

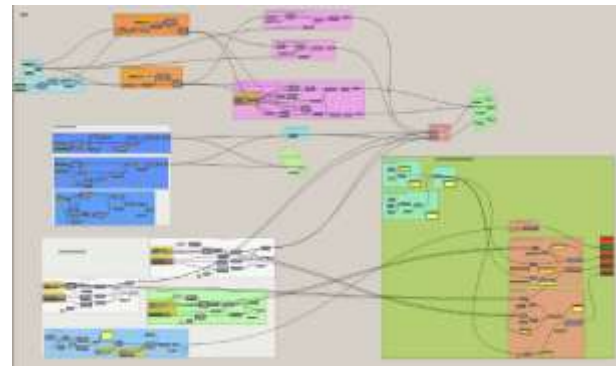
An aerial night view of a city, likely Eindhoven, with a prominent red overlay. The city lights are visible, and the red overlay covers the top half of the image. The text is overlaid on this red area.

1+1=3 – Decentralizing data and systems for a better built environment – Right??

25 JUNE 2024 - SYMPOSIUM WOI & TU/E: DATAGEDREVEN SLIMME GEBOUWDE OMGEVING

Pieter Pauwels, Associate Professor

Department of the Built Environment, Information Systems in the Built Environment



BUILDINGS AND SEMANTICS

Data Models and Web Technologies for the Built Environment

Edited by
Pieter Pauwels
Kris McGlinn



TU/E CAMPUS DIGITAL TWIN FOR SMART BUILDING MANAGEMENT AND CONTROL

Pieter Pauwels (BC), Daria Terna (BC), Gertjan Deurs (TFC), Sjoerd Pijlmeester (BC), Thijs Hecker (BC), Jack Ankersmit (PBC) (R&D)

- Build artificial systems for the Atlas and Control buildings (Data Evaluation Lab, Control building)
- Smart management of facilities through an ultra-energetic detection and control monitoring
- Unsupervised robot navigation through sensor-driven (AI) path detection and real-time data analysis (data-driven)
- Developing a 3D campus information system for digital accessibility of campus facilities and services in technology and open spaces

BUILDING DATA

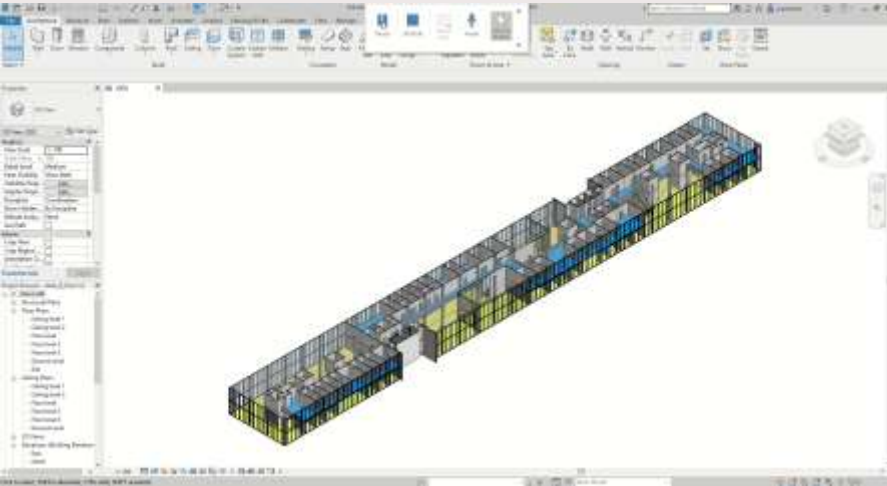


LDAC2019
7th Linked Data in Architecture and Construction Workshop
17 - 21 June 2019

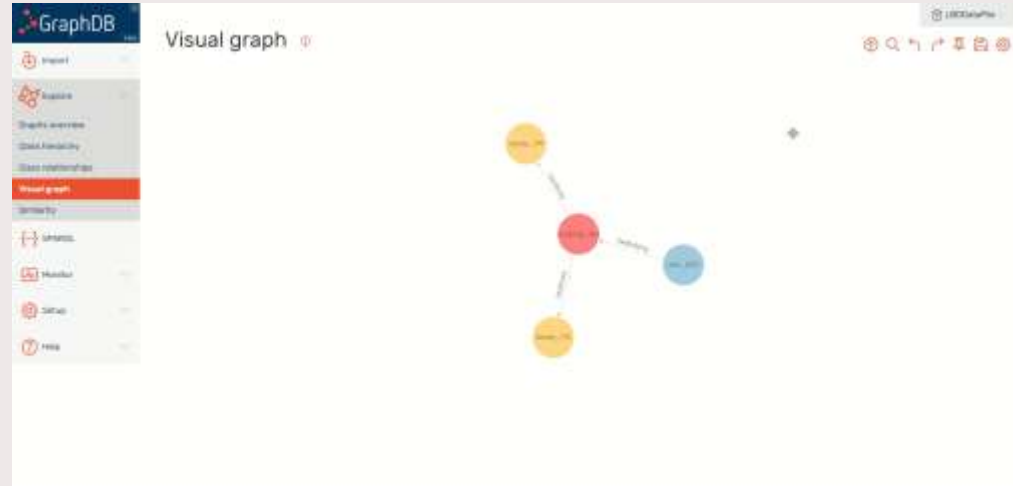
Incl. SUMMER SCHOOL!

<http://linkedbuildingdata.net/ldac2019/>

Linked Building Data and moving building data to the web using graph databases



Building Information Modelling (BIM)



Graph Databases

Research projects



Smart Buildings

IN - Distributed data modelling and Federated Digital Learning for lifecycle data-driven sustainable operation and management of buildings and districts (2024-2028)

Brains4Buildings' Energy Systems project (2021-2025)

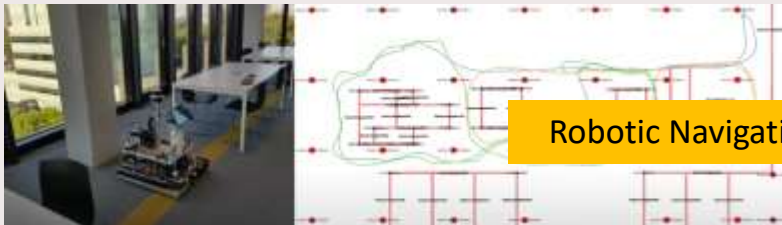


UPSCALE - Cross-linking, Tracing and Reusing Construction and Demolition Waste across Circular Supply Networks in Construction (2024-2029)

Circularity



Modular Prefabricated Construction: a circular asset management system for closed-loop supply and logistics chains – TKI Dinalog Project (2024-2028)



Robotic Navigation

Cooperative Mobile Robots - EuroTech PhD Project (2024-2028)

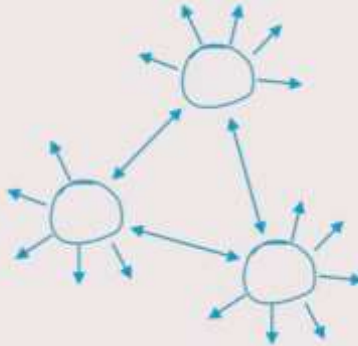
Decentralizing Building Data

Democratizing Building Data

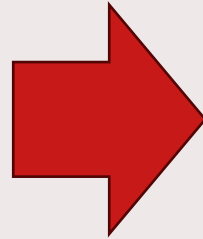
**Making Building Data available over the
Web**

The big ... decentralization of data and systems!!

Centralized



- Central authority
- Data outdated
- Data inaccessible



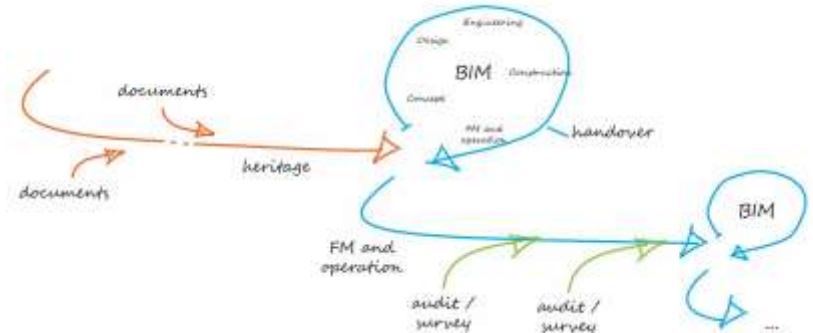
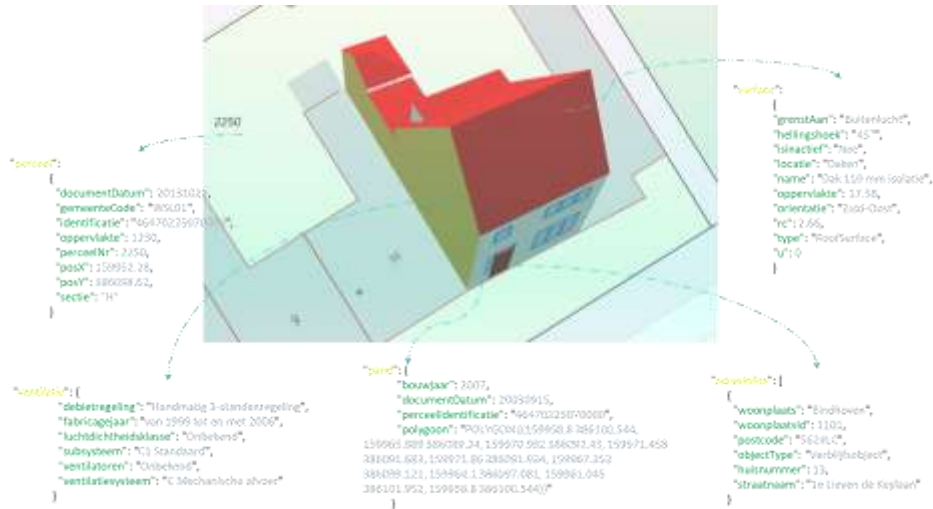
Decentralized



- Data with owner
- Versioning and updating
- Granular access

- Plenty of advantages!!

Every building is a data hub with many interconnections that change over time

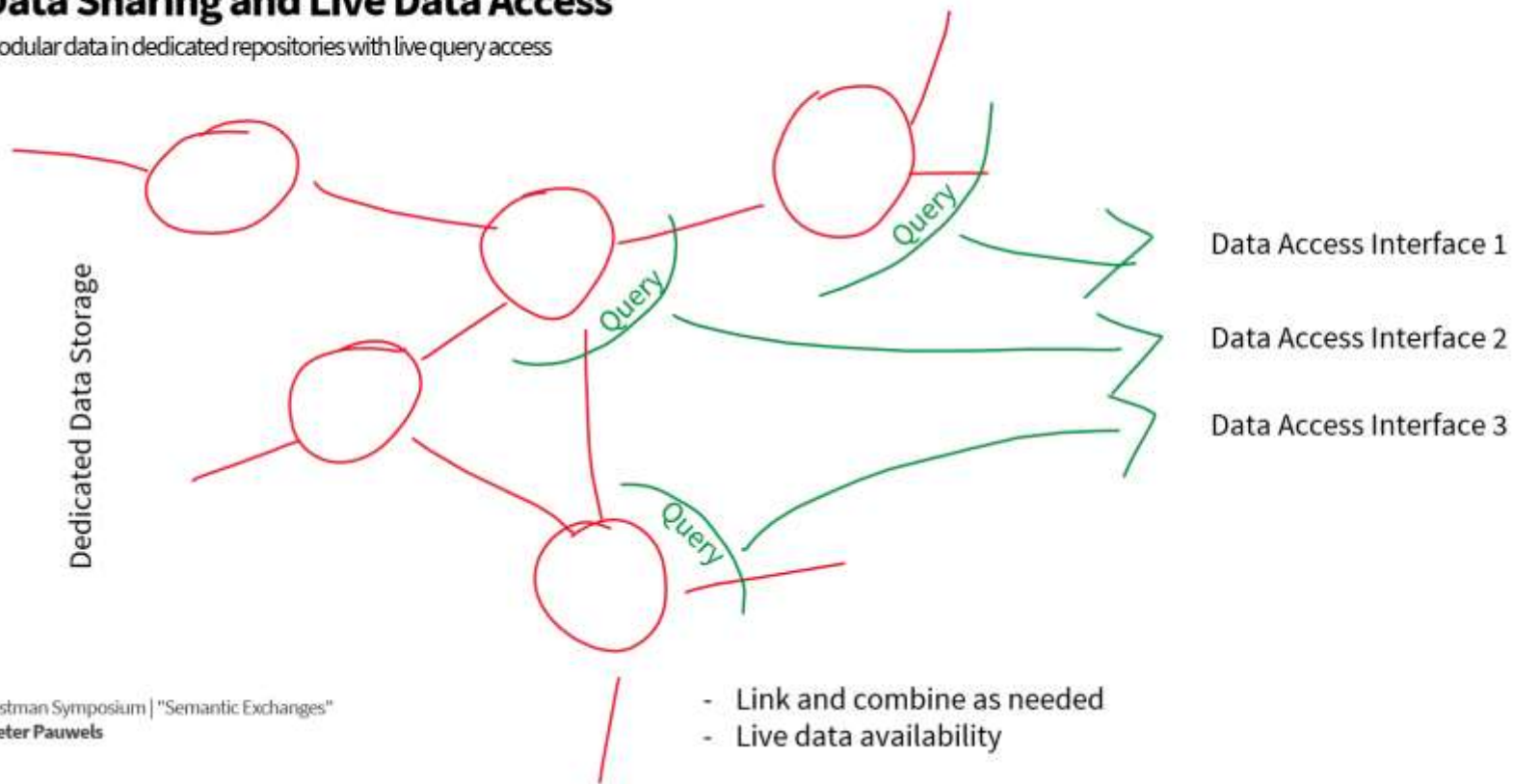


Kafeai, M. (2022). Design and development of a data platform for managing the residential buildings' physical and geospatial information required for large-scale renovations. Technische Universiteit Eindhoven. <https://research.tue.nl/en/publications/design-and-development-of-a-data-platform-for-managing-the-reside>

Pieter Pauwels. Supporting decision-making in the building life-cycle using linked building data. Buildings 4 (3): 549–579. 2014.

Data Sharing and Live Data Access

Modular data in dedicated repositories with live query access



Smart Buildings



<https://brains4buildings.org/>

Data sources to integrate

- Plenty of **semantic data** models (RDF/OWL) allowing semantic inference:
 - » LBD: BOT, BEO, MEP, FOG, BPO, BRICK, HTO, IFC, SSN, SOSA, ...
 - » Modular approach of smaller scale specialized semantic models in graphDBs
 - » Rules, queries, and inference readily available (declarative coding)
- **Tabular and/or timeseries data** allowing list-oriented and statistic machine learning (pattern recognition, fault detection, etc.)
 - » Plenty of data wrangling => ML
- **Specialised** 2D and 3D data, images, point clouds and documents
 - » Specialised algorithms (procedural coding): 3D computations and analysis, NLP, image recognition, visual data analysis, etc.

Digital Twinning of TUE Campus Buildings

EAISI EINDHOVEN
AI SYSTEMS
INSTITUTE

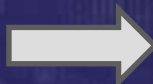
TU/e



TU/E CAMPUS DIGITAL TWIN FOR SMART BUILDING MANAGEMENT AND CONTROL

Pieter Pauwels (BE), **Elena Torta** (ME), **Ganze Dane** (BE), **Sonja Rijlaarsdam** (RE), **Thijs Meulen** (RE), and **Annelieke Pelt** (ME)

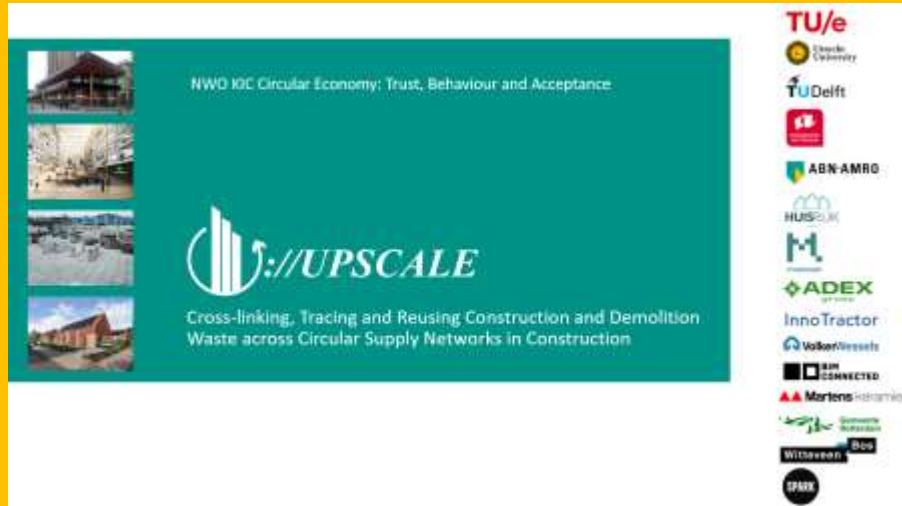
- Build a Digital Twin system for the Atlas and Gemini buildings (Zero Emission Lab, Gemini building)
- Smart management of facilities through on-site anomaly detection and device monitoring
- Unsupervised robot navigation through semantic (model-driven) path detection and real-time data analysis (data-driven)
- Developing a 3D campus information system for digital accessibility of campus facilities and services in buildings and open spaces



Under Development

<https://www.tue.nl/en/research/institutes/eindhoven-artificial-intelligence-systems-institute/digital-twin-lab>

Circular Material Reuse



The image shows a promotional graphic for the Upscale project. On the left, a teal background features three small images of construction sites and the text "NWO KIC Circular Economy: Trust, Behaviour and Acceptance" at the top. Below the images is the Upscale logo, which consists of a stylized bar chart with an upward arrow, followed by the word "UPSCALE" in a serif font. Underneath the logo is the text "Cross-linking, Tracing and Reusing Construction and Demolition Waste across Circular Supply Networks in Construction". To the right of the teal area is a vertical list of partner logos, including TU/e, Utrecht University, TU Delft, ABN-AMRO, HUISPARK, M, ADEX, InnoTractor, VolkerWessels, BIM CONNECTED, Marrens, Gemeente Rotterdam, Willeboer Bos, and SPARK.

NWO KIC Circular Economy: Trust, Behaviour and Acceptance

UPSCALE

Cross-linking, Tracing and Reusing Construction and Demolition Waste across Circular Supply Networks in Construction

TU/e
Utrecht University
TU Delft
ABN-AMRO
HUISPARK
M
ADEX
InnoTractor
VolkerWessels
BIM CONNECTED
Marrens
Gemeente Rotterdam
Willeboer Bos
SPARK

<https://upscaleproject.nl/>

Bouwhubs in Nederland



<https://www.bouwhub.amsterdam/>

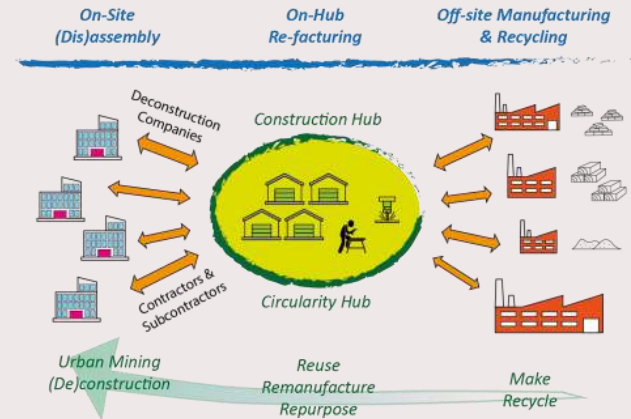


https://topsectorlogistiek.nl/wp-content/uploads/2022/07/Stills_Bouwhub04-800x450-1.jpeg

Realisatie in de praktijk

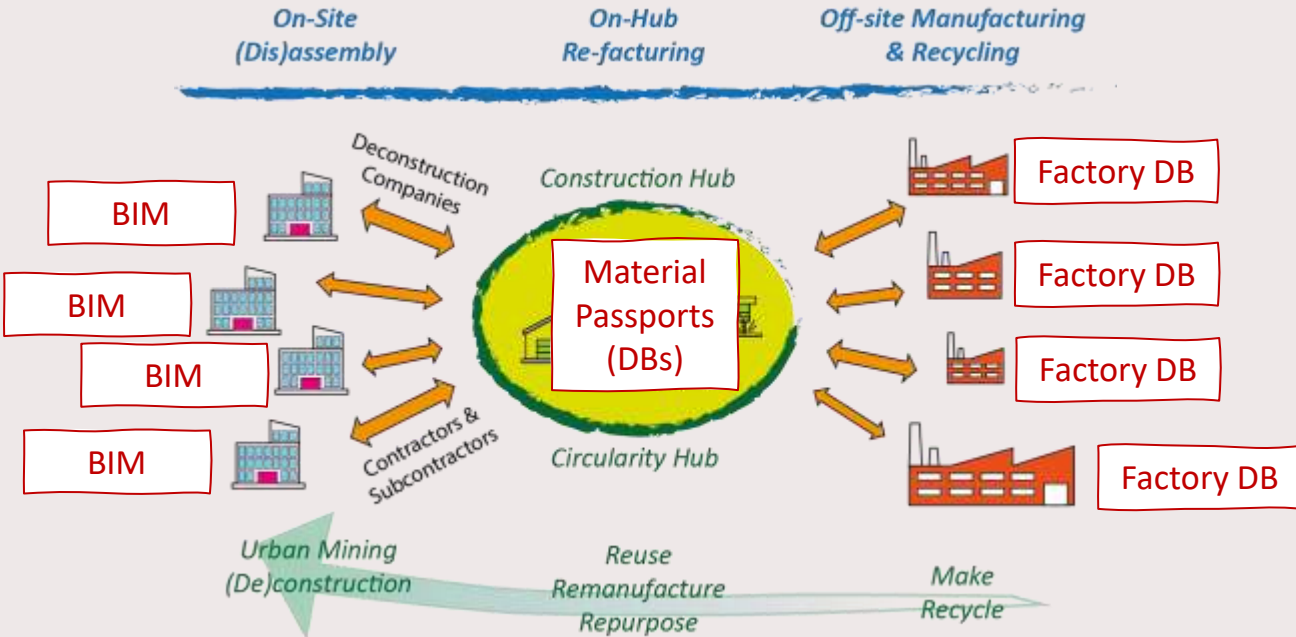


De circulaire bouwhub Amsterdam van ADEX group (voorheen Beelen Next)



afbeelding van Bouwcirculair, Landelijk netwerk van Circulaire BouwHubs, <https://bouwcirculair.nl/nieuws/2021-2-23-landelijk-netwerk-van-circulaire-bouw-hubs-lees-verder/>

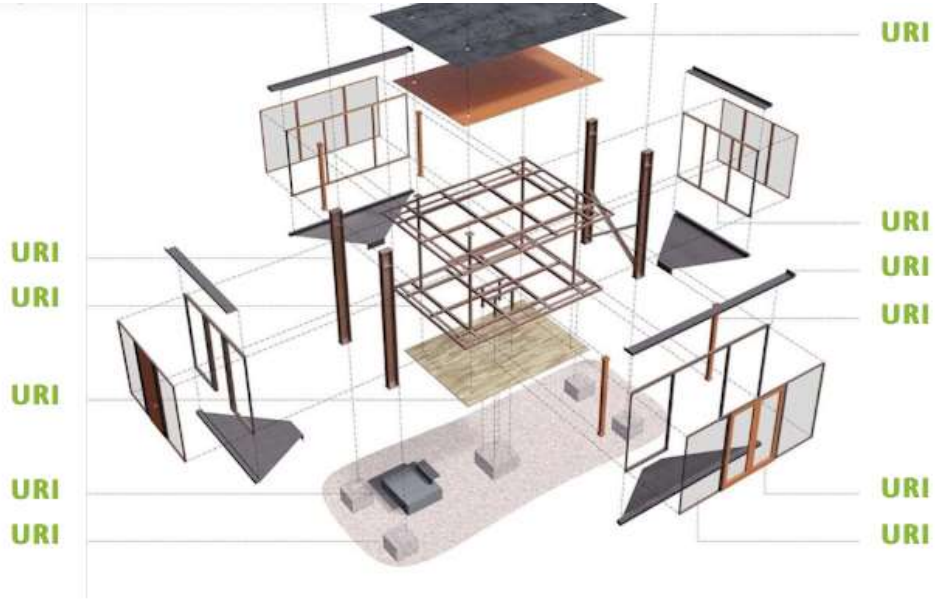
Circulariteit in de bouwhubs: veel meer nadruk op linkerzijde van keten



P. Pauwels (2023). De route naar circulaire ketens: impact op de installatiesector. TVVL Magazine, in press.

- Meer nadruk en vergroting van materiaalstromen en informatiestromen van gebouwen naar hubs.
- Minder gebruik van off-site productie- en recyclagefaciliteiten.
- De productiefaciliteiten op een bouwhub worden circulaire opwaarderingsfaciliteiten (pre-processing).
- Groot belang van digitale tracering van objecten:
 - Track-and-Trace models
 - Take back models

Every building is a data hub in a mesh of hubs



1. Every building element has its **authoritative Uniform Resource identifier (URI)**.
2. **Data-follows-object** principle for ownership and liability.
3. **Layered** and **versioned** information sharing.
4. **Standardised information exchange** (e.g. structure of ISO 19650).
5. **Object-centric exchange** instead of geometry-centric exchange.

UPSCALE research project

TKI Dinalog ModPrefabConstr research project

Circl demonstrator in Amsterdam



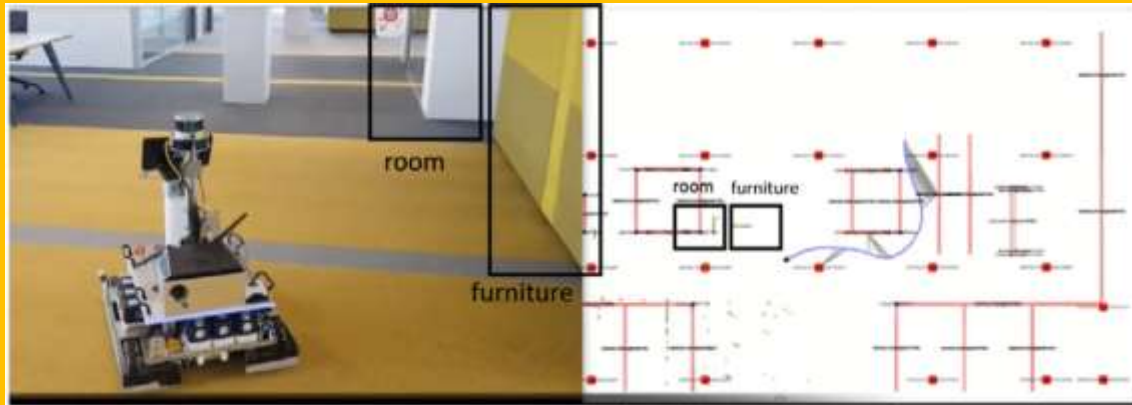
Circl. Toekomst van Circl: De volgende stap.
<https://circl.nl/verdieping/toekomst-van-circl-de-volgendestap>

Circulaire Flexbouw De Meeuw



afbeelding van De Meeuw, De Alliatie - Karmijn,
<https://www.demeeuw.com/projecten/de-alliatie-karmijn/>

Indoor Robotic Navigation



Outline

Abstract

Keywords

1. Introduction

2. State of the art for robot world models and BIM

3. Method for evaluating data flows from BIM to r...

4. In-depth evaluation of data flows

5. Validation

6. Conclusion and future work

Declaration of Competing Interest

Data availability

References

Show full outline








Advanced Engineering Informatics

Volume 56, April 2023, 101959






Full length article

Live semantic data from building digital twins for robot navigation: Overview of data transfer methods

Pieter Pauwels^a  , Rens de Koning^b , Bob Hendriks^b , Elena Torta^b 


Show more 

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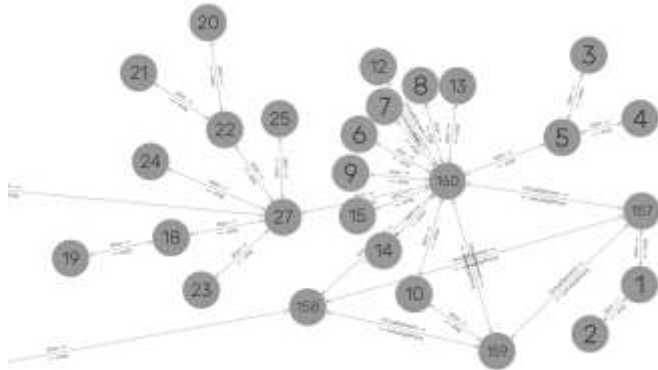
<https://doi.org/10.1016/j.aei.2023.101959>

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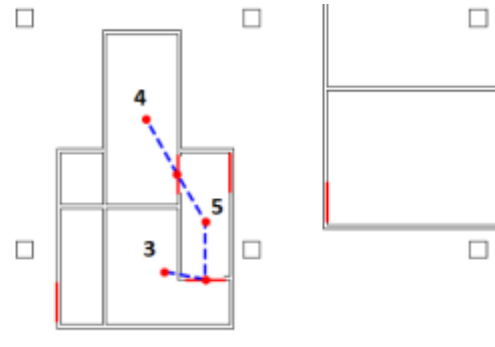
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- A **topological map** abstracts metric information and represents, in a bidirectional undirected graph (unlike the RDF graphs), how spaces are connected to each other.
- A **metric map** includes all metric information needed for path planning

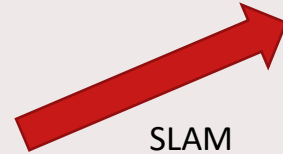


Topological map

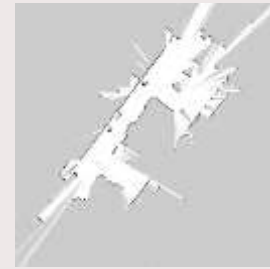


Metric map

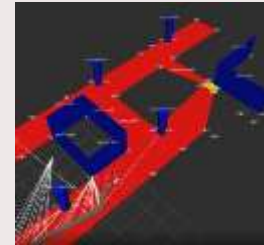
Investigation of an alternative method



SLAM



Manual
creation



Digital Twin



Physical Twin

Semi-automatic
DT-based
creation



Third alternative



Hendriks, B., Pauwels, P., Torta, E., van de Molengraft, M. J. G. R. & Bruyninckx, H. P. J. (2021). Connecting Semantic Building Information Models and Robotics: An application to 2D LiDAR-based localization. In: IEEE International Conference on Robotics and Automation (ICRA) (Accepted/In press). <https://www.youtube.com/watch?v=b7LKU3C6gCQ>

Context-aware robotics based on up-to-date Digital Twin data (BIM, geometry, telemetry)

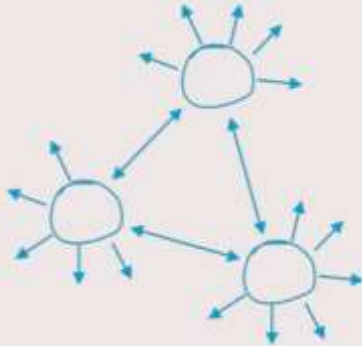


Hendrikx, B., Pauwels, P., Torta, E., van de Molengraft, M. J. G. R. & Bruyninckx, H. P. J. (2021). Connecting Semantic Building Information Models and Robotics: An application to 2D LiDAR-based localization. In: IEEE International Conference on Robotics and Automation (ICRA).

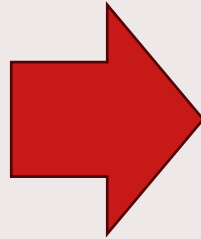
Decentralized Data and Systems

The big ... decentralization of data and systems!!

Centralized



- Central authority
- Data outdated
- Data inaccessible



Decentralized



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- Granular access

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Research projects



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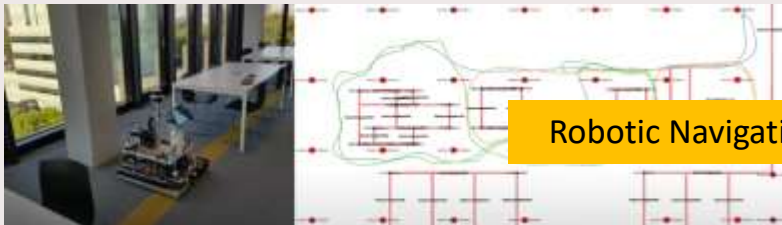


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From Decentralal Hubs to P2P Networks

1. Central Management

- Who has data ownership?
- Who pays the price?
- Hard to scale in diverse communities

2. Decentral hubs

- Achievable
- Current trend and realisation
- Dependency on shared use of infrastructure
- Who has data ownership?
- Who pays the price?

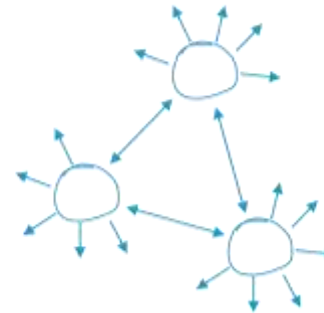
3. Peer-to-Peer (P2P) network

- Not existing for the building sector
- Scalable if done properly
- Price and data ownership stays with the source
- Infrastructure needed
- How to manage this data mesh over time?

Central
management



Decentral
Hubs



P2P
Network



The future?

Thank you



<https://isbe.bwk.tue.nl/>

Questions?

Pieter Pauwels - p.pauwels@tue.nl



BUILDINGS AND SEMANTICS

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