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Towards digital interoperability for the Facilities Management domain: a review of Semantic Web-based approaches

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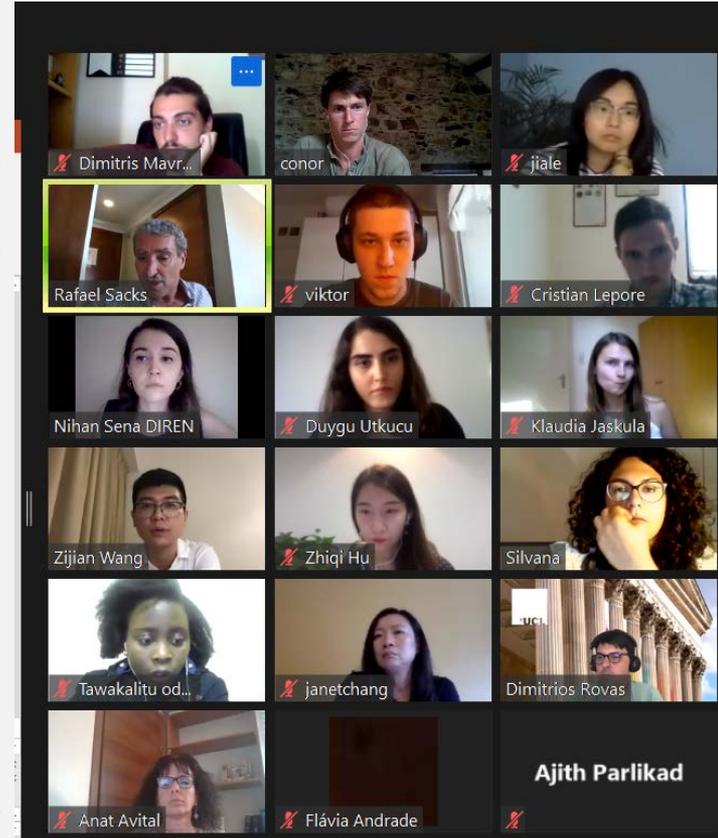


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<https://cbim2020.net.technion.ac.il/>

Cloud-BIM European Training Network

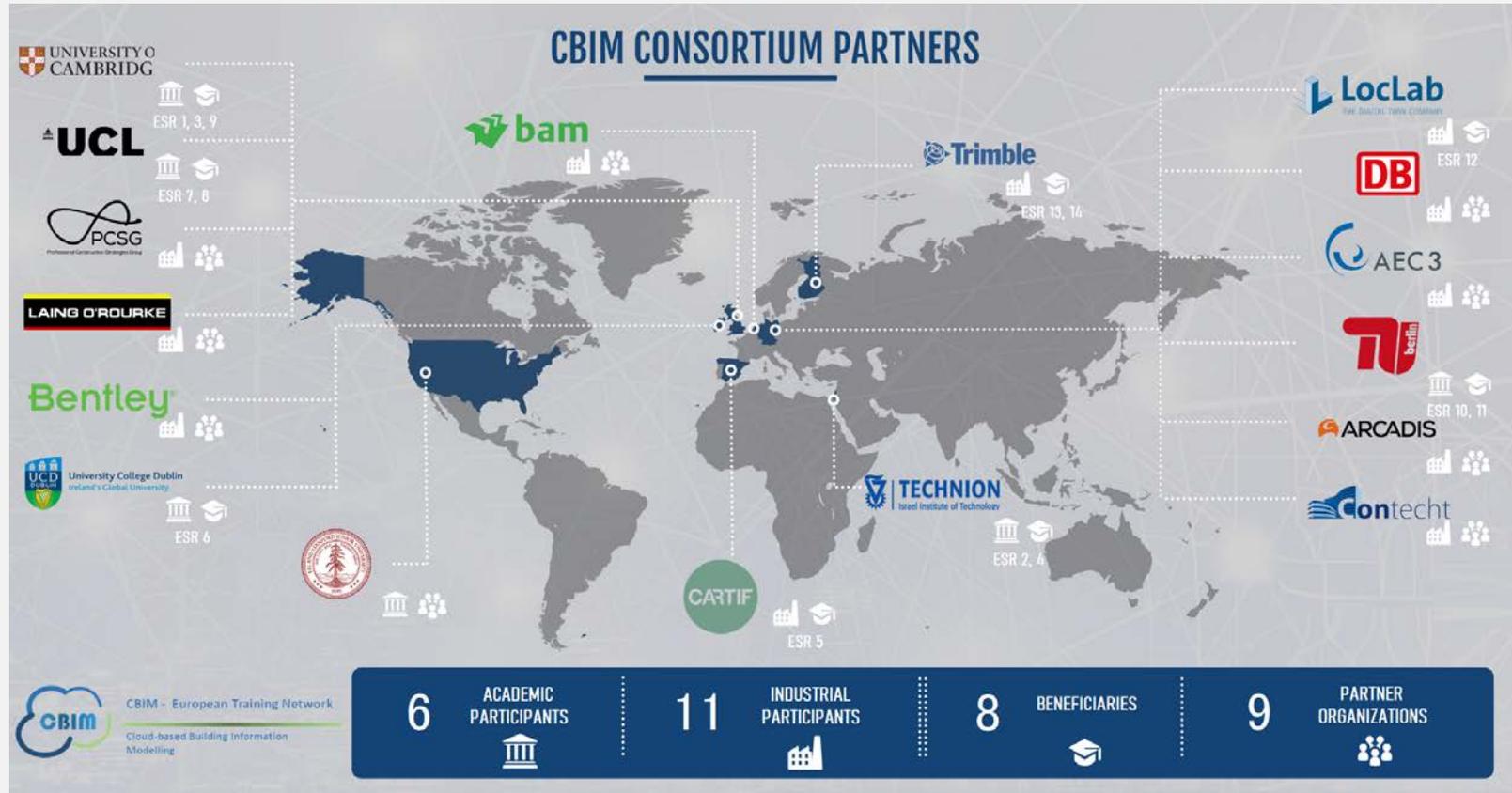


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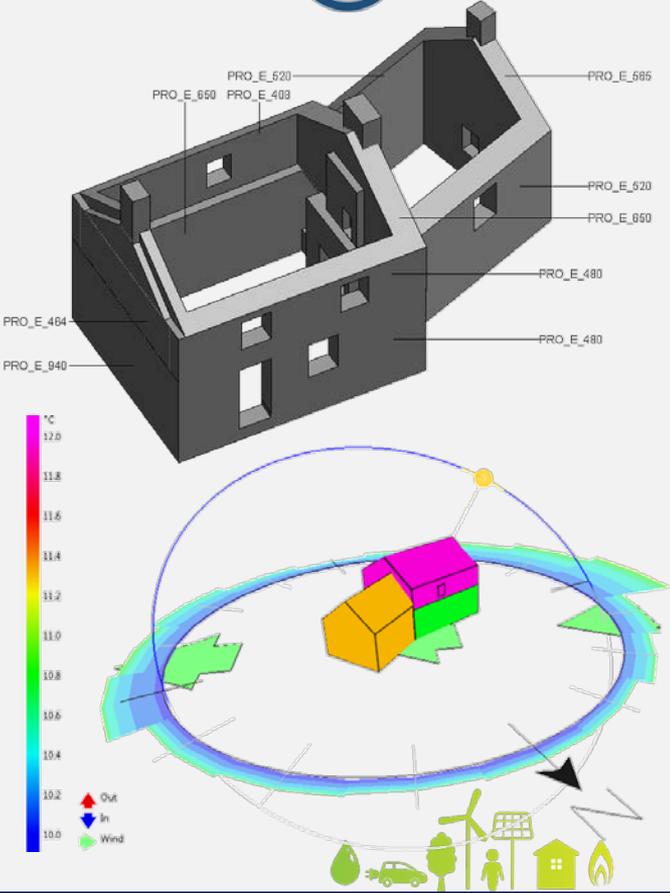


European Commission

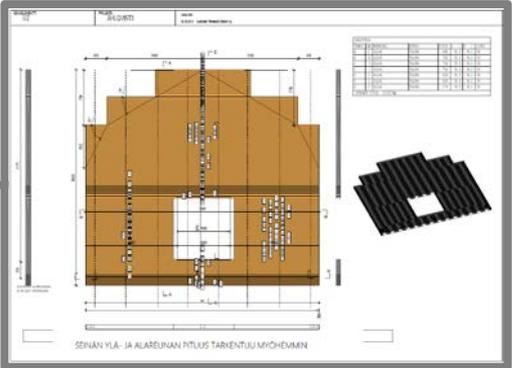
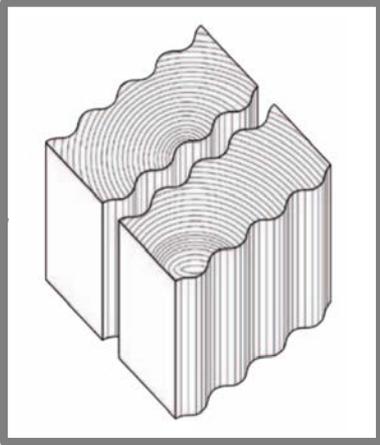
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Digitalisation of the built environment



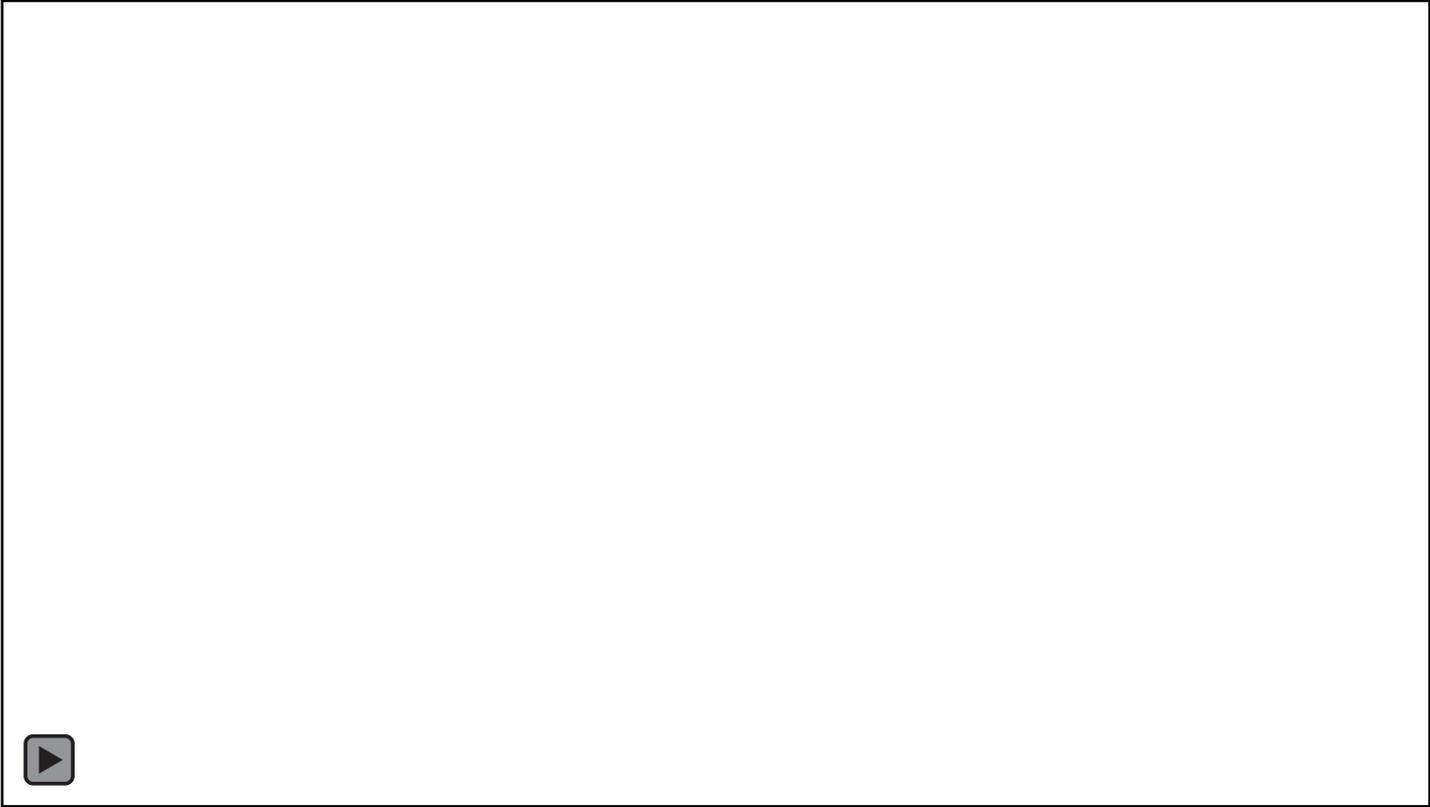
Designer / contractor-led BIM paradigm



Why focus on the **operational phase**?



Motivation = Global climatic situation



Source: NASA Global Climate Change, 2019

Operational phase = significant resource drain

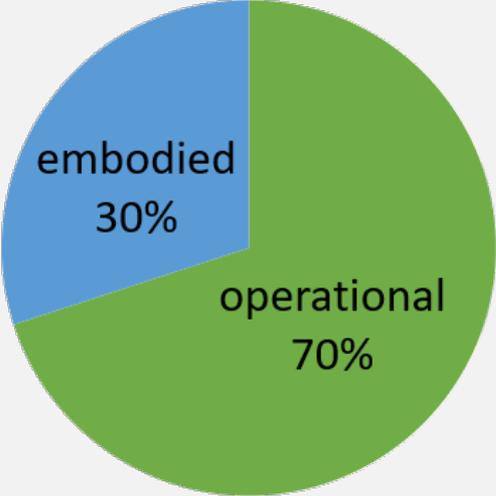
climate
crisis

(IPCC 2018)



built
environment
significant
contributor
(~40%)

(UN EIEA 2017)



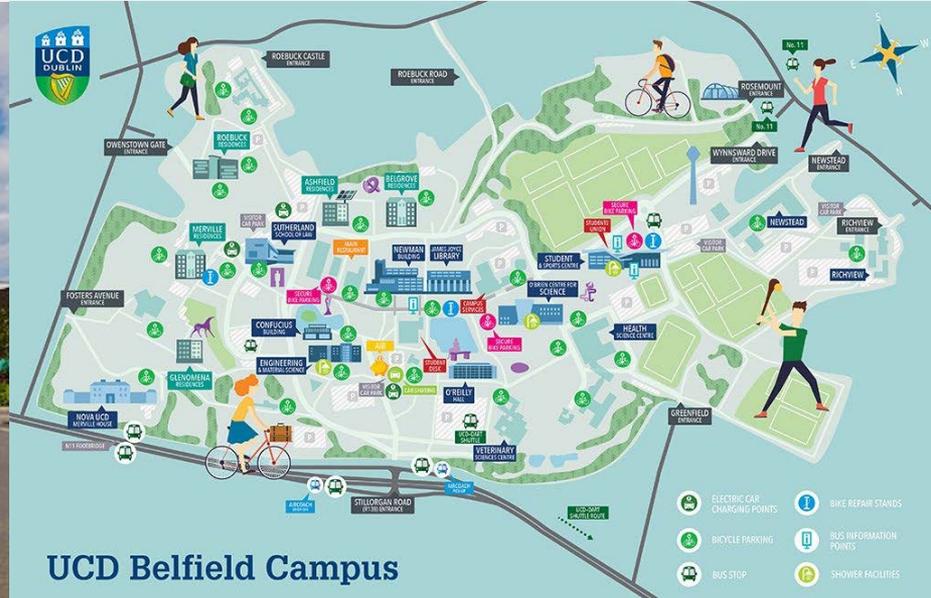
Energy use of buildings over whole life
(Geekiyana & Ramachandra 2018)



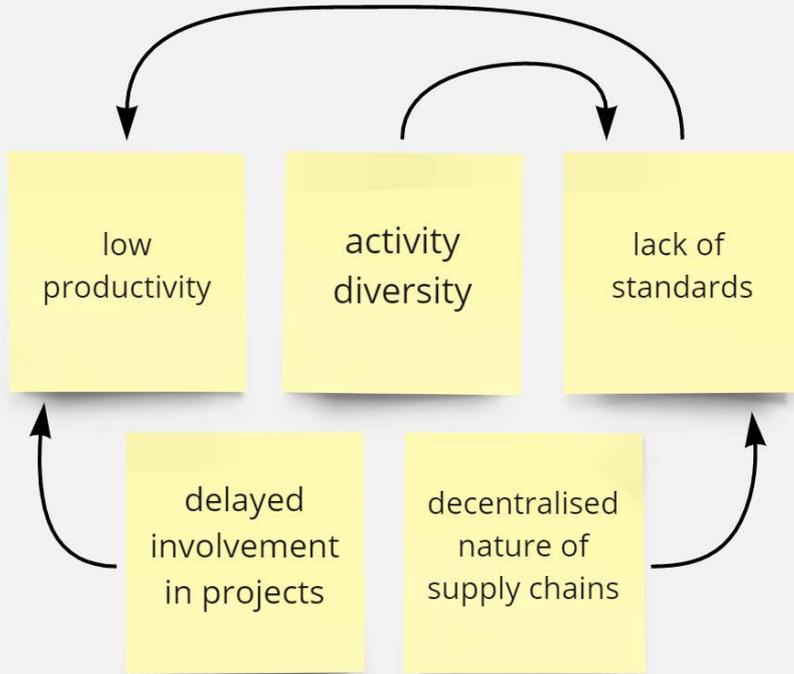
The role of facility managers

“an integrated approach to operating, maintaining, improving and adapting the buildings and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of that organization”

(Barrett & Baldry 2003)



EC3 (Shaw et al. 2021)



2021 European Conference on Computing in Construction
Ixia, Rhodes, Greece
July 25-27, 2021



FACILITIES MANAGEMENT DOMAIN REVIEW: POTENTIAL CONTRIBUTIONS TOWARDS DIGITALISATION

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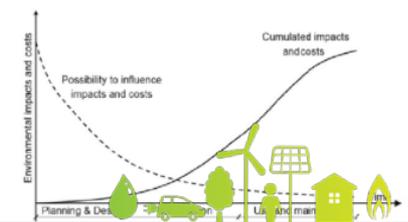
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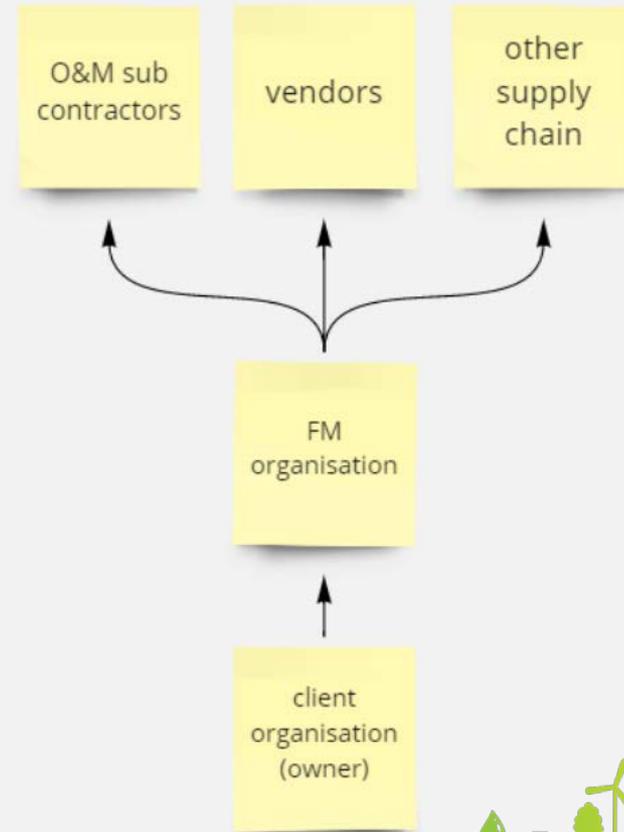
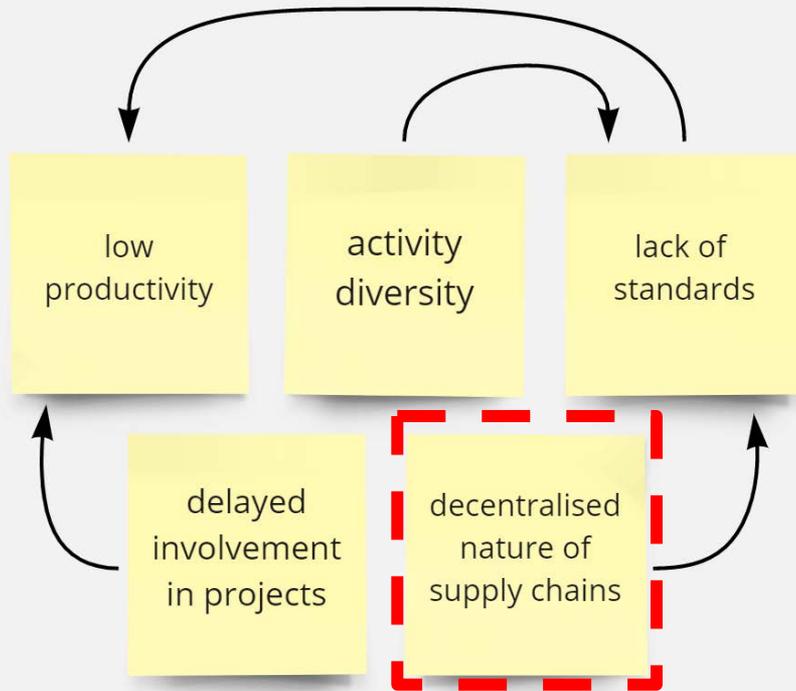
ABSTRACT

Digitalisation within the facilities management (FM) sector has great potential to positively impact the environmental performance of the architecture, engineering, construction and operations (AECO) industry. Currently, the domain suffers from poor data integration with other disciplines and earlier life-cycle phases. Though solutions which address the interoperability issue are replete in the literature, there remains no comprehensive alignment. This domain review paper synthesises the key literature around digitalisation within FM. In doing so, it outlines a broader working definition of FM, identifies key subtopics and gaps in knowledge and recommends a

mapped the stages of a construction project against the familiar graph of diminishing influence on cost over time (Figure 1) from project management theory.



Challenges faced by facility managers organisational complexity



Challenges faced by facility managers process misalignment

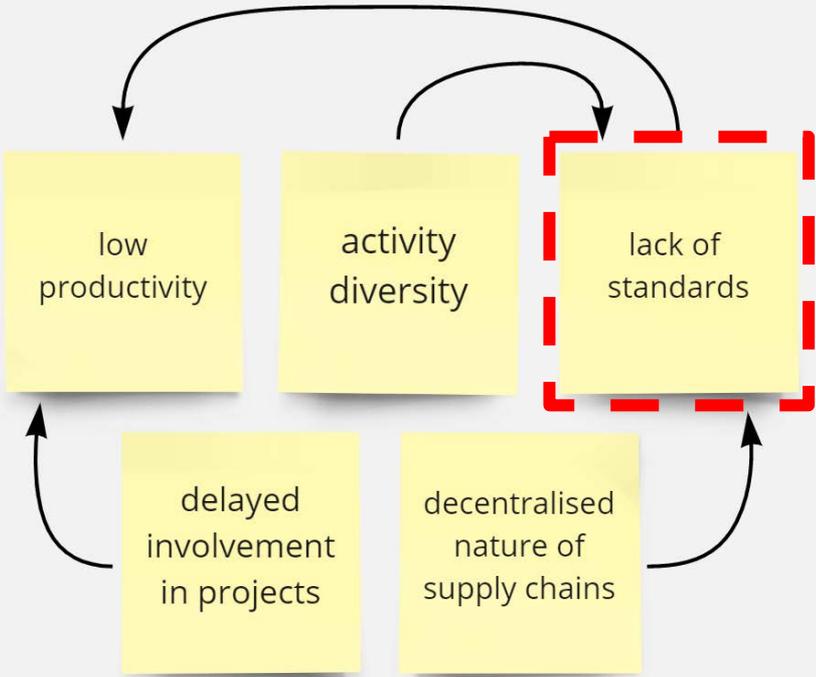


image source: Whole Building Design Guide (2021)



Challenges faced by facility managers process misalignment

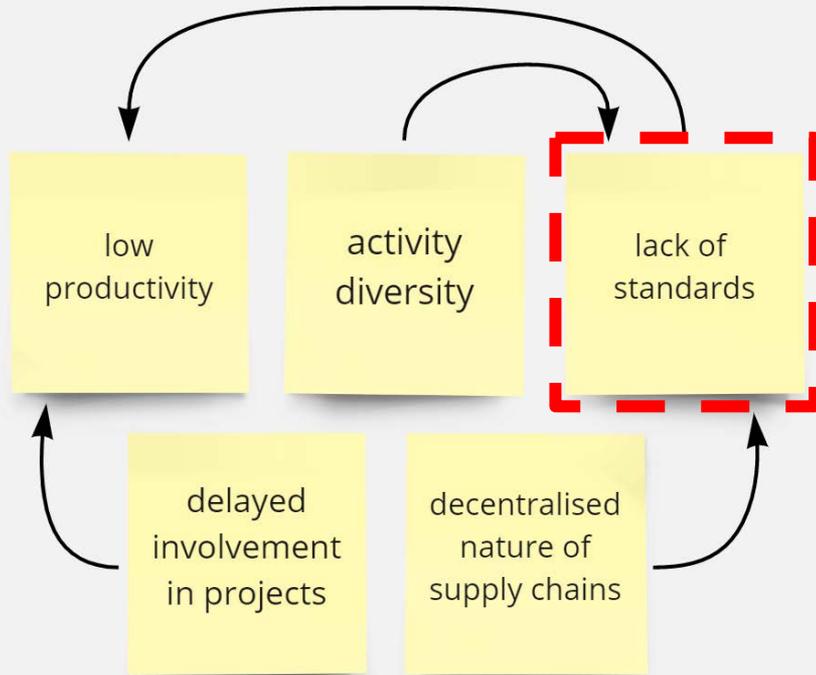


image source: thenewswheel.com (2021)



image source: Whole Building Design Guide (2021)



Challenges faced by facility managers **delayed involvement**

image source: EXCEL property consul (2019)

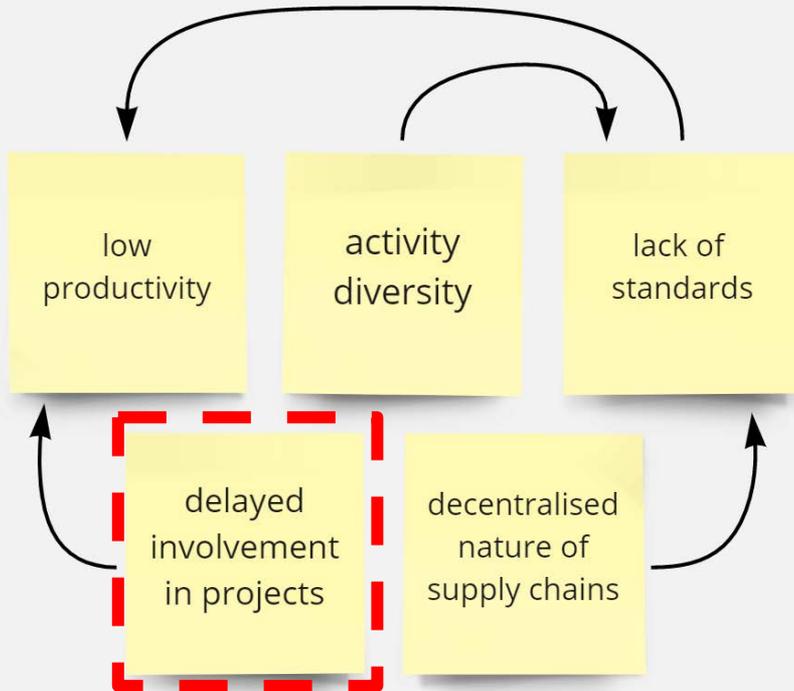
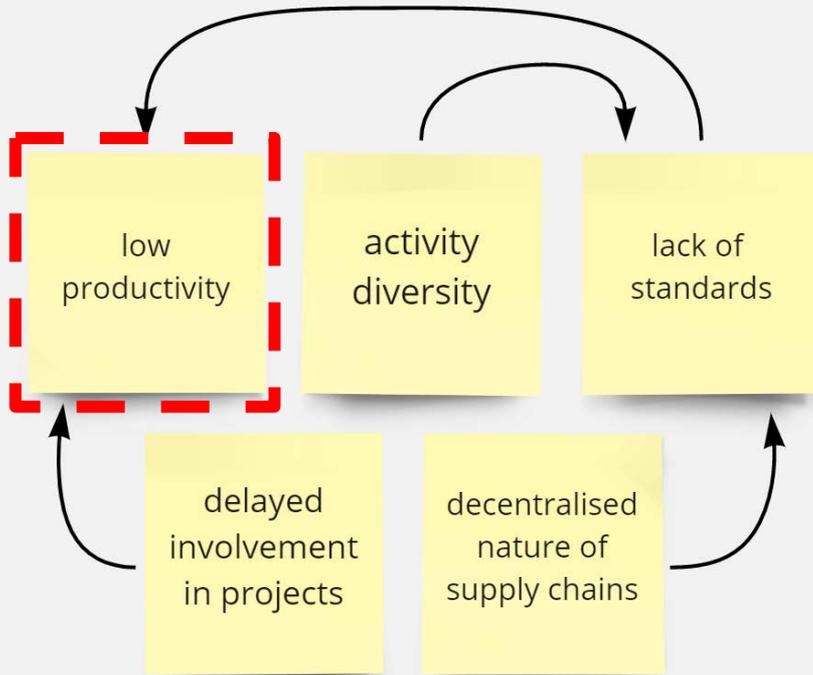


image source: Whole Building Design Guide (2021)



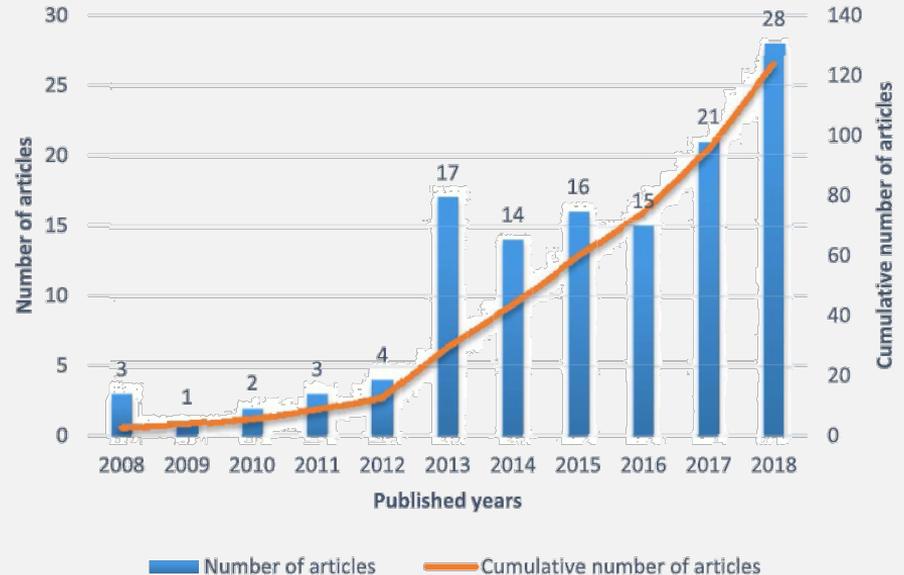


“decline in productivity at industry scale following the last financial crash”
(Bröchner 2017)

“two-thirds of waste [due to] various degrees of manually retrieving information from poorly managed sources”
(NIST 2004) a dated, but often cited source



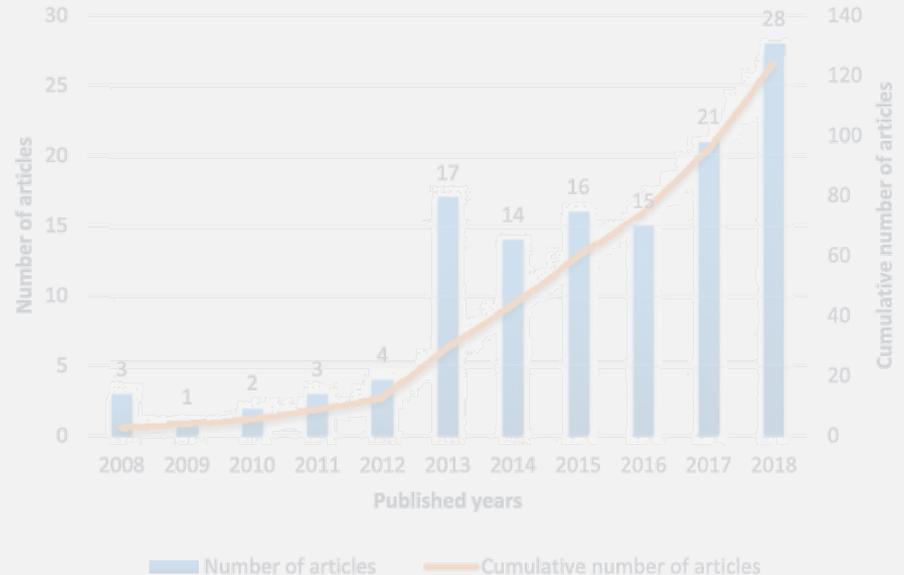
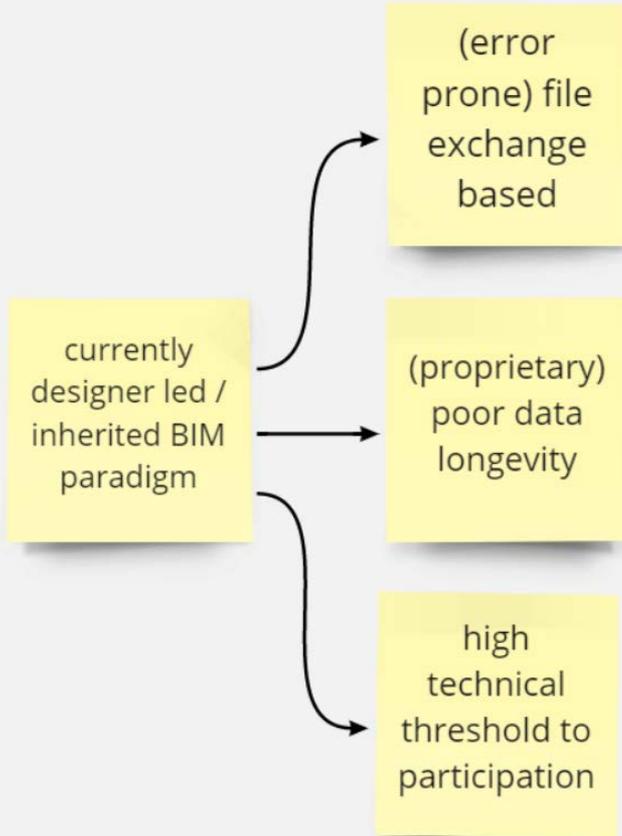
Increasing interest in digitalisation within the FM domain



BIM for FM articles published over the last decade (Matarneh et al. 2019)



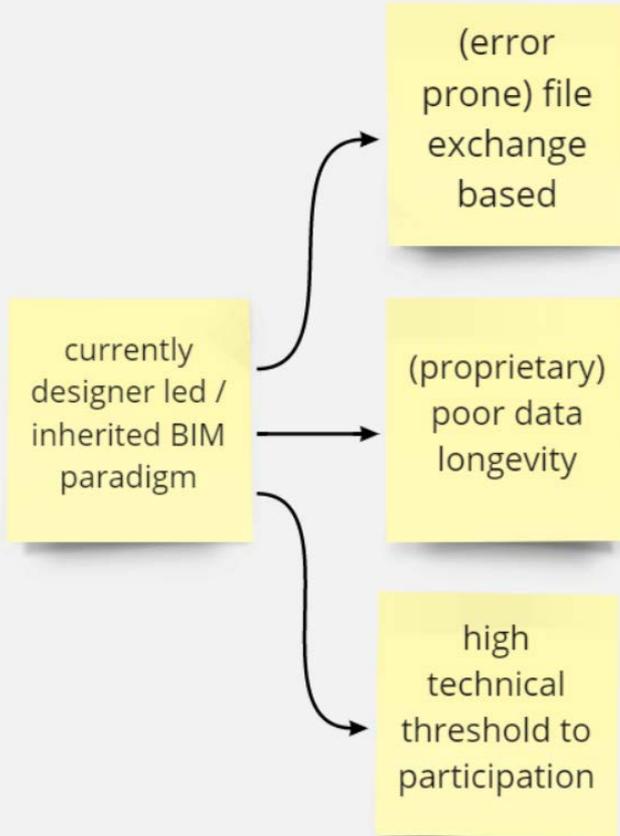
Current BIM paradigm not suited to FM needs



BIM for FM articles published over the last decade (Matarneh et al. 2019)



Current BIM paradigm not suited to FM needs

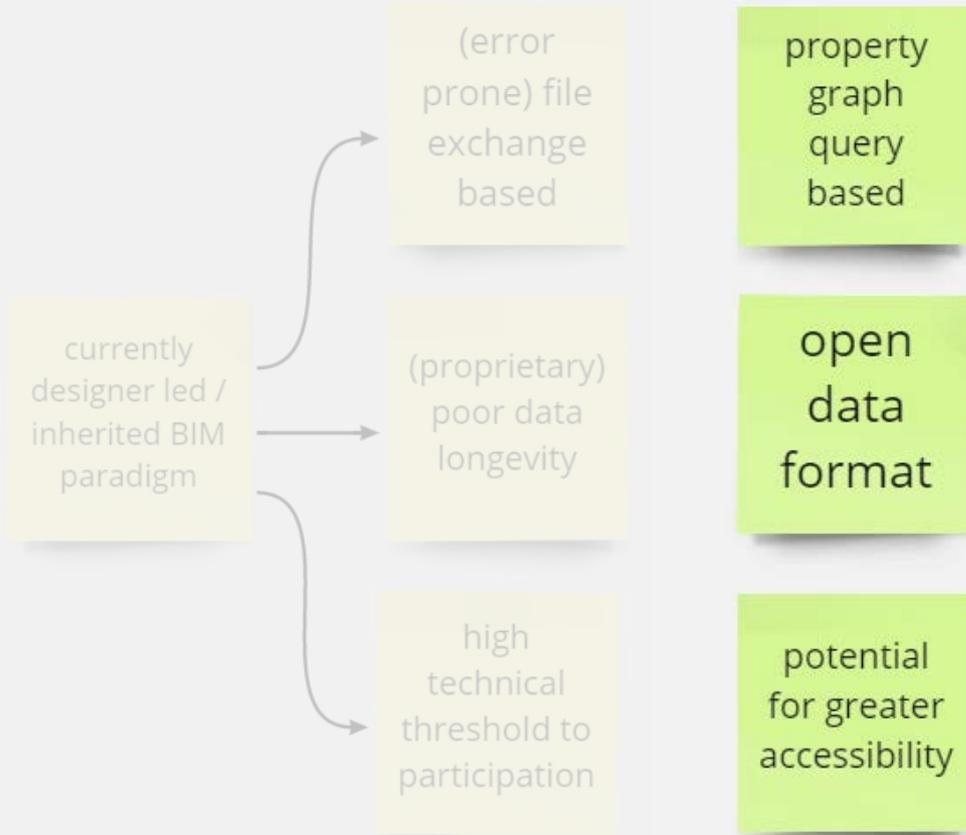


“FM practitioners have experienced reduced access to data since a move towards digitisation in the built environment”

(Quinn et al. 2020)



Semantic Web Technology of great interest in the field



“suited to decentralised context”
(Santos et al. 2017)

“uses established technologies”
(Pauwels et al. 2017)

“step in democratising the market”
(Rasmussen et al. 2018)



What is the **Semantic Web**?

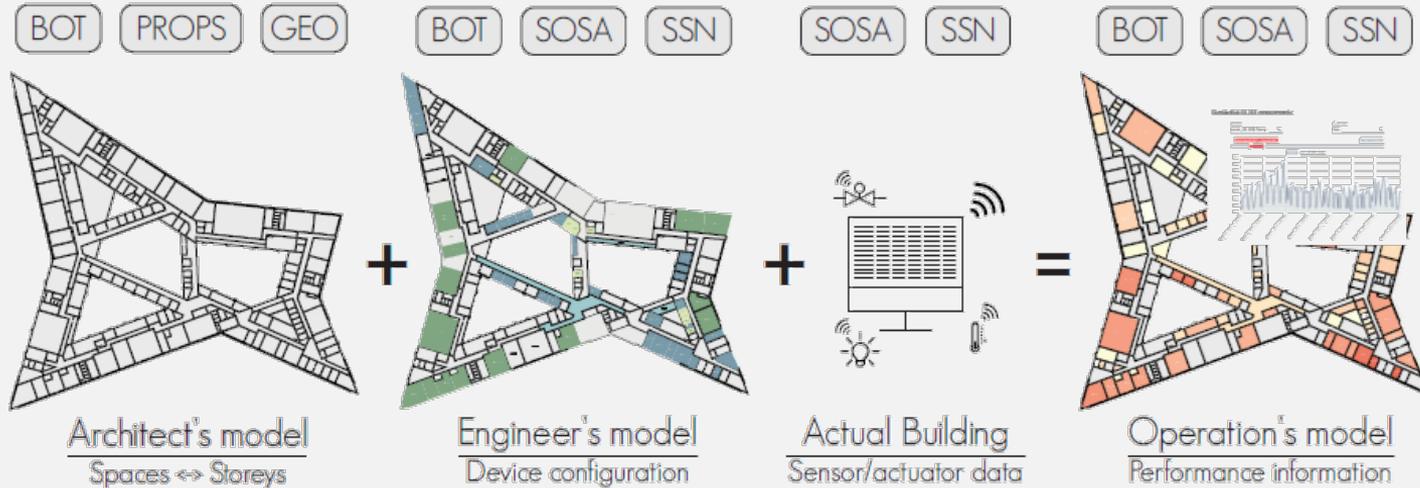


“an enhancement of the current World Wide Web with machine-understandable information (as opposed to most of the current Web, which is mostly targeted at human consumption)”

(CACM, 2021)



Semantic web technologies facilitating data fusion



Demonstration of Semantic Web-enabled data fusion
(Rasmussen 2019)



CIB W78 - LDAC (Shaw et al. 2021)

Digital Interoperability for the Facilities Management Domain: a Review of Semantic Web-based Approaches

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Abstract

The use of Semantic Web-based Technologies (SWT) to support digital Facilities Management (FM) activities has been shown to address interoperability challenges between disciplinary stakeholders. By establishing shared understanding through ontologies, eliminating precarious file exchanges and democratising participation through non-proprietary technologies, SWTs are receiving growing interest from the research community. Despite this, no comprehensive review exists which analyses works with a specific focus on the FM domain. This paper reviews 35 academic works and provides a broad discussion around academic and industry initiatives in SWTs for the FM domain, identifying research gaps and future directions of interest. We find that SWTs are already being used by FM practitioners and that implementation is highly case-specific and thus, developments need to be flexible and user-oriented in their design. This work towards a comprehensive domain review provides a useful reference for others in the field as well as informing our own future research activities.

Keywords: facilities management, digitalisation, interoperability, semantic web technologies

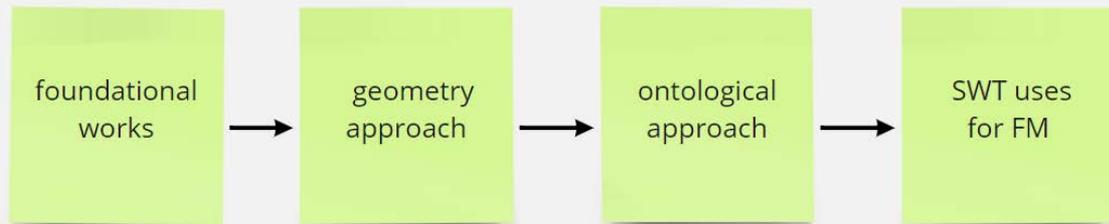


Table 1: classification of literature sources per the guiding conceptual model

relevant area	reviewed authors
foundational works	Noy & McGuinness (2001), Schevers et al. (2007), East (2007), Vanlande & Nicolle (2008), Ruikar et al. (2007), Törmä (2013), Beetz (2009), Redmond et al. (2012), Belsky et al. (2016), Pärn et al. (2017), Godager (2018), Patacas et al. (2020)
geometric approach	Pauwels & Roxin (2016), Rasmussen, Pauwels, Karlshøj & Hviid (2017), McArthur & Bortoluzzi (2018), Chen et al. (2018), Bonduel et al. (2018), Krämer & Besenyői (2018), Wagner et al. (2020), East et al. (2021), Jung (2021)
ontological approach	Rasmussen, Pauwels, Karlshøj & Hviid (2017), Niknam & Karshenas (2017), Bonino & De Russis (2018), Rasmussen et al. (2020), Luo et al. (2021)
SWT uses for FM	Kim et al. (2018), Chen et al. (2018), Yalcinkaya & Singh (2018), Hammar et al. (2019), Gouda Mohamed et al. (2020), Kumar & Teo (2021), Droog & Baayen (2021), Liu & Chou (2021)



demonstrators
translating /
representing
geometry in
RDF

(Pauwels et al. 2017)

integration
of static and
dynamic
data in graph

(Rasmussen et al. 2018)

post-
processing /
simulation
using graph
data

(Hu et al. 2021)



- For the FM domain, the current building data model (BIM) is inappropriate
- FM industry already using SWT (not limited to academic tinkering!)
- Academic works in the domain validate developments with (multiple) practitioners
- COBie of great interest, though should be careful about seeing this as a panacea
- A need for abstraction away from programming languages (to enable greater participation)
- A need for flexible and intuitive middleware layers (given changing nature of the domain and need for case specificity)
- A need for extending enrichment capabilities to supply chain



Lowering the participatory (technical) threshold for FM service providers to contribute to (enrich) a shared facility information database, using semantic web-based processes, will increase productivity in the use case.

- A need for abstraction away from programming languages (to enable greater participation)
- A need for flexible and intuitive middleware layers (given changing nature of the domain and need for case specificity)
- A need for extending enrichment capabilities to supply chain



Lowering the participatory (technical) threshold for FM service providers to contribute to (enrich) a shared facility information database, using semantic web-based processes, will increase productivity in the use case.

what ontological arrangement supports the enrichment / propagation?

1.

what are the data exchange requirements (queries) to support the use case?

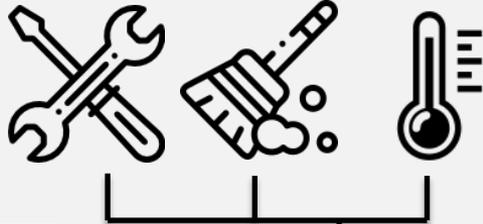
2.

what is the framework to abstract this process for greater participation?

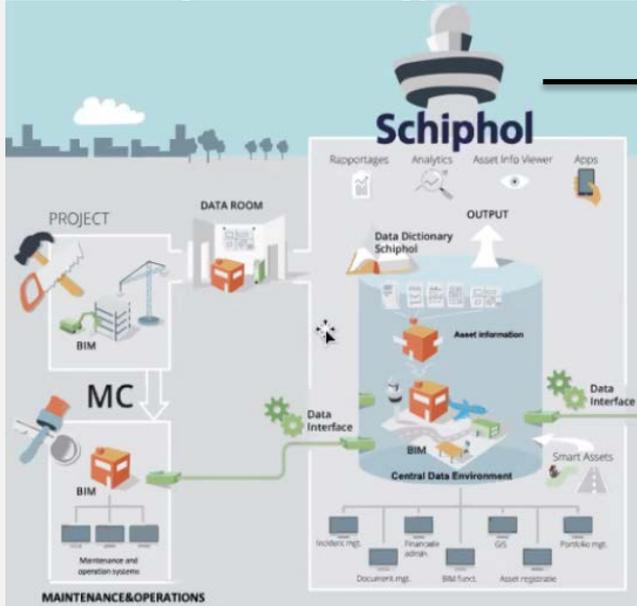
3.



Use case - Suppliers of FM team at Schiphol airport

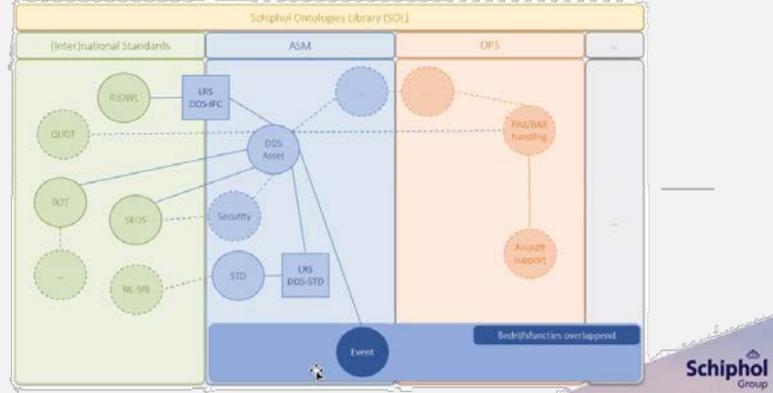


Data Management Strategy



bam
facilities management

Ontology Library – Our Vision



Demonstration of linked data and ontology use in FM industry (Droog & Baayen 2021)





References



Barrett, P. & Baldry, D. (2003), Facilities Management: Towards Best Practice, 2nd edition.

Intergovernmental Panel on Climate Change (2018), Global warming of 1.5°C, Technical report. OCLC:1056192590.

UN Environment and International Energy Agency (2017), Towards a zero-emission, efficient, and resilient buildings and construction sector. UN Global Status Report, Technical report.

Geekiyana, D. & Ramachandra, T. (2018), Significant Factors Influencing Operational and Maintenance (O&M) Costs of Commercial Buildings, 7th World Construction Symposium.

Bröchner, J. (2017), Measuring the productivity of facilities management, Journal of Facilities Management.

Gallaher, M. P., O'Connor, A. C., Dettbarn, Jr., J. L. & Gilday, L. T. (2004), Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry, Technical Report NIST GCR 04-867, National Institute of Standards and Technology.

Matarneh, S. T., Danso-Amoako, M., Al-Bizri, S., Gaterell, M. & Matarneh, R. (2019), Building information modelling for facilities management: A literature review and future research directions, Journal of Building Engineering.

Quinn, C., Shabestari, A.Z., Misic, T., Gilani, S., Litoiu, M. & McArthur, J.J. (2020), Building automation system - BIM integration using a linked data structure, Automation in Construction.

Niknam, M. & Karshenas, S. (2017), A shared ontology approach to semantic representation of BIM data, Automation in Construction

Sack, H. & Alam, M. (2020) Open HPI Knowledge Graphs course, FIZ Karlsruhe - Leibniz Institute for Information Infrastructure & Karlsruhe Institute of Technology

Hu, S., Wang J., Hoare, C., Li, Y., Pauwels, P. & O'Donnell, J. (2021) Building energy performance assessment using linked data and cross-domain semantic reasoning, Automation in Construction.

Pauwels, P., Krijnen, T., Terkaj, W. & Beetz, J. (2017), Enhancing the ifcOWL ontology with an alternative representation for geometric data, Automation in Construction.

Rasmussen, M. H., Frausing, C., Hviid, C. & Karlshøj, J. (2018) Demo: Integrating Building Information Modeling and Sensor Observations using Semantic Web, Semantic Sensor Networks Workshop 2018.





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