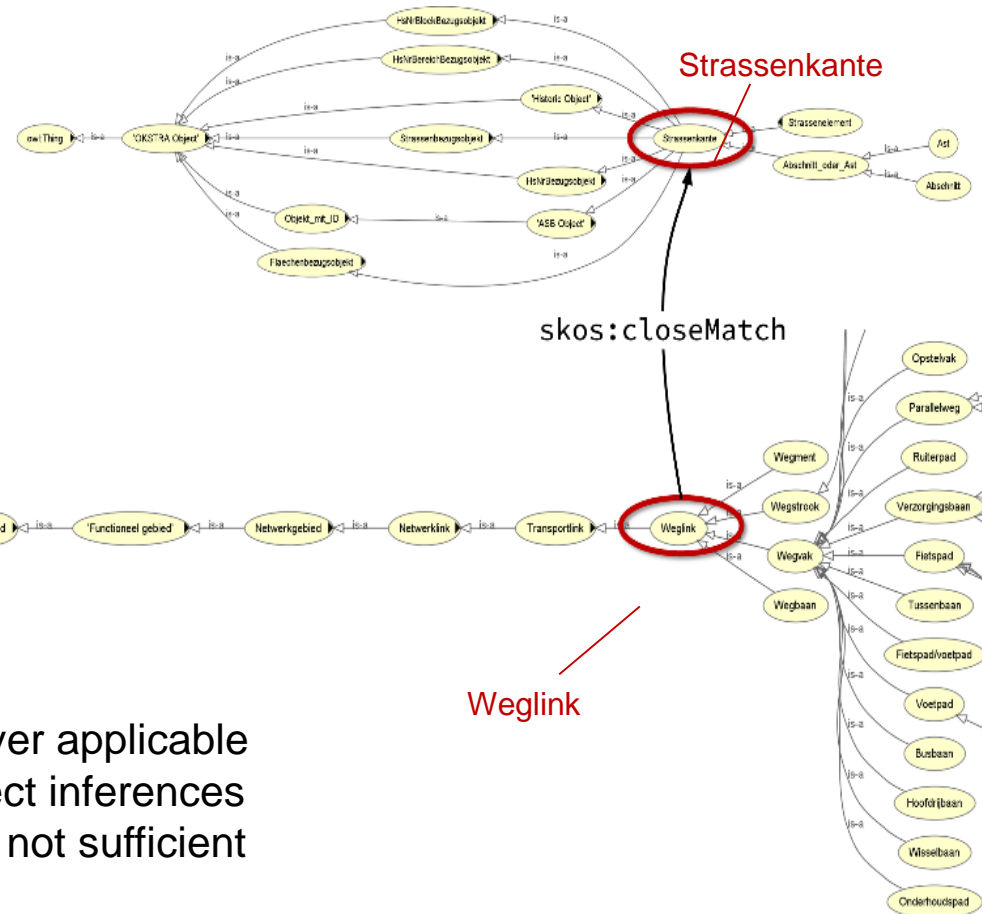
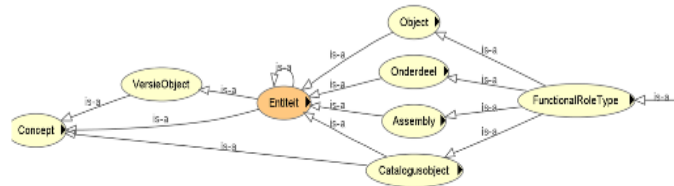
Comment - Wegment alleen in de nieuwe situatie instantiëren - Wegment bij knooppunten denkbeeldig doortrekken tot aan het snijpunt van de WOL's.

source: <https://otl.rws.nl/publicatieomgeving/#/>

Linking okstraOWL and RWS-OTL

Explicit linking

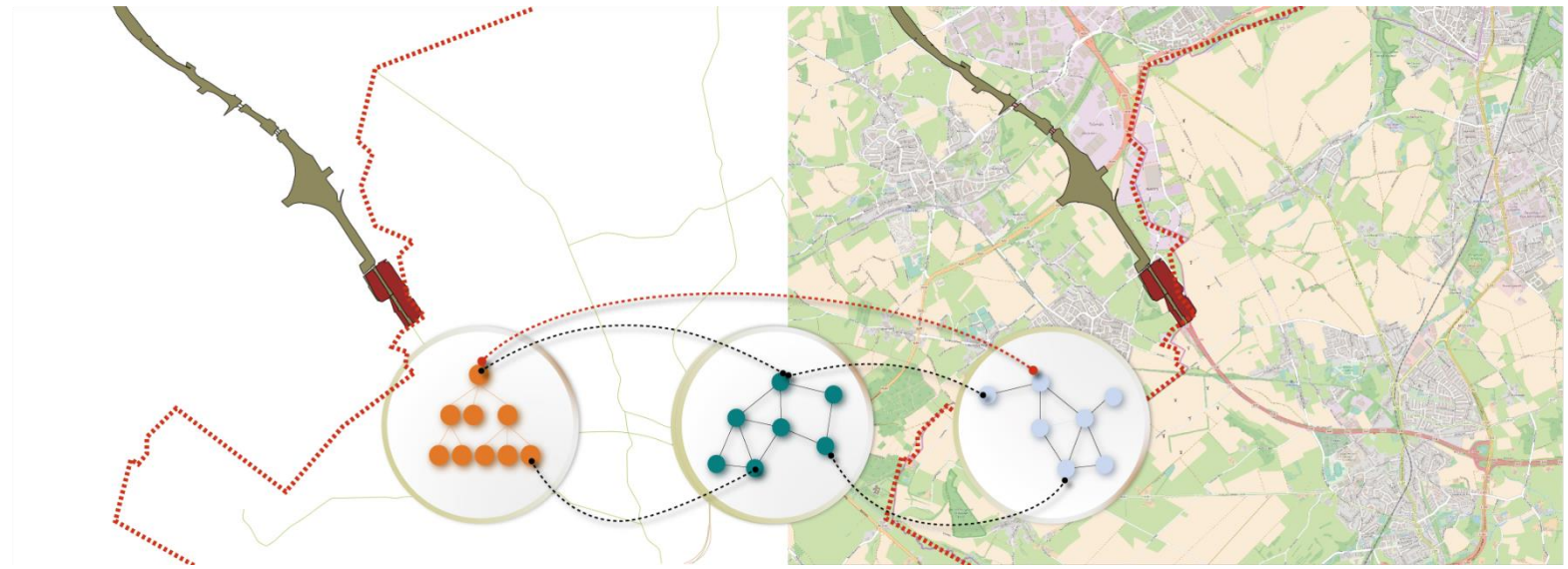
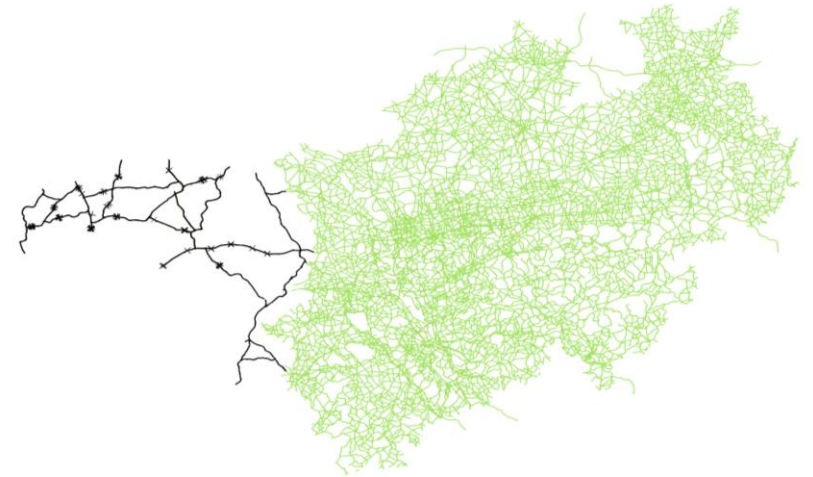
owl:sameAs
owl:equivalentClass



- Semantically strong links almost never applicable
- Weak semantic links prevent incorrect inferences
- Automated pre-alignment useful but not sufficient

Linked Data in Road Construction: Scenario 1: Explicit mapping of RWS-OTL and OKSTRA data sets

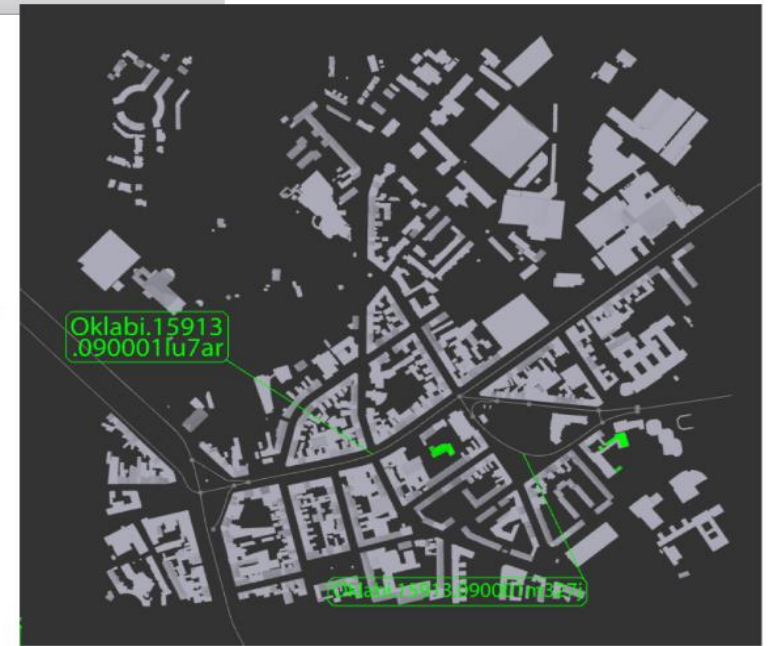
- okstraOWL and CB-NL instance data
- Additional classifications of road sections through schema mappings and SPARQL rules
- Graphs of > 140 Mio triples
- Queries across (physically distributed) graphs



[Beetz & Borrmann 2018]

Scenario 2: Implicit mapping OKSTRA with CityGML

- Integration of LOD2 CityGML data sets (Open Geo Data NRW federal state)
- Intensive use of GeoSPARQL functionalities
- “Retrieve all kindergardens with a distance $< 100\text{m}$ to highways“

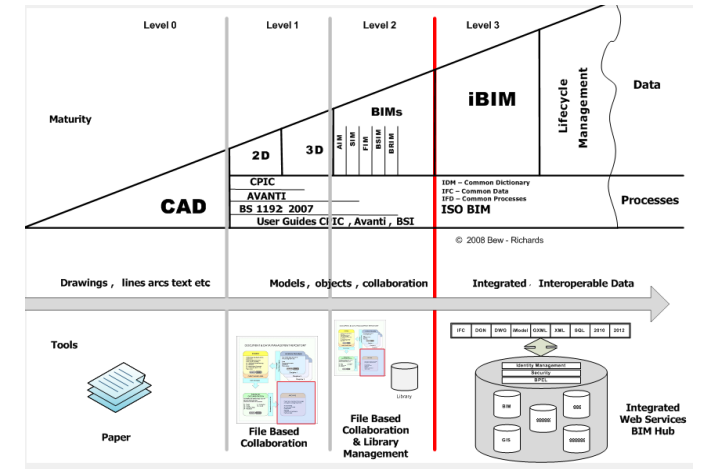


[Beetz & Borrmann 2018] [Zheng 2017]

Design Computation Curriculum in Arch. B.A.

Kontext im Curriculum des Bachelor Architektur

Level 0	Level 1		Level 2	Level 3	
CAD	2D	3D	Federated BIMs	Integrated BIM	DC.start DC.littlebim DC.BIGBIM DC.B DC.M1, M2, M3
	Proprietary Formats				
Drawings	Geometric models		Coordinated Discipline specific BIM models	Integrated, interoperable Building Information Models for the entire life-cycle	Exchange Formats
Paper	File-based collaboration		Central management of files (Common Data Environment), Shared libraries	Cloud-based model management (BIM Hub)	Coordination and Collaboration



- [Borrmann König, Koch, Beetz 2015] auf Bew & Richards basiert

Design Computation Curriculum | Bachelor

Studienverlaufsplan des Bachelor of Science in Architektur nach der Prüfungsordnung 2019

Studienbeginn nur im Wintersemester



* Sofern ein Freies Projekt im Ausland belegt werden soll, das wesentlich in Inhalt, Umfang und Anforderungen von diesem Modul abweicht, wird eine Überprüfung der Anerkennbarkeit im Rahmen des Learning Agreements vor Antritt des Austauschs dringend empfohlen.

- Fachmodule
- Projekte
- Profilerung / Mobilität
- Pflichtmodule
- Wahlpflichtmodule
- Wahlmodule

Nachweis eines achtwöchigen Baupraktikums in Vollzeit bis spätestens zur Zulassung zur Bachelorarbeit.

Design Computation Curriculum | Master

Lectures

- Advanced Fundamentals of Building Information Modelling
- GIS-Box: DataFactory (Blended Learning)

Projects

- Design Driven Project ([Construction & Robotics](#))
- TCR Design Project ([Transforming City Regions](#))
- DC.Prototype, Intelligence & Buildings,
- M1, M2, M3
- Short infos: RingFrei, Virtuelle JAA, Fahrradparkaus

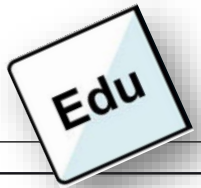
exercies

- BIM.Basic (Auflage), PixelStudio, Allplan....

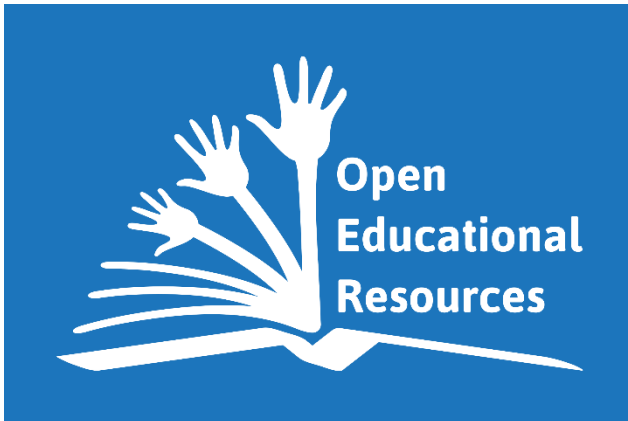
Meine Kurse	
Semester	
SoSe21	
DC.RELOADED - SoSe 2021	🔵
Vorbereitung Stachelhaus #2	🔵
Kurs_Bachelorarbeit_DC (ReiffTwin) (PT) [21ss-21.00097]	🔵
Bachelorthesis (PT) [21ss-20.00035]	🔵
Kurs_STEG_DC (Virtuelle JAA) (PT) [21ss-20.00077]	🔵
Kurs_WF_MA_PT (C) (GIS-Box: Theory) (SE) [21ss-21.00175]	🔵
CR_Advancend Fundamentals of Building Information Modelling (VO) [21ss-21.00082]	🔵
Kurs_DC.littleBIM (VU) [21ss-20.00003]	🔵
G&D2-CAAD (Pixel.Studio) (SE) [21ss-21.00014]	🔵
IGP1-CAAD (Intelligence & Buildings) (PT) [21ss-21.00060]	🔵
Kurs_Building Information Modeling (BIM) (VU) [21ss-20.00147]	🔵
Kurs_FF_1b_DC (DC.Prototype) (SE) [21ss-21.00117]	🔵
Kurs_M2_1b_DC (PT) [21ss-21.00055]	🔵
Kurs_WF_BA_DC (Allplan) (SE) [21ss-20.00145]	🔵
Kurs_WF_MA_CAAD (Pixel.Studio) (SE) [21ss-21.00145]	🔵
Kurs_WF_MA_DC (Advancend Fundamentals of Building Information Modelling) (SE) [21ss-21.00168]	🔵
Kurs_WF_MA_DC (Intelligence & Buildings) (SE) [21ss-21.00147]	🔵
Masterthesis (PT) [21ss-20.00198]	🔵
SGD-CAAD (BIM.Basics) (SE) [21ss-21.13689]	🔵
TCR_Territorial analysis, digital tools (GIS-Box Data Factory) (VO) [21ss-21.00026]	🔵
Geo_CAAD_2 (GIS-Box Data Factory) (SE) [21ss-20.00162]	🔵
Kurs_WF_BA_DC (BIM.Basics) (SE) [21ss-20.00059]	🔵
Kurs_WF_MA_DC (GIS-Box Data Factory) (SE) [21ss-20.00034]	🔵

Meine Kurse	
Semester	
WiSe21/22	
DC.RELOADED - WiSe 2021	🔵
Zentraler Moodleraum Fakultät Architektur	🔵
CAAD.team (UE) [21ws-21.09508]	🔵
Kurs_STEG_DC (DC.Ring_Frei_Aachen) (PT) [21ws-20.00077]	🔵
CR_Advancend Fundamentals of Building Information Modelling (SE) [21ws-21.00093]	🔵
CR_Design Driven Project (PT) [21ws-21.15003]	🔵
CR_SGD-DC (BIM_Basic) (SE) [21ws-21.00111]	🔵
Kurs_WF_BA_DC (DC.Project) (SE) [21ws-20.00059]	🔵
Kurs_DC_start (UE) [21ws-20.00002]	🔵
Kurs_FF_1a_DC (DC.Prototype) (SE) [21ws-20.00099]	🔵
Kurs_GuD II_DC (Pixel.Studio) (SE) [21ws-20.00190]	🔵
Kurs_M2_1a_DC (Forschungsprojekte in der Architekturinformatik) (PT) [21ws-21.00315]	🔵
Kurs_WF_BA_DC (Allplan) (SE) [21ws-20.00206]	🔵
Kurs_WF_MA_CAAD (Data Factory) (SE) [21ws-21.00084]	🔵
Kurs_WF_MA_CAAD (Pixel.Studio) (SE) [21ws-21.00113]	🔵
Kurs_WF_MA_DC (Advancend Fundamentals of Building Information Modelling) (SE) [21ws-21.00168]	🔵
Geo_CAAD_2 (GIS-Box Data Factory) (SE) [21ws-20.00162]	🔵
Kurs_WF_MA_DC (Intelligence & Buildings) (SE) [21ws-21.00017]	🔵
Masterthesis (PT) [21ws-20.00198]	🔵
TCR_Integrated Project III: Networked urban systems in Europe (Sustainable neighbourhoods, public space and social resilience) (PT) [21ws-21.00199]	🔵
TCR_Territorial analysis, digital tools (GIS-Box Data Factory) (VO) [21ws-21.00298]	🔵
TCR_Integrated Project III: Networked urban systems in Europe (Sustainable neighbourhoods, public space and social resilience.) (PT) [21ws-21.00128]	🔵

IfcOpenShell Programming in Jupyter Notebooks



<https://github.com/jakob-beetz/ifcopenshell-notebooks>



DOI 10.5281/zenodo.5733973

launch binder

The screenshot shows a Jupyter Notebook interface with a file browser on the left and a code editor on the right. The file browser shows a directory structure with files like '00_introduction.ipynb', '01_python.ipynb', '02_control_flow_and_loops.ipynb', '03_functions_and_classes.ipynb', '04_hello_ifc.ipynb', '05_hello_viewer.ipynb', '06_changing_and_creating.ipynb', '07_import_export.ipynb', 'added_properties_added.ifc', 'changed-properties.ifc', and 'Untitled.ipynb'. The code editor shows the following code:

```
[1]: %load_ext autoreload
      %autoreload 2

[5]: import ifcopenshell
      #m = ifcopenshell.open("../data/hello_reiff_2021.ifc")
      m = ifcopenshell.open("../data/231110AC-11-Smiley-West-04-07-2007.ifc")

To invoke it we have to import the models residing in the local utils folder.

[6]: from utils.JupyterIFCRenderer import JupyterIFCRenderer
      viewer = JupyterIFCRenderer(m, size=(400,300))
      viewer
```

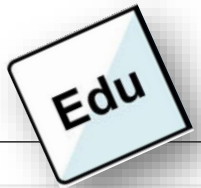
Below the code, there are interactive controls for the viewer:

- Axes: Compute (dropdown), X section: 19.47 (slider), Z section: 9.10 (slider)
- Grid: Hide/Show (dropdown), Remove (button)
- Reset View (button)

The viewer displays a 3D model of a building with a green roof and a brown base. The model is rendered on a grid. Below the viewer, there is a text prompt: [6]:

Instances of building elements with representations can be selected interactively. Information such as the attributes GUID, Name etc. are displayed to

IfcOpenShell Programming in Jupyter Notebooks



Display documentation on IFC Model parts

Importing and using the helper class `utils.IfHelp` allows you to load the official IFC documentation `IfcHelp3(Entity)` and `IfcHelp4(Entity)`.

```
1] import utils.IfHelp as IfcHelp
IfcHelp.getHelp4("ifcdoor")
```

1]:

6.1.3.16 IfcDoor



Natural language names

DE	Tür
EN	Door
FR	Porte

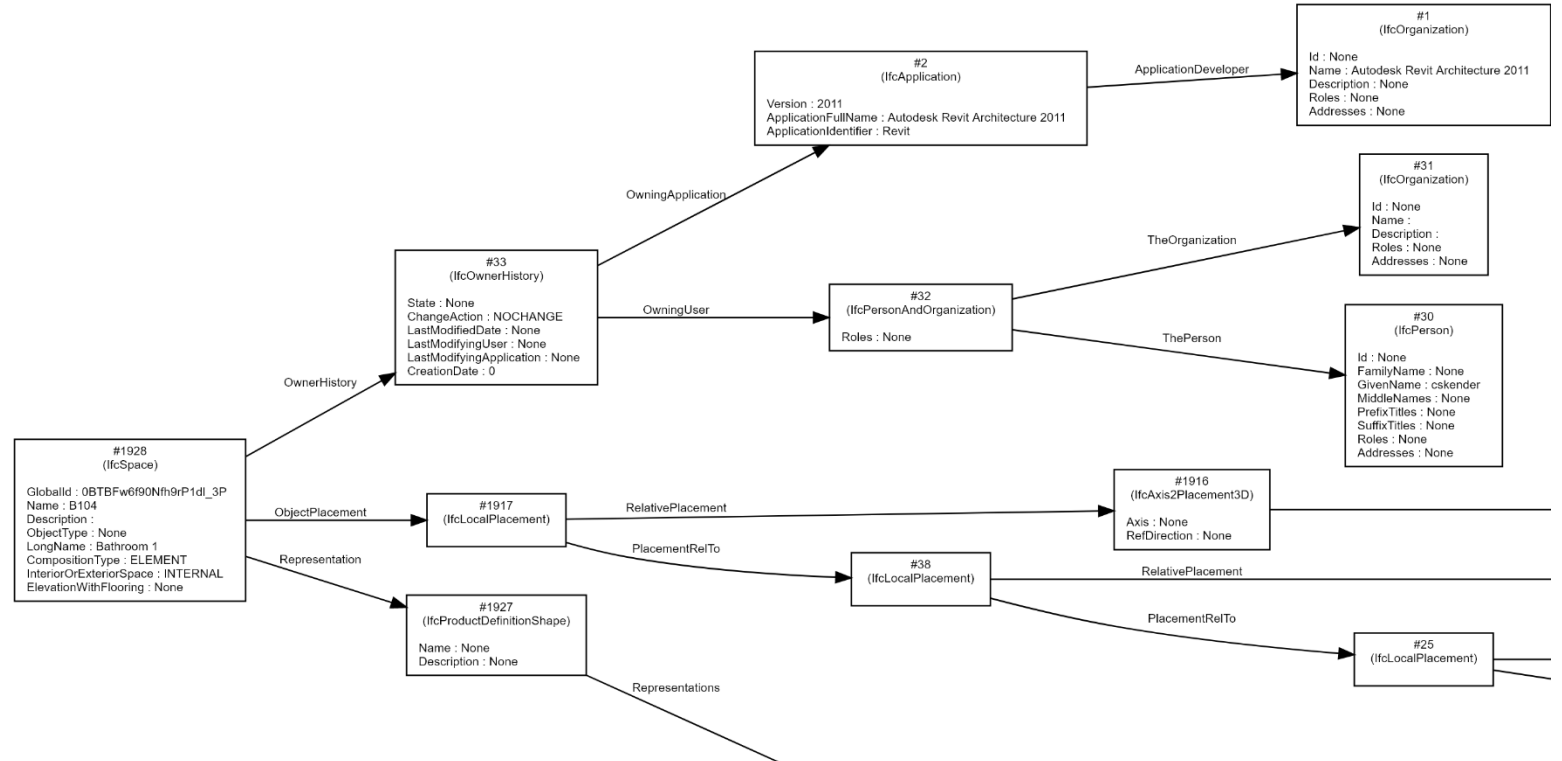
Change log

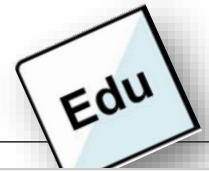
Item	SPF	XML	Change	Description
4.0.0.0				
IfcDoor				
OwnerHistory			MODIFIED	Instantiation changed to <i>OPTIONAL</i> .
PredefinedType			ADDED	
OperationType			ADDED	
UserDefinedOperationType			ADDED	

6.1.3.16.1 Semantic definitions at the entity

Entity definition

```
1 from utils import IfcGraphViz
2 #graph = IfcGraphViz.IfGraphViz().plot_graph(m, r)
3 graph = IfcGraphViz.IfGraphViz().plot_graph(m, r)
4 graph
```





Walk through all keys and values of a dictionary with `.items()`

```
] : for layer, thickness in layers.items():  
    print (f"{layer} \t: {thickness}" )
```

Exercise: Calculate the U-value of the wall

Thermal resistance $R_{Si} = 0.13$

Thermal resistance $R_{Se} = 0.04$

$$R_{\text{construction}} = \frac{d_1}{\lambda_{R1}} + \frac{d_2}{\lambda_{R2}} + \dots + \frac{d_n}{\lambda_{Rn}}$$

$$U\text{-value} = \frac{1}{R_{Si} + R_{\text{construction}} + R_{Se}}$$

Material	thermal transmittance λ in W/(m*K)
lime brick	0.99
mineral wool	0.04
air layer 1 cm	0.15

```
] : lambdas = {"KS": 0.99, "Mineral Wool": 0.04, "Air 1 cm" : 0.15}  
r_total = 0  
for layer, thickness in layers.items():  
    l = 0  
    if layer.find("KS") > -1:  
        l = lambdas["KS"]  
    elif layer.find("Mineral Wool") > -1:
```

Alle Properties in einen Pandas DataFrame

(nur für Interessierte und Fortgeschrittene=

```
[30]: import pandas as pd  
elements = m.by_type("IfcElement")  
df = pd.DataFrame()  
#df = pd.DataFrame({"element_id":[], "pset":[], "name":[], "value":[]})  
  
for elem in elements:  
    psets = ifcopenshell.util.element.get_psets(elem)  
    for psetname, props in psets.items():  
        for name, value in props.items():  
  
            data = {"element_id":elem.id(), "elem-name":elem.Name, "type":elem.is_a(), "pset":psetname, "r  
  
            df = df.append(data, ignore_index=True)  
df = df.astype({"element_id":"int32"})
```

```
[31]: df.tail()
```

```
[31]:
```

	elem-name	element_id	name	pset	type	value
8731	Dach-4	157012	Perimeter	BaseQuantities	IfcSlab	29.666
8732	Dach-4	157012	GrossArea	BaseQuantities	IfcSlab	54.99664
8733	Dach-4	157012	NetArea	BaseQuantities	IfcSlab	54.99664
8734	Dach-4	157012	GrossVolume	BaseQuantities	IfcSlab	10.999328
8735	Dach-4	157012	NetVolume	BaseQuantities	IfcSlab	10.999328

```
[28]: df.info()
```

Student Reports

```
Davon sind 0 Fenster

Fassade 4 hat 70 Öffnungen
Davon sind 10 Fenster

Antwort Aufgabe 2.5: Hier haben wir die weiteren Ergebnisse. In der ersten Fassade liegen also 70 Fenster, in der zweiten und dritten Fassade liegen keine Fenster und in der vierten Fassade liegen 10 Fenster. Die Überprüfung im 3D Modell zeigt, dass die Ergebnisse richtig sind.

Zur Aufgabe 2.6 schauen wir uns erst einmal das property-set von einem Beispielfenster an:
```

```
[53]: windows = m2.by_type("IfcWindow")
      psets = ifcopenshell.util.element.get_psets(windows[1])
      psets
```

```
[53]: {'Pset_WindowCommon': {'IsExternal': True},
      'BaseQuantities': {'GrossArea': 0.46875,
      'Height': 0.625,
      'Width': 0.75,
      'Perimeter': 2.75,
      'Area': 0.46875,
      'Volume': 0.01268875,
      'Depth': 0.2}}
```

Das Volumen eines jeden Fensters ist in den properties angegeben. Wir können also einfach die Volumina aller Fenster addieren. Um auf die Masse aller Fenster zu kommen, verrechnen wir das Gesamtvolumen mit einem gängigen Gewicht von Glas. Dieses liegt bei 2500 kg/m³:

```
[54]: FensterGesamtVolumen = 0
      for x in windows:
          psets = ifcopenshell.util.element.get_psets(x)
          Geometrie = psets.get('BaseQuantities')
          FensterGesamtVolumen += Geometrie.get("Volume")
      print(f"Gesamtvolumen aller Fenster: {round(FensterGesamtVolumen,4)} m³")
      print(f"Gesamtmasse aller Fenster: {round(FensterGesamtVolumen*2500,2)} kg")
```

```
Gesamtvolumen aller Fenster: 1.7004 m³
Gesamtmasse aller Fenster: 4251.03 kg
```

Antwort Aufgabe 2.6: Das Gesamtvolumen aller Fenster beträgt also 1.7004m³. Verrechnet mit unserem Glasgewicht kommen wir so auf eine Gesamtmasse von 4251.03kg

16

124	FLUR-6-4	9.932 m ²
125	ZIMMER-7-3	14.629 m ²
126	ZIMMER-7-4	14.633 m ²
127	BAD / WC-7-1	3.796 m ²
128	FLUR-7-4	9.932 m ²
129	ZIMMER-8-3	14.629 m ²
130	ZIMMER-8-4	14.633 m ²
131	BAD / WC-8-1	3.796 m ²
132	FLUR-8-4	9.932 m ²
133	ZIMMER-9-3	14.629 m ²
134	ZIMMER-9-4	14.633 m ²
135	BAD / WC-9-1	3.796 m ²
136	FLUR-9-4	9.932 m ²
137	ZIMMER-10-3	14.629 m ²
138	ZIMMER-10-4	14.633 m ²
139	BAD / WC-10-1	3.796 m ²
140	FLUR-10-4	9.932 m ²

2 Aufgabe 1 Unterschiede der Modellvarianten

(Anna Stecher und Melissa Kazimir)

2.0.1 Vergleich der beiden Modellvarianten hinsichtlich der Räume und ihrer Eigenschaften

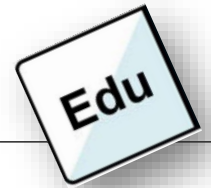
Der offensichtlichste Unterschied zwischen den beiden Smiley-West Modellen ist die Größe. Es handelt sich bei beiden Modellen um Reihenhäuser, das eine besteht allerdings aus 5 Häusern mit 70 Räumen und das andere aus 10 Häusern mit 140 Räumen. Die Nettogrundfläche der Räume unterscheidet sich in den beiden Modellen nicht besonders.

In den psets der beiden Modelle fallen weitere Unterschiede auf. In dem kleineren Modell sind nur Grundlegende Informationen, wie Name, ID, Grundfläche und Position, sowie Informationen zu Temperatur, öffentlichem Zugang und Barrierefreiheit zu finden. Das größere Modell beinhaltet zusätzlich zu den Informationen, die man auch in dem anderen Modell findet, noch detaillierte Angaben über Feuersicherheitsanforderungen, Heiz- und Lüftungsanforderungen und Angaben zu Maßen, Flächen und Volumen des Raumes.

2.0.2 Mögliche Kategorisierung der Räume

Die Räume kann man folgendermaßen kategorisieren: Nach Raumgröße, Raumart, Nutzung der Räume, Zimmerart, Unter- Obergeschoss, Nutzungsanforderungen (klimatisiert, barrierefrei, ...).

24



Basics of

- RDF(S), Linked Data
- SPARQL
- RDFLib (Python), Jena(Java)
- Node Red

<https://github.com/linkedinbuildingdata/SummerSchoolOfLDAC/>

The screenshot shows a GitHub repository page for "Summer School of LDAC". The main heading is "Summer School of LDAC" with a sub-heading "Summer School of Linked Data in Architecture and Construction (17-18 June 2019)". Below this is a description: "This repository contains the documentation and source of the coding challenge of the Summer School of Linked Data in Architecture and Construction held 17 - 18 June in Lisbon, Portugal. The summer school precedes the 7th Workshop on Linked Data in Architecture and Construction (LDAC)."

The "Getting Started" section contains the text: "Please move to [Index](#) to start working with the material of the 2019 edition of the Summer School of LDAC. You can also launch the content by opening it in Binder or Colab:" followed by buttons for "launch binder" and "Open in Colab".

The "Usage and Tools" section states: "The content of this summer school are distributed using [Jupyter](#) notebooks. The notebooks can be statically examined in Github by simply clicking on it. To execute the scripts they can be either locally executed or the project can be opened using [Binder](#) [1]. For the local usage a [iPython](#) installation is required. We suggest using a python distribution such as [Anaconda](#) to work locally."

The "Authors" section lists: "A couple of persons contributed to the content of this repository (Sorted alphabetically):" followed by a bulleted list: "• [Jakob Beetz, RG](#)" and "• [Matthias Bonduel, RG](#)".

On the right side of the repository page, there is a "Contributors" section showing 10 avatars and a "Languages" section with a progress bar: "Jupyter Notebook 95.7%" and "HTML 4.3%".

Why standards matter

- Imagine if bricks formats would be reinvented over and over
- Your laptop contains 250+ standards
 - 44 % by consortia
 - 36 % by formal standards organization
 - 20 % by single companies
- 75 % Reasonable and non-discriminatory (RAND) terms, also known as reasonable, and non-discriminatory (FRAND)
- 22 % royalty free
- 3 % patented

Biddle, Brad and White, Andrew and Woods, Sean, How Many Standards in a Laptop? (And Other Empirical Questions) (September 10, 2010).

Available at SSRN: <https://ssrn.com/abstract=1619440> or <http://dx.doi.org/10.2139/ssrn.1619440>

The New York Times

Opinion

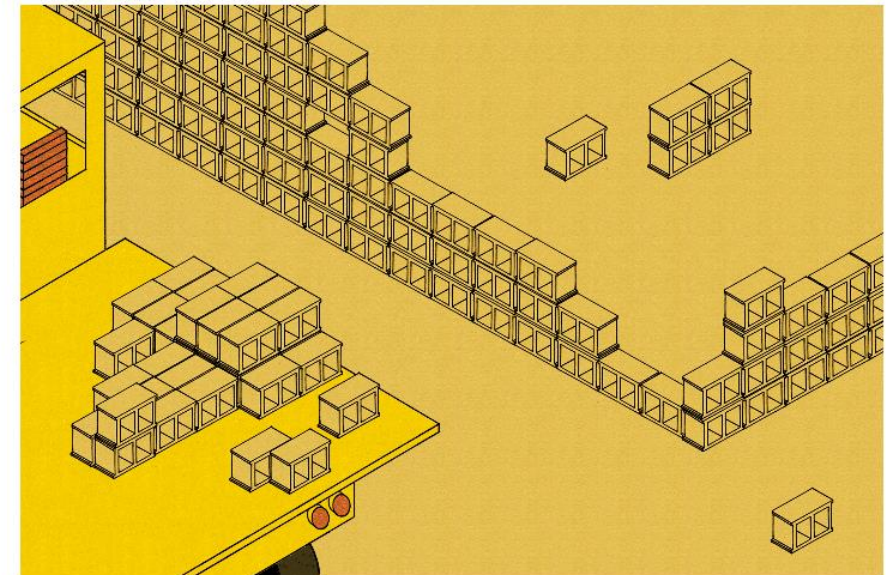
The Joy of Standards

Life is a lot easier when you can plug in to any socket.

By Andrew Russell and Lee Vinsel

Dr. Russell and Dr. Vinsel study technology.

Feb. 16, 2019

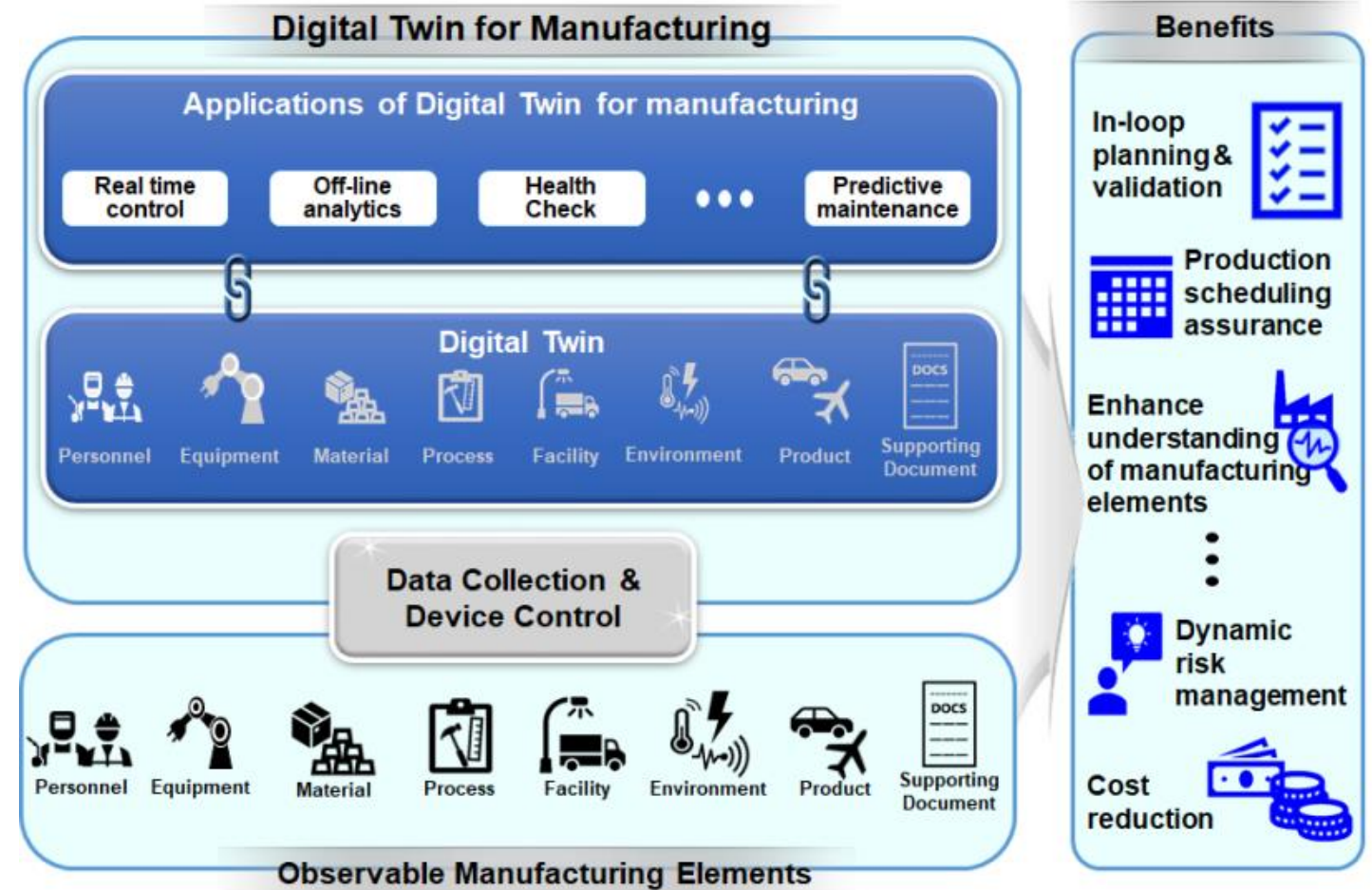
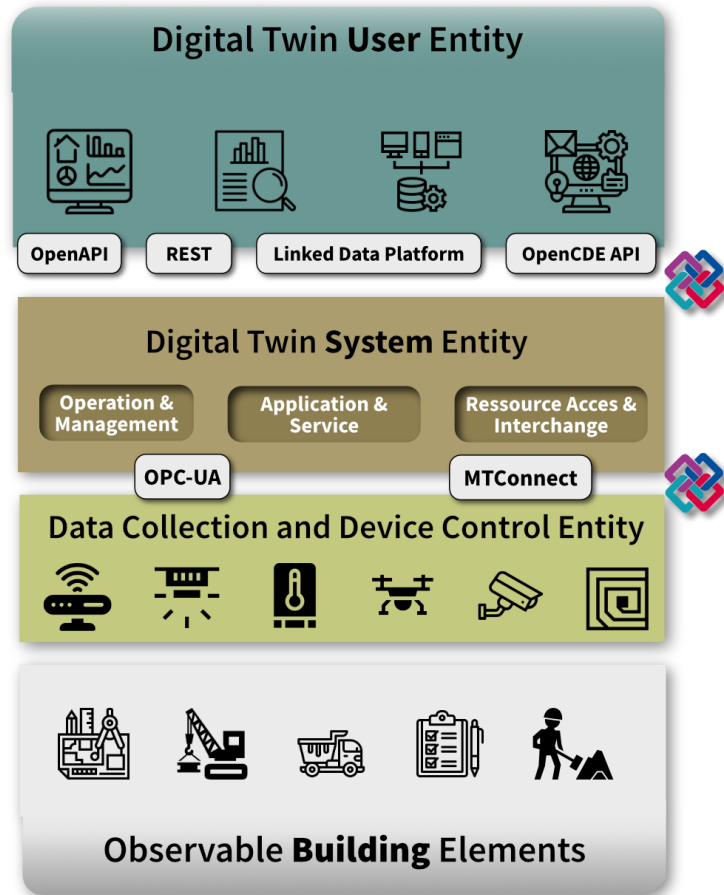


Semantic DTs for the Built Environment: Overview

- **Standardized static DT (BIM)**
 - Industry Foundation Classes [ISO 16739-1:2018](#)
 - buildingSMART Data Dictionary bSDD [ISO 12006-3](#)
 - Properties and QA for bSDD – PPBIM [ISO 23386](#)
 - HVAC [VDI 3805](#)
- **Augmenting DT with standardized dynamic data**
 - Data Protocols for building-specific IoT
 - BPS, BAS
 - BACNet ([ISO 16484](#), ASHRAE SSPC 135)
 - MVD for BACNet
 - KNX [ISO/IEC 14543-3](#)
 - Simulation interoperability [Annex 60](#), [FMI 2.0](#)
 - SHM
 - [OASIS](#) MQTT and Geo MQTT
 - Products
 - Product Catalogues [ISO 16757](#)
- **Semantic Enrichment and Organization and integration of heterogeneous DT data**
 - OpenCDE API [DIN SPEC 91391](#)
 - IDM [ISO 29481-2:2012](#)
 - Multimodal Multi-models and ICDD [ISO 21597-1:2019](#)
 - [W3C SSN](#)
 - SAREF
 - Linked Data, data silos and the long run: [W3C RDF](#), [OWL](#), [SPARQL](#), [JSON-LD](#), [XML](#)
 - Solid
- **Long term access to DT data**
 - Long Term preservation and the OAIS [ISO 14721:2012](#)
 - Blockchain, Interplanetary File System IPFS

ISO DIS 23247-2:2019 Automation systems and integration — Digital Twin framework for manufacturing

Digital Twin for the Built Environment based on the ISO 23247 framework



How should Semantic Digital Twins for the Built Environment, such that ...

... standardised yet extensible?

- Make compatibility with agreed upon **OPEN standards** part of **contracting** (manufacturers, home automation, Facility Managers, construction companies, HVAC engineering).
- Create common, reusable reference **IDMs** (UCs, ER, EIR/MVD ...) , for common use cases (Energy use in buildings, Structural Health Monitoring of infrastructure assets, construction logistics monitoring etc.
- **Extend** in separate models, standards, descriptions **only where necessary**
- Agree on **common** decomposition and aspect model views (e.g. building, storey, space)
- **Simplicity**, reduction of complexity, transparency
- **Privacy** for personal data – home automation highly dependent on user behavior patterns
- include **provenance** information (data stemming from which sensors? measured how? date of last calibration? tolerances, margins of error?)
- Move to **collaborative, open source development** (Git etc.)
- **Release early, release often**

How should Semantic Digital Twins for the Built Environment, such that they are...

... able to address key use cases directly and specialty use cases with extensions?

- **reuse** and **integrate** existing standards
 - Alignments and mappings of existing
 - AEC/FM standards (IFC, gbXML, CityGML, BACnet ISO 16484-5, KNXm, LOD),
 - **IoT** protocols (HTTP, WebSockets, CoAP, MQTT, XMPP and WebRTC), modelling of sensor meaning SensorML, SSN ect.) and
 - Information **Archival** Strategies (ISO 14721:2012, OAIS)
- agree on **common mappings**, best practices and usage patterns
- publish **reference data sets**,
- specify quality standards, **certification** and testing

How should Semantic Digital Twins for the Built Environment, such that they are...

... cloud and computationally friendly?

- Look at what is proven, simplify, embrace bottom up developments: e.g. **JSON**, **JSON-LD**, **REST**
- Specify simple, domain-specific **APIs**
- move **out of proprietary silos**, use simple representations at least as derived
- **stick strictly to protocols**
- secure and **encrypt** with authentication layers (OAuth etc.)

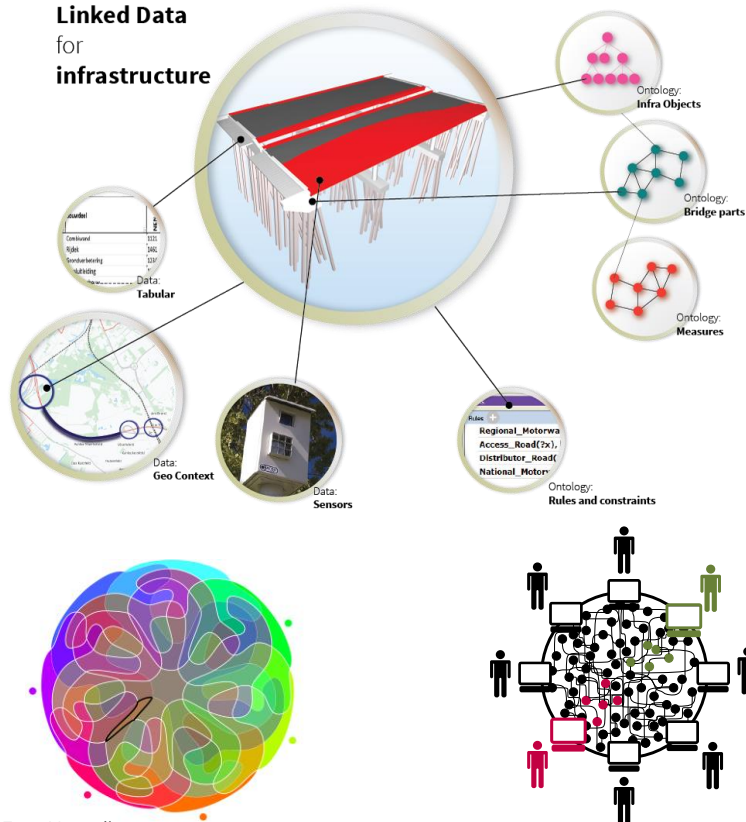
How should Semantic Digital Twins for the Built Environment, such that they are...

... scalable and verifiable?

- **Decentralize**
- Look at what is proven, simplify, embrace bottom up and community developments and best practices: e.g. **JSON, JSON-LD, REST, GraphQL**
- **Test-driven** development
- Do not rely only on low-level technologies only (sharding etc.)
- create common **references**
- include **provenance** information
- checksums/fingerprints in **aggregators** for authenticity

Thank you

j.beetz@caad.arch.rwth-aachen.de



source 7-set Venn diagram:
[Ortiz 2013]

André Borrmann · Markus König · Christian Koch · Jakob Beetz *Editors*

Building Information Modeling

Technology Foundations and Industry Practice

Building Information Modeling (BIM) refers to the consistent and continuous use of digital information throughout the entire lifecycle of a built facility, including its design, construction and operation. In order to exploit BIM methods to their full potential, a fundamental grasp of their key principles and applications is essential. Accordingly, this book combines discussions of theoretical foundations with reports from the industry on currently applied best practices.

The book's content is divided into six parts: Part I discusses the technological basics of BIM and addresses computational methods for the geometric and semantic modeling of buildings, as well as methods for process modeling. Next, Part II covers the important aspect of the interoperability of BIM software products and describes in detail the standardized data format Industry Foundation Classes. It presents the different classification systems, discusses the data format CityGML for describing 3D city models and COBie for handing over data to clients, and also provides an overview of BIM programming tools and interfaces. Part III is dedicated to the philosophy, organization and technical implementation of BIM-based collaboration, and discusses the impact on legal issues including construction contracts. In turn, Part IV covers a wide range of BIM use cases in the different lifecycle phases of a built facility, including the use of BIM for design coordination, structural analysis, energy analysis, code compliance checking, quantity take-off, prefabrication, progress monitoring and operation. In Part V, a number of design and construction companies report on the current state of BIM adoption in connection with actual BIM projects, and discuss the approach pursued for the shift toward BIM, including the hurdles taken. Lastly, Part VI summarizes the book's content and provides an outlook on future developments.

The book was written both for professionals using or programming such tools, and for students in Architecture and Construction Engineering programs.

Computer Science

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André Borrmann · Markus König
Christian Koch · Jakob Beetz *Eds.*



Building Information Modeling

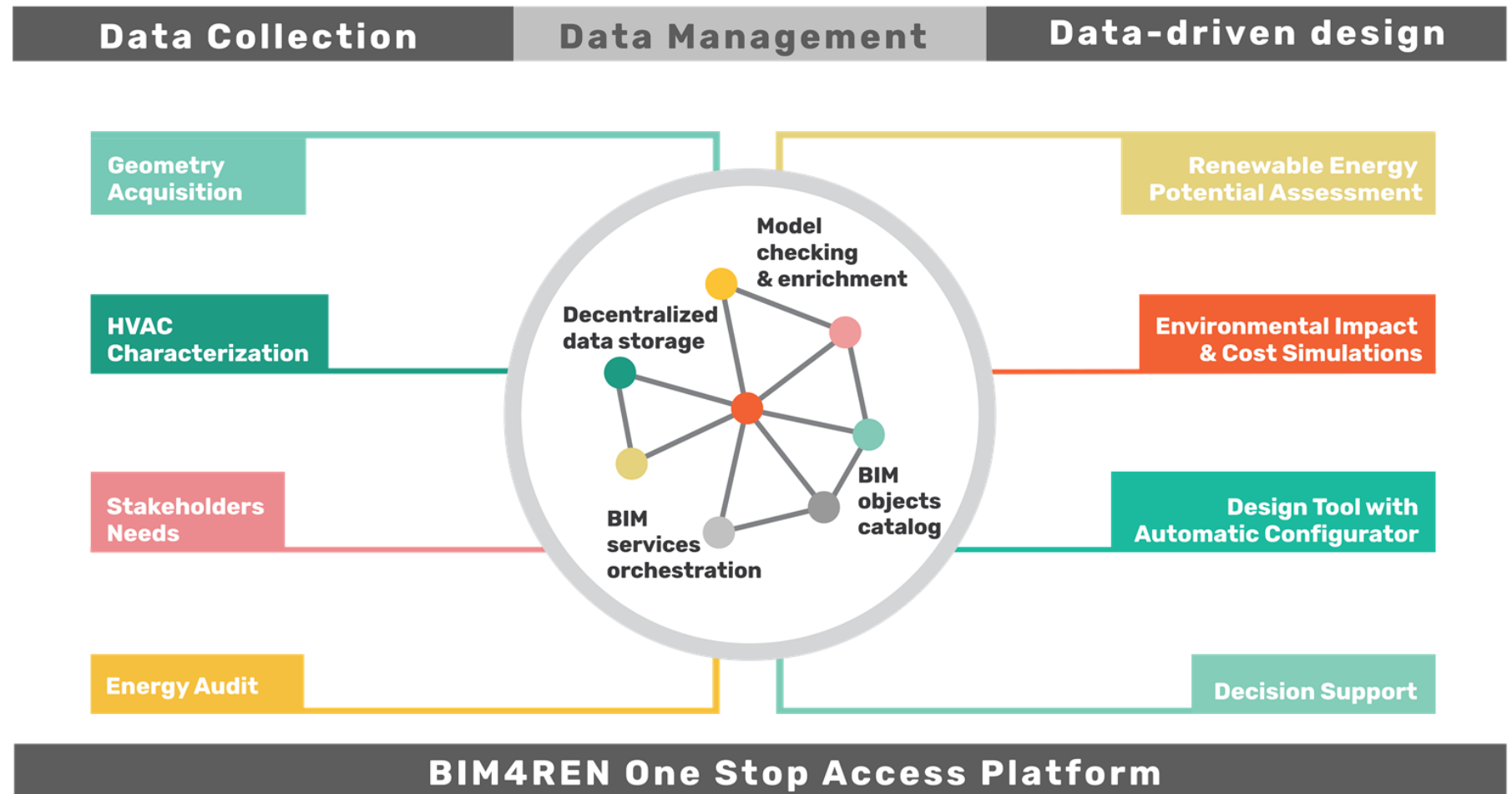
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Building Information Modeling

Technology Foundations
and Industry Practice

Springer

Semantic Digital Twins on the Building level : BIM4Ren



Semantic Digital Twins on the Building level : BIM4Ren (1)

Project : 2018-2022

Easy-to-use BIM tools and workflows for collaborative and energy-efficient renovation of residential buildings

Consortium: 23 partners from 10 European countries

Coordinator: Nobatek/INEF4

Duration: 48 months

Start: 1st Oct 2018

Budget: 7M€

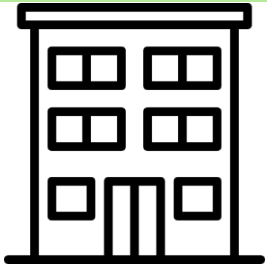
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Data Management

Data collection

WHAT IS THE EXISTING DATA ?

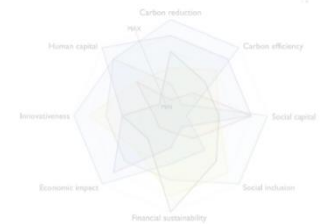
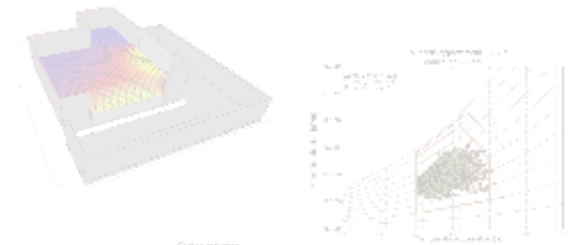


- Year?
- Local regulation?
- Cost € ?
- Energy performance?
- Geometry?
- Stakeholders expectations?
- Type of occupants ?
- Renovation potential ?
- State of the existing infrastructure ?

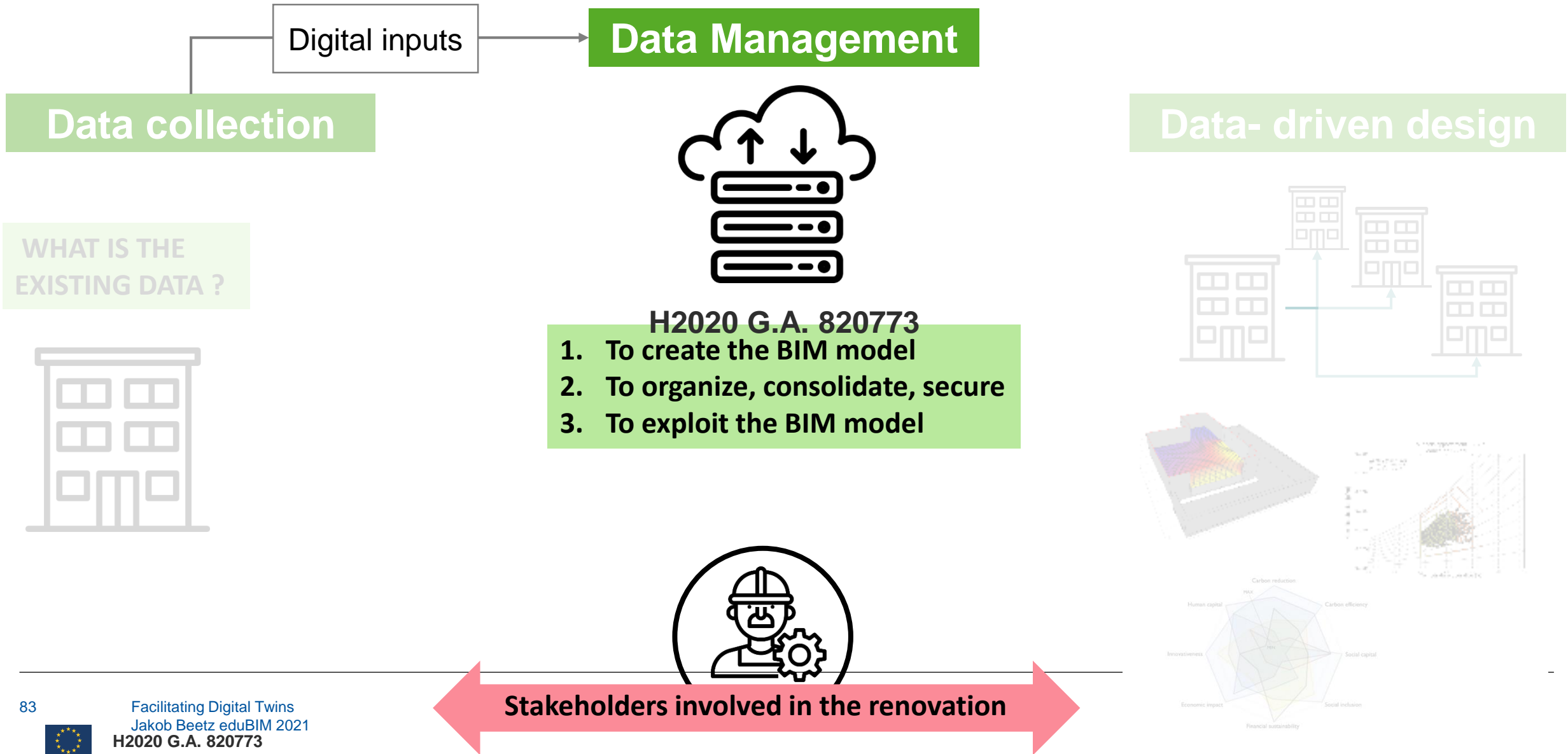


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Data-driven design



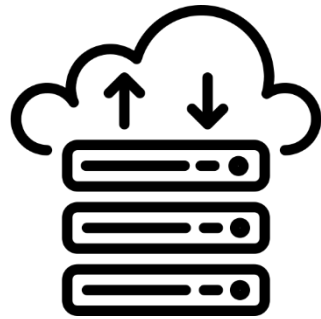
← Stakeholders involved in the renovation →



Data collection

Digital inputs

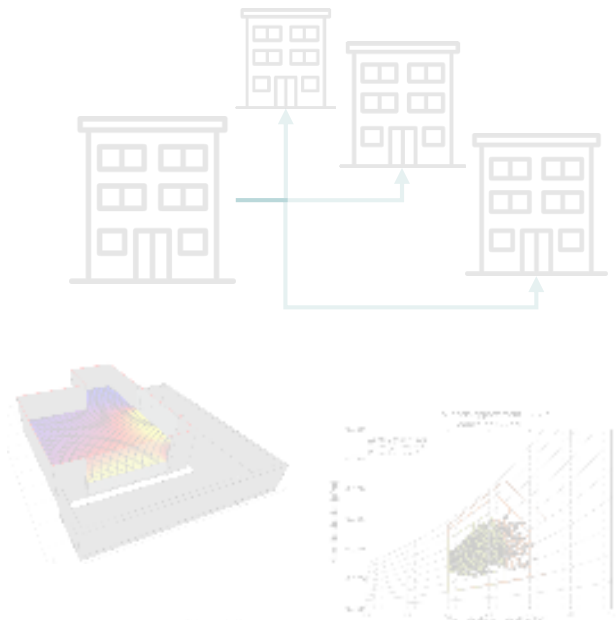
Data Management



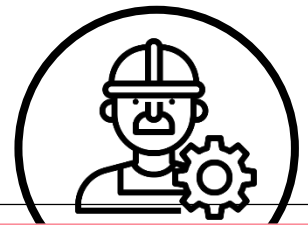
WHAT IS THE EXISTING DATA ?

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- 1. To create the BIM model
- 2. To organize, consolidate, secure
- 3. To exploit the BIM model

Data-driven design



Stakeholders involved in the renovation



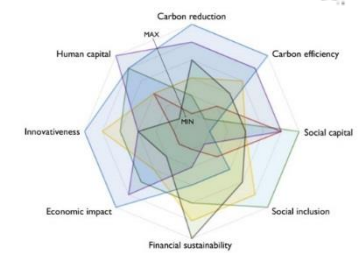
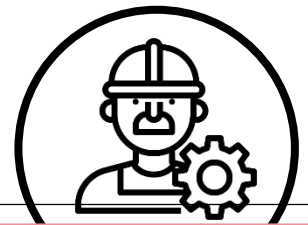
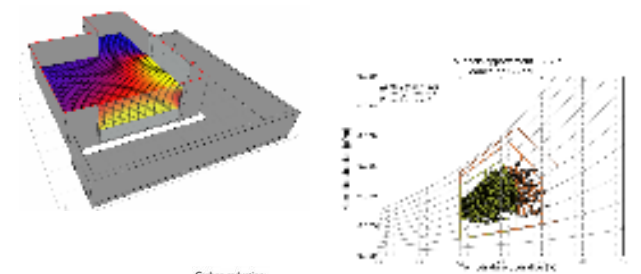
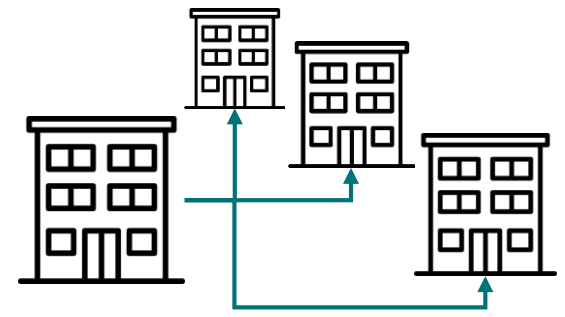
BIM4Ren CONCEPT

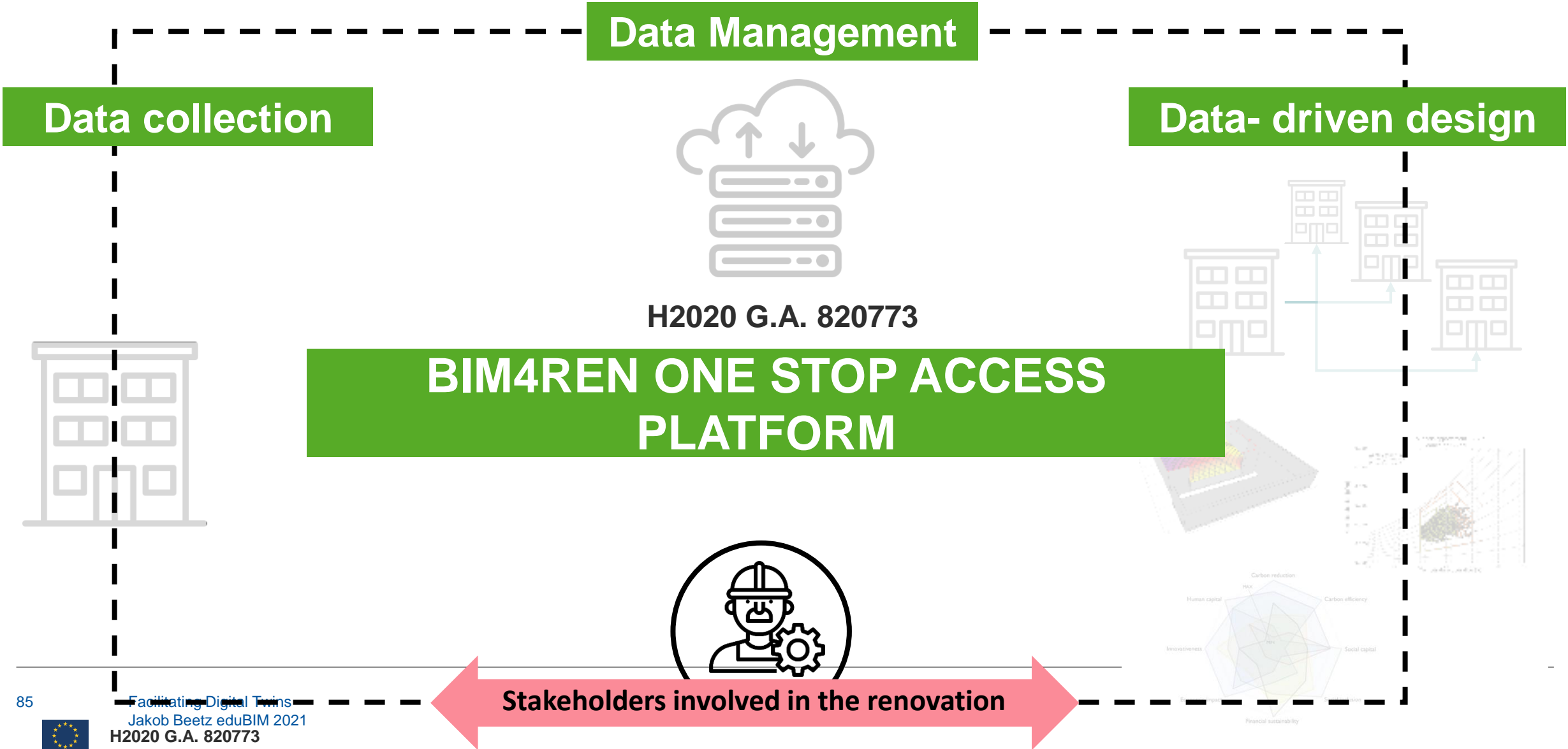


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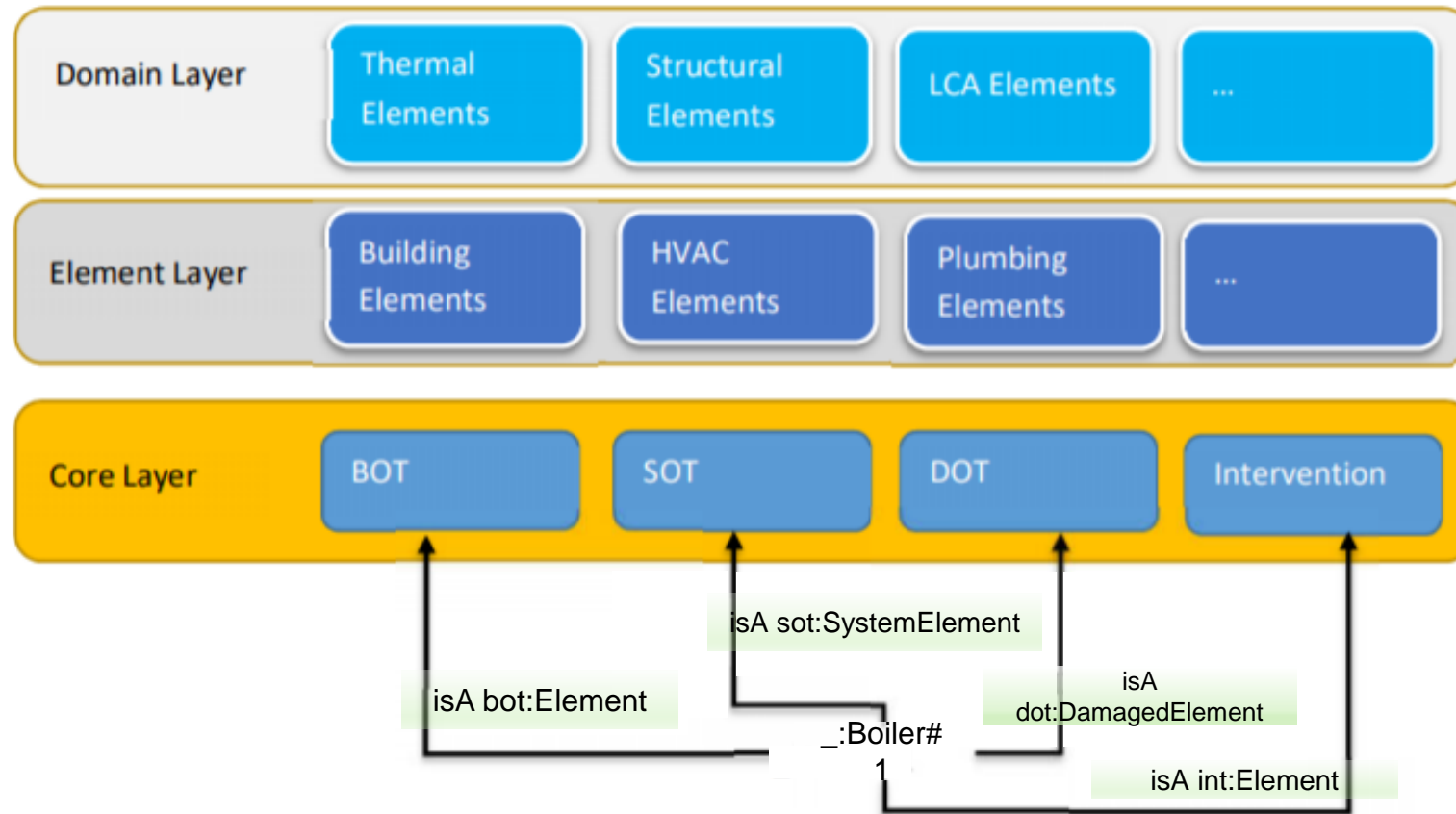


- H2020 G.A. 820773**
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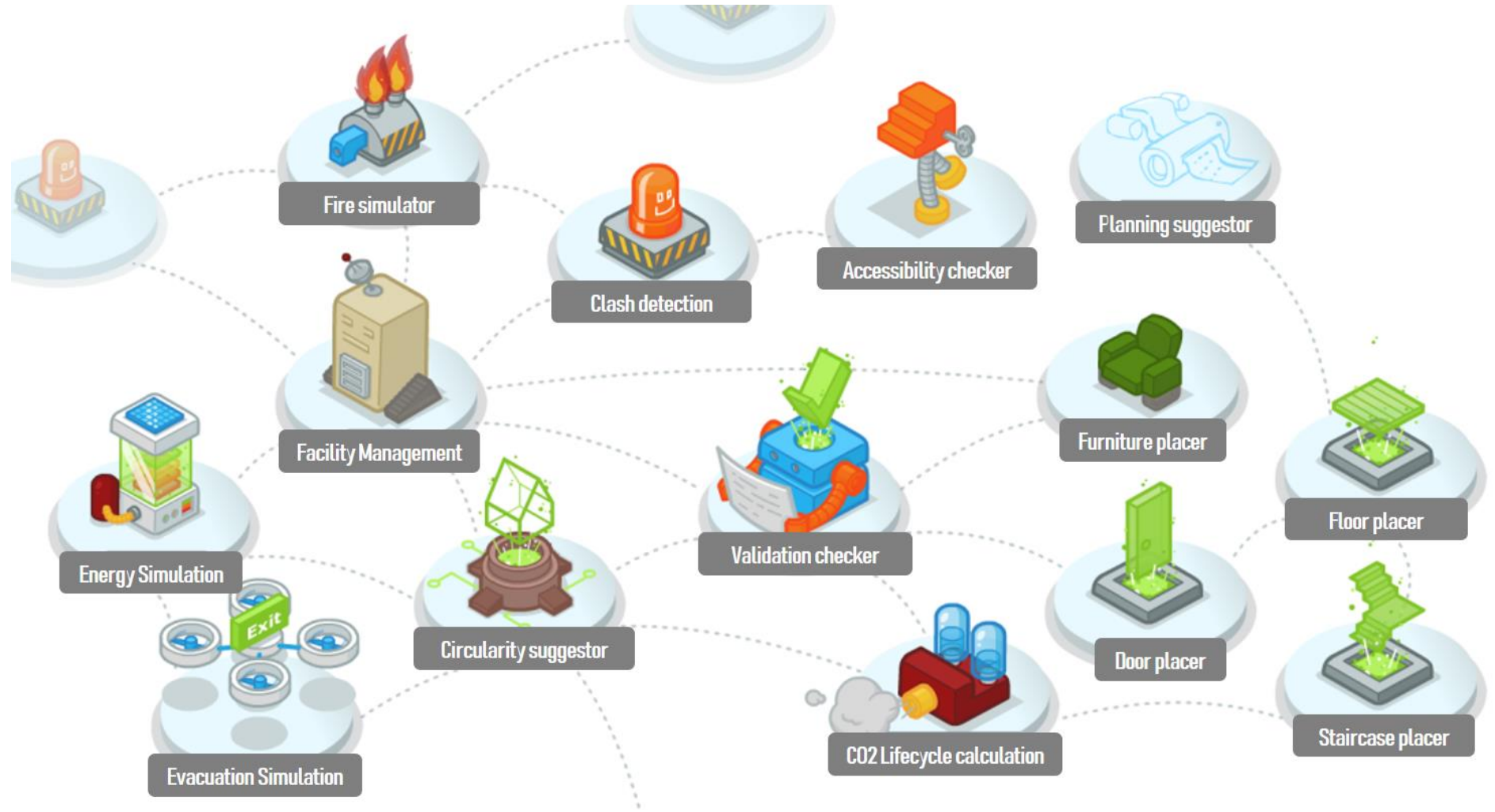




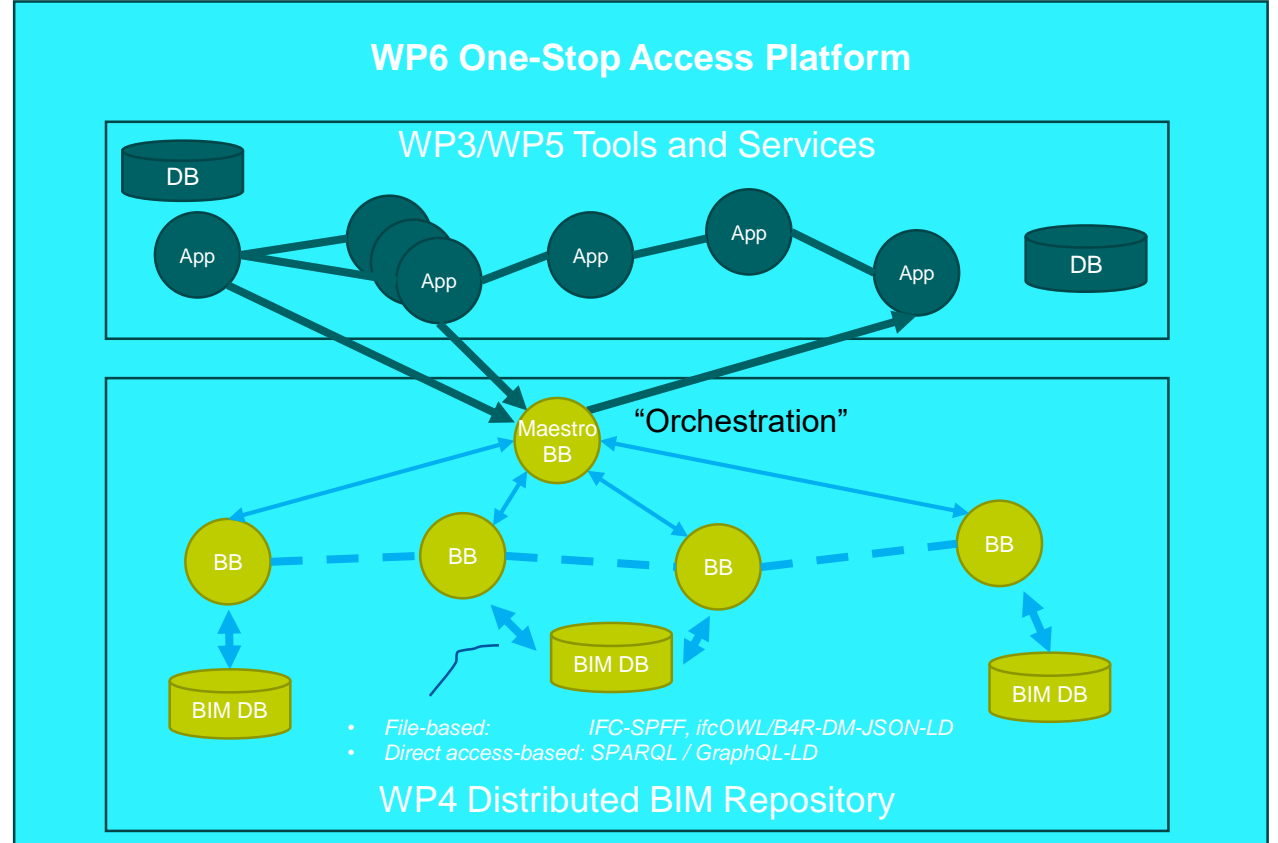
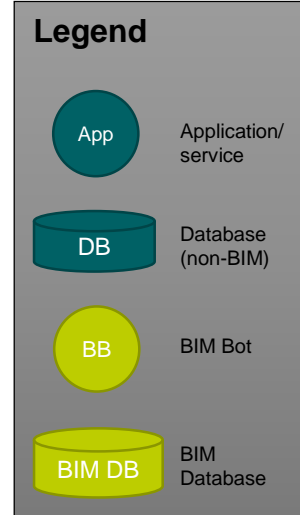
Proposed BIM4Ren Data Model



BIM4Ren Architecture



BIM4Ren Architecture



Applications/services & BIM Bots

- implemented as “OpenAPI micro services”
- deployed in Amazon Web Services (AWS) & CSTB KROQI cloud platforms

BIM4Ren Architecture

