Data-driven design under uncertainty

Jennifer Whyte – May 2022

THE UNIVERSITY OF SYDNEY

Data-centric engineering programme

Lloyd's Register Foundation

Grand challenges

Data-driven engineering design under uncertainty

Themes

- **Infrastructure**
- **Complex systems**
- **People-centric design**

Focus

- Predicting system interactions and potential failures
- Model integration
- Problem structuring and scenario generation
- Bringing knowledge from operations into project delivery
- Managing design change
- Sensitivity analyses

Data-driven engineering design under uncertainty

Core projects

1. Data-driven design assurance
2. Data-driven design of civic infrastructure
3. Digital twin - design change in complex systems
4. Design for retrofit

Associated research

- AEC Production Control Room, UKRI funded work (Dr Ranjith Soman and Dr Karim Farghaly, 2020-1)
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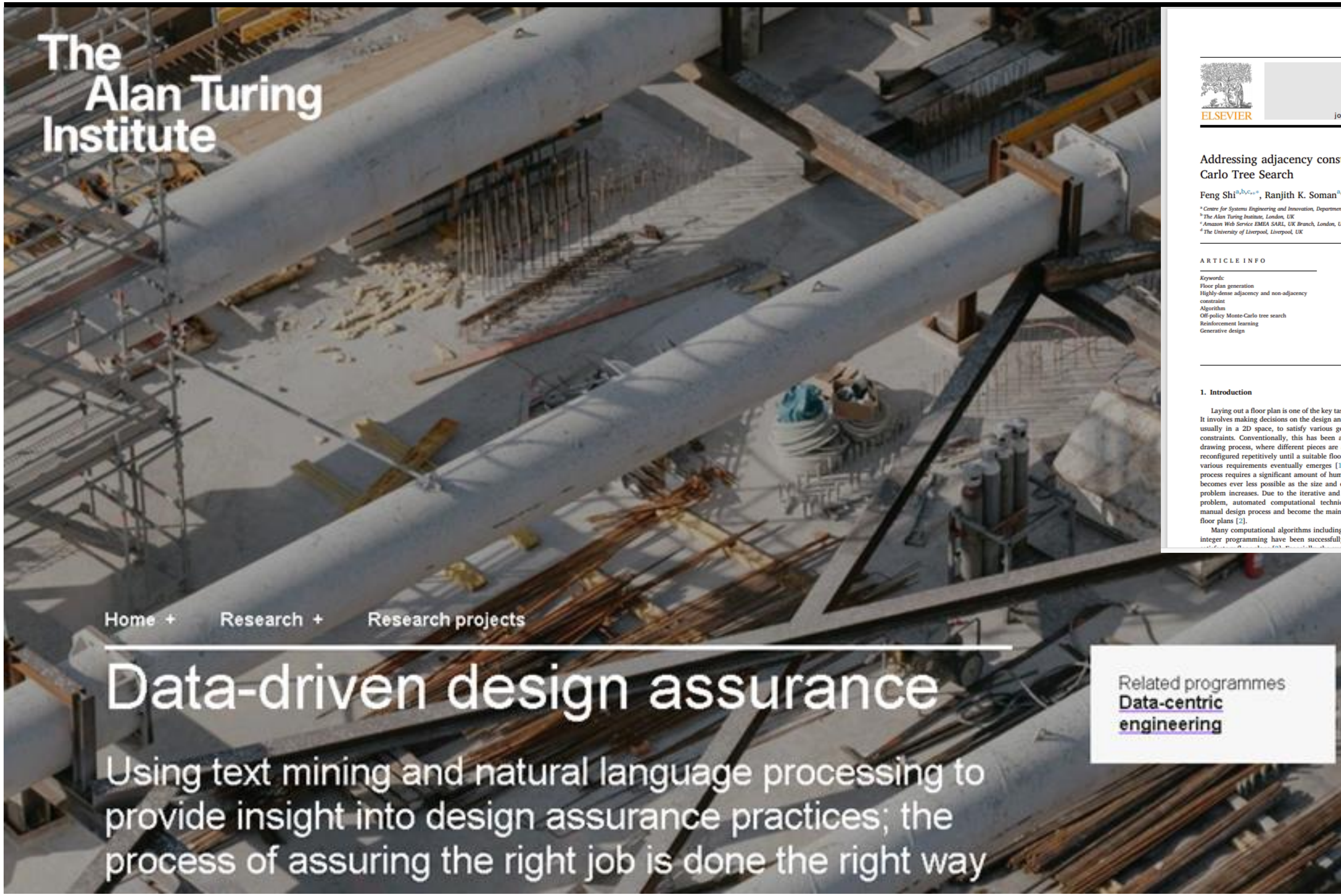


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Addressing adjacency constraints in rectangular floor plans using Monte-Carlo Tree Search

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Highly-dense adjacency and non-adjacency constraint
Algorithm
Off-policy Monte-Carlo tree search
Reinforcement learning
Generative design

ABSTRACT

Manually laying out the floor plan for buildings with highly-dense adjacency constraints at the early design stage is a labour-intensive problem. In recent decades, computer-based conventional search algorithms and evolutionary methods have been successfully developed to automatically generate various types of floor plans. However, there is relatively limited work focusing on problems with highly-dense adjacency constraints common in large scale floor plans such as hospitals and schools. This paper proposes an algorithm to generate the early-stage design of floor plans with highly-dense adjacency and non-adjacency constraints using reinforcement learning based on off-policy Monte-Carlo Tree Search. The results show the advantages of the proposed algorithm for the targeted problem of highly-dense adjacency constrained floor plan generation, which is more time-efficient, more lightweight to implement, and having a larger capacity than other approaches such as Evolution strategy and traditional on-policy search.

1. Introduction

Laying out a floor plan is one of the key tasks in architecture design. It involves making decisions on the design and layout of all the rooms, usually in a 2D space, to satisfy various geometric and topological constraints. Conventionally, this has been a manual trial and error drawing process, where different pieces are adjusted, rearranged and reconfigured repetitively until a suitable floor layout that satisfies the various requirements eventually emerges [1]. This iterative manual process requires a significant amount of human labour and time, and becomes ever less possible as the size and complexity of the design problem increases. Due to the iterative and repetitive nature of this problem, automated computational techniques have replaced the manual design process and become the main approach for generating floor plans [2].

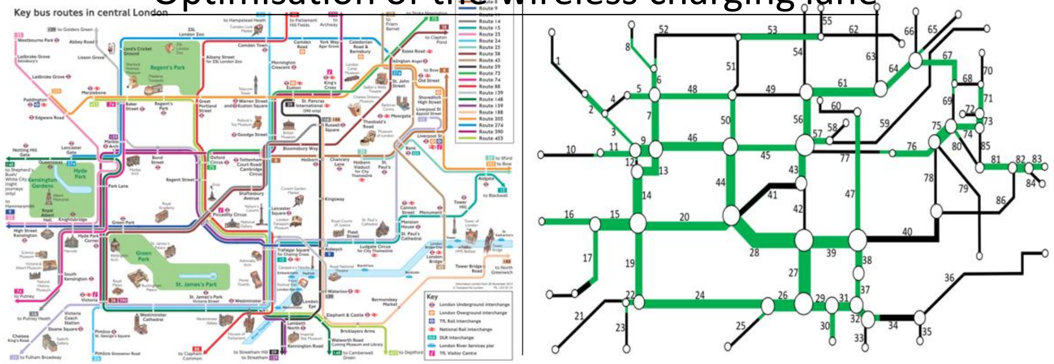
Many computational algorithms including heuristic search, mixed-integer programming have been successfully developed to generate

is usually equally around (or at least no more than twice) the number of rooms. For example, Camozzato et al. [4] proposed a procedural method to generate a floor plan of 8 rooms with only 1 adjacency constraint. In [5], the authors illustrate a rectangular dissection method through an example of only 4 rooms with 3 adjacency constraints. Case study [6] tackles totally 9 adjacency constraints within 9 rooms, so the number of adjacency constraints is still no more than the number of rooms. Therefore, these approaches become inefficient with increased scale and density due to their limited scalability. For example, Rodrigues et al. [7] have applied the evolutionary methods to generate floor plans for a hotel up to 30 rooms, however the total number of adjacency constraints is only 34 and therefore still leads to a sparse adjacency matrix. Also, their case is not to generate a rectangular floor plan, therefore rooms can be placed in a more creative way with flexible boundaries. Finally, their algorithm had a runtime of 52 min on a 4GHz 8-core computer with multi-threading, which is not expensive when considering all kinds of granular constraints that were tackled in

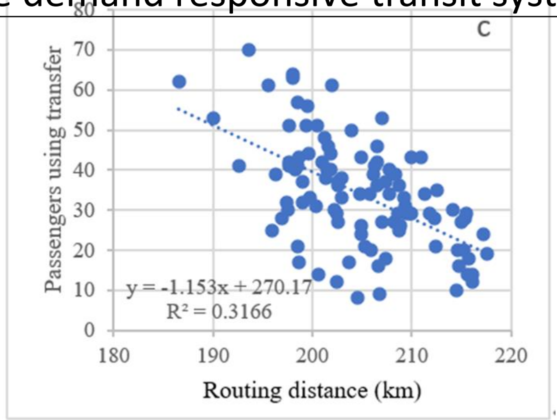
Design for uncertainty focusing on infrastructures and urban mobility

Mathematic modelling techniques are employed for quantifying uncertainties and further optimising the design of urban infrastructure and mobility services based on the large quantity data collected.

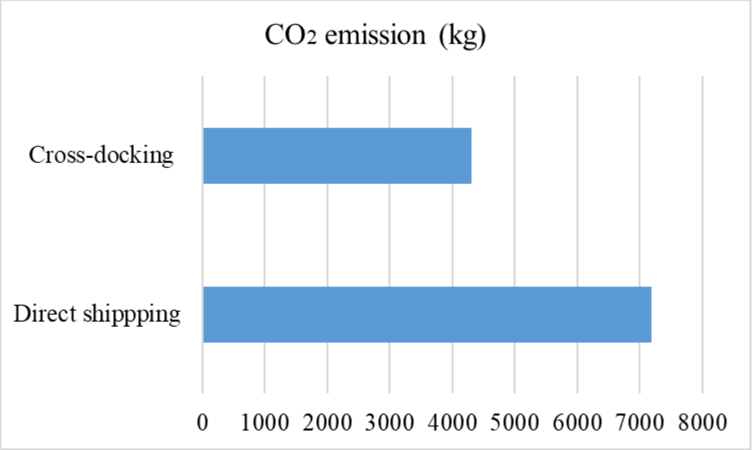
Optimisation of the wireless charging lane



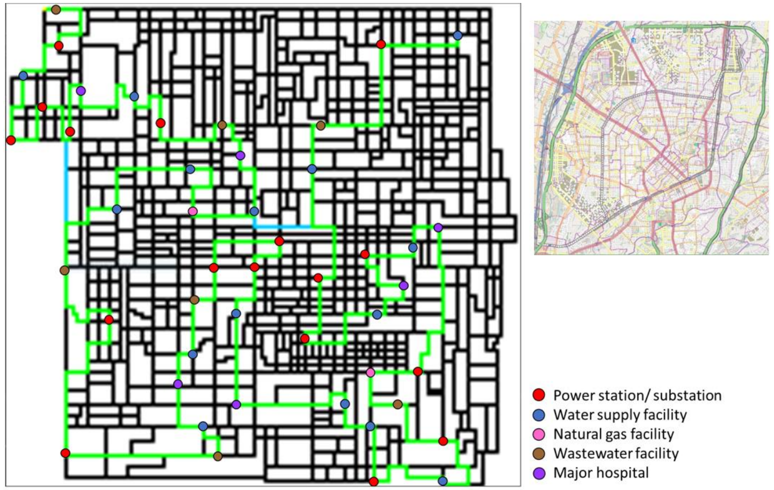
Optimisation of the demand responsive transit system with transfer



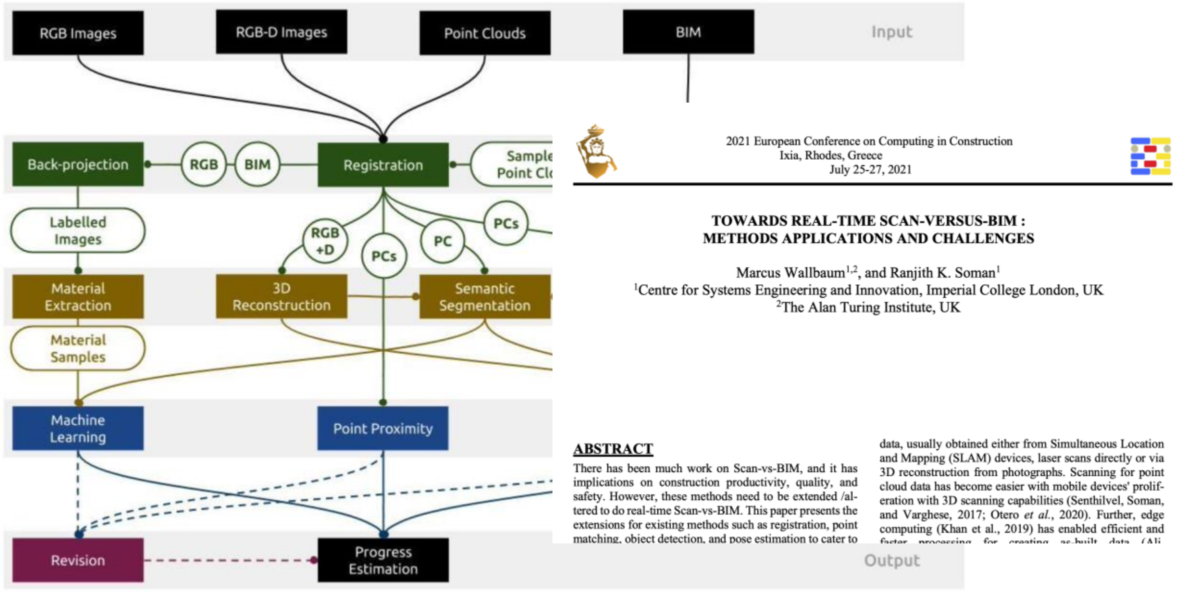
The design of environmentally friendly construction supply chain



The optimal post disaster infrastructure repairing scheme via Q-learning



Continuous Scan-vs-BIM to identify changes in digital-twins and understanding change propagation



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

TOWARDS REAL-TIME SCAN-VERSUS-BIM : METHODS APPLICATIONS AND CHALLENGES

Marcus Wallbaum[1,2], and Ranjith K. Soman[1]
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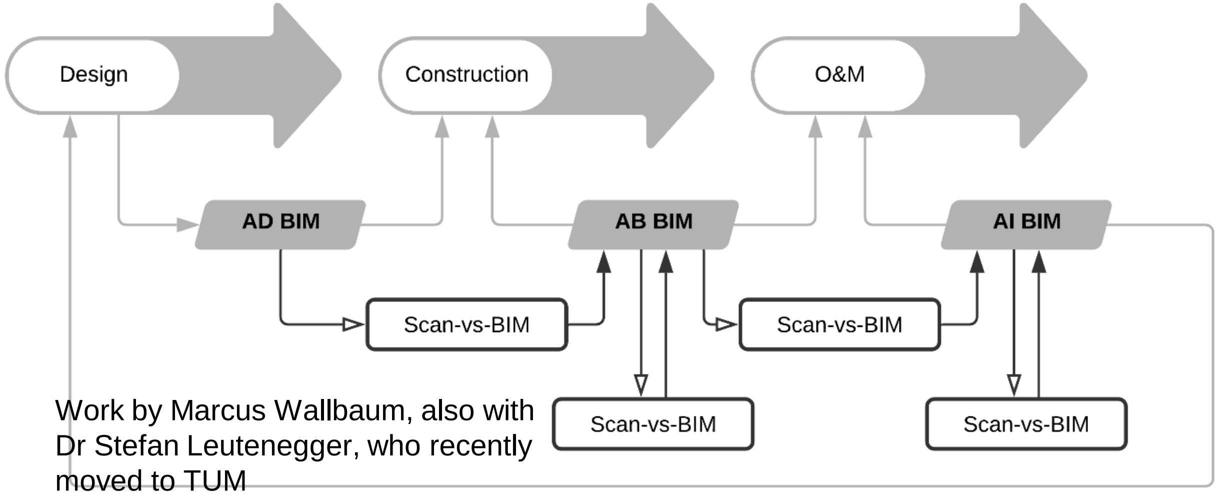
[2]The Alan Turing Institute, UK

ABSTRACT

There has been much work on Scan-vs-BIM, and it has implications on construction productivity, quality, and safety. However, these methods need to be extended /altered to do real-time Scan-vs-BIM. This paper presents the extensions for existing methods such as registration, point matching, object detection, and pose estimation to cater to

data, usually obtained either from Simultaneous Location and Mapping (SLAM) devices, laser scans directly or via 3D reconstruction from photographs. Scanning for point cloud data has become easier with mobile devices' proliferation with 3D scanning capabilities (Senthilvel, Soman, and Varghese, 2017; Otero *et al.*, 2020). Further, edge computing (Khan et al., 2019) has enabled efficient and

- Identify changes using Scan-vs-BIM
- Calculate change propagation using DSM
- Collaborative decision making
- Better design

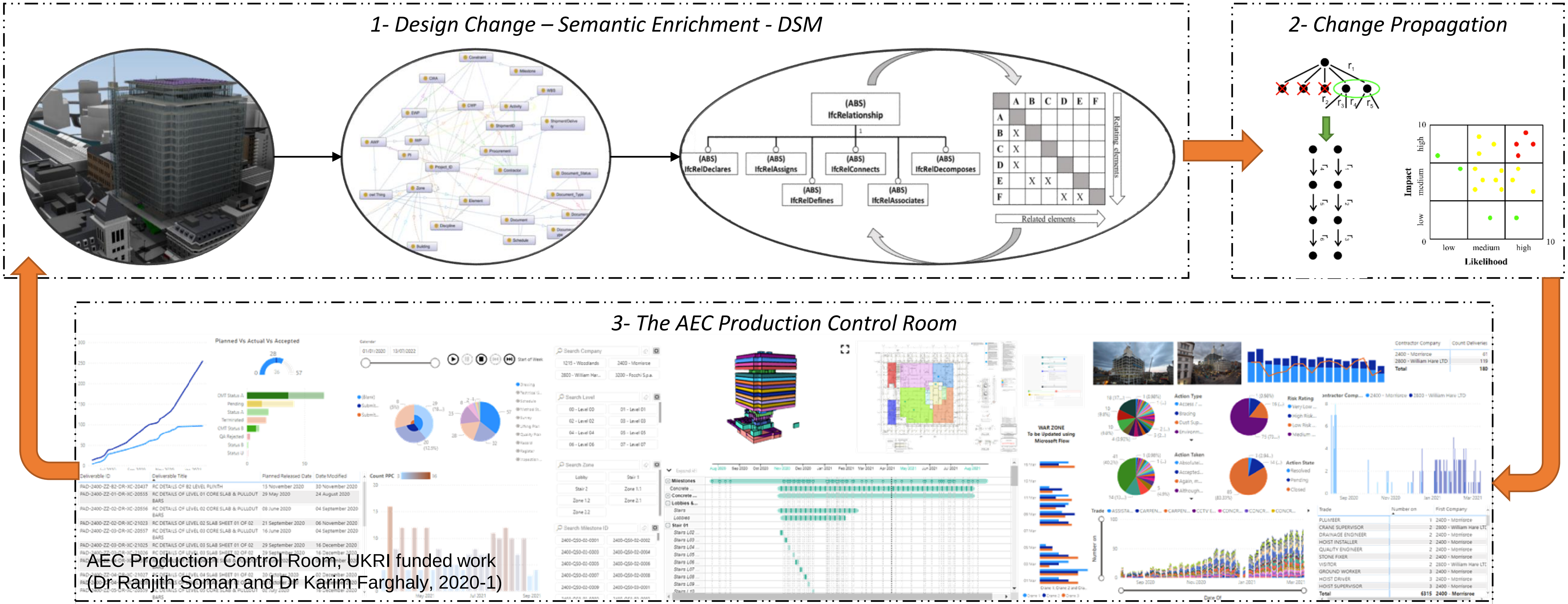


Work by Marcus Wallbaum, also with Dr Stefan Leutenegger, who recently moved to TUM

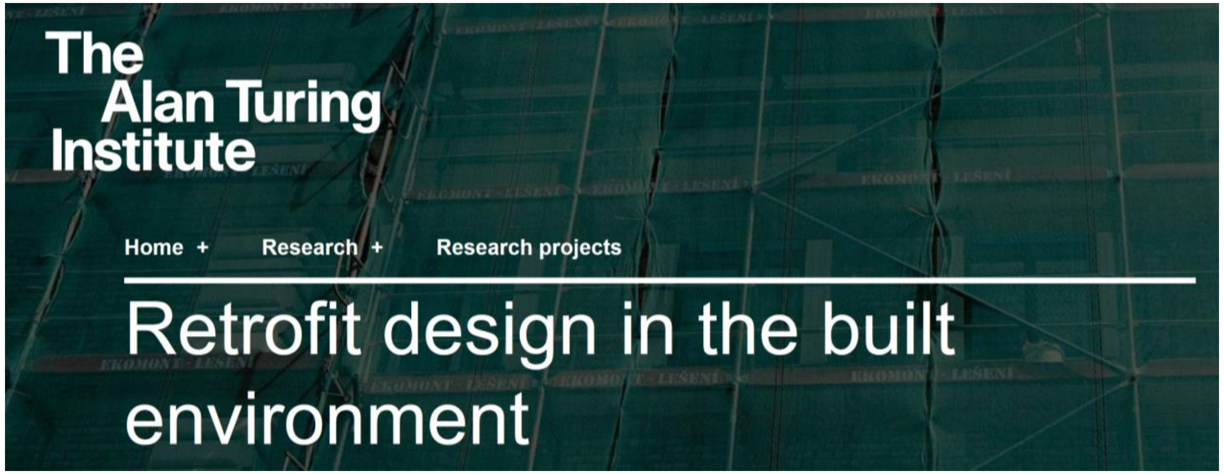
The Alan Turing Institute

Home + Research + Research projects

Design change in digital twins

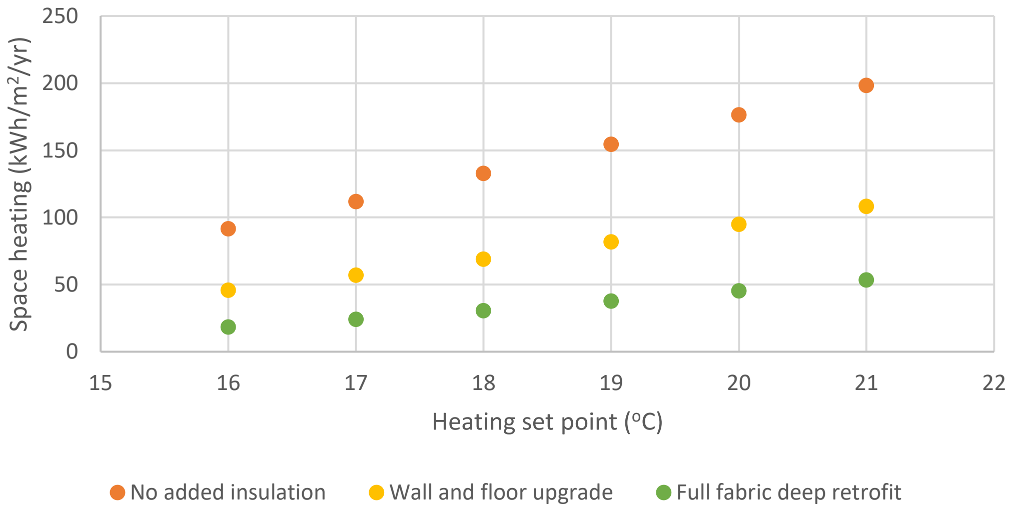


AEC Production Control Room, UKRI funded work
(Dr Ranjith Soman and Dr Karim Farghaly, 2020-1)



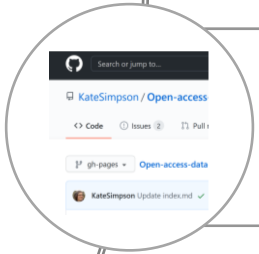
2: Addressing uncertainty in building energy modelling

Space heating energy demand for a semi-detached dwelling pre, and post retrofit per differing heating set points



1: Review of data-centric retrofit research methods

2: Addressing uncertainty in building energy modelling



3: Develop and maintain open access database

4: Use Structured Decision-Making (SDM) for wider uncertainty

Simpson, K., Whyte, J., & Childs, P. (2020). Data-centric innovation in retrofit: A bibliometric review of dwelling retrofit across North Western Europe. Energy and Buildings, 229, 110474 https://doi.org/10.1016/j.enbuild.2020.110474

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Imperial College London

Data Handover

Learning legacy

Lessons learned from the London 2012 Games construction project

Data handover from project delivery into operations

Authors

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Research Fellow, Reading University

Abstract

High quality information is important for the safe and sustainable operation of infrastructure.

On the Olympic Park, and its associated off-Park venues, information about venues and infrastructure is important for operation during and after the London 2012 Olympic and Paralympic Games.

Across the industry, data handover from project delivery to operations remains poor though policy makers recognise that high quality information is crucial in creating a sustainable built environment. The information management focus of the Olympic Delivery Authority (ODA) was on providing high quality and complete record-sets to operators.

By the end of the delivery programme, there were many thousands of record drawings and documents. The aspiration was for facilities and their documentation to be handed over together.

To achieve this, structured processes were developed and completion preparation meetings were held with Tier One contractors at least six months before the delivery programme began to ensure documentation was progressively developed and completed in parallel with construction works.

Whilst 100 per cent of the records were not submitted on the day of completion, on average around 88 per cent was achieved for venues, a unique achievement on a construction programme, which meant that subsequent data handover was more effective than it otherwise would have been.

Across the industry, data handover presents a significant challenge, even for leading clients and practitioners.

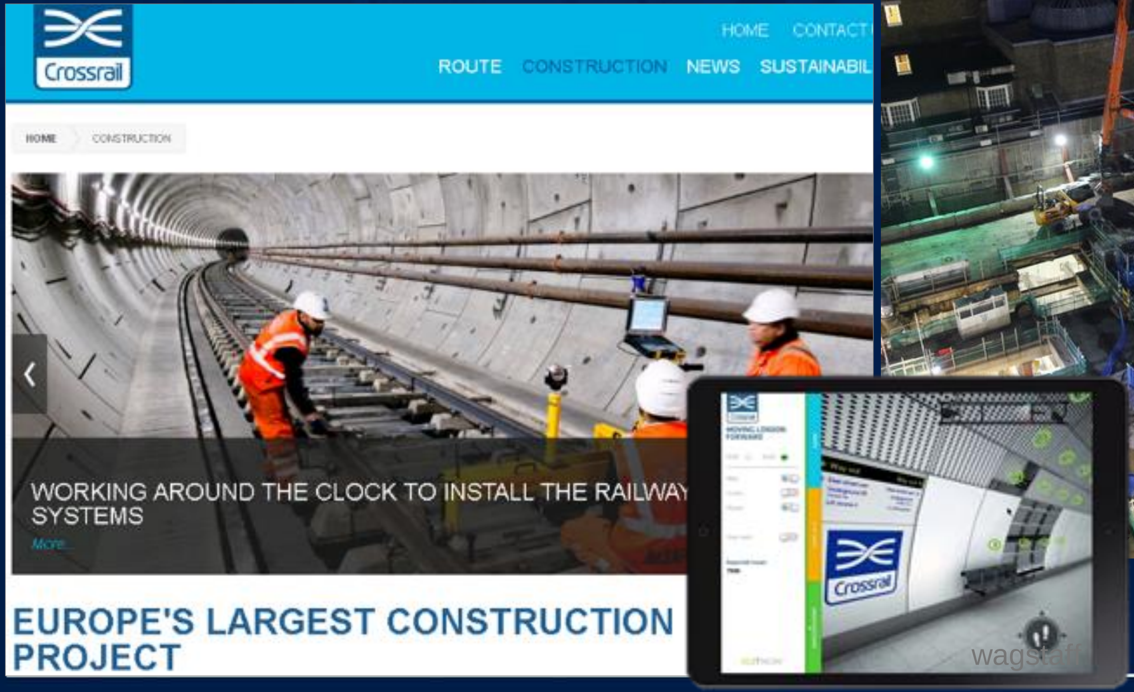
Trainee document controller in the Olympic Village

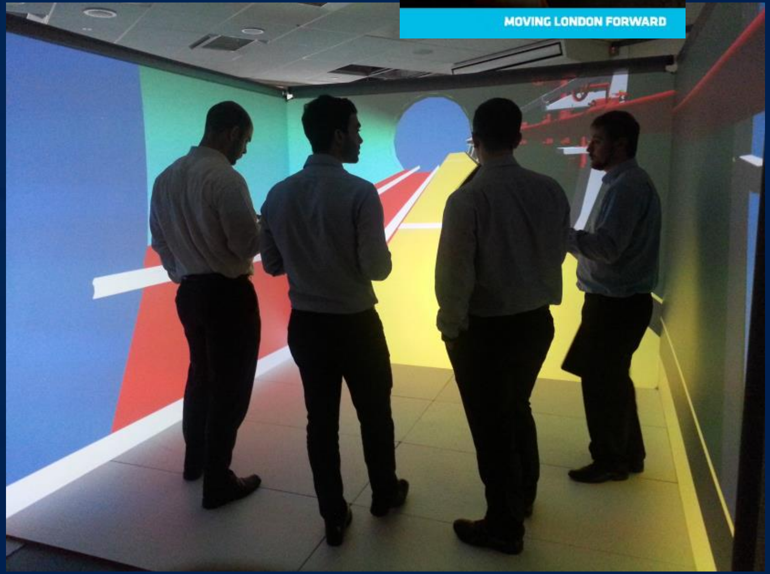
London 2012 Olympics, £6.7bn (12.15bn AUD), Completed 2012

Imperial College London

Managing Change

Whyte, J., Stasis, A. and Lindkvist, C. (2016) Managing change in complex projects: configuration management; asset information and big data. International Journal of Project Management, 34, 2, 339–351



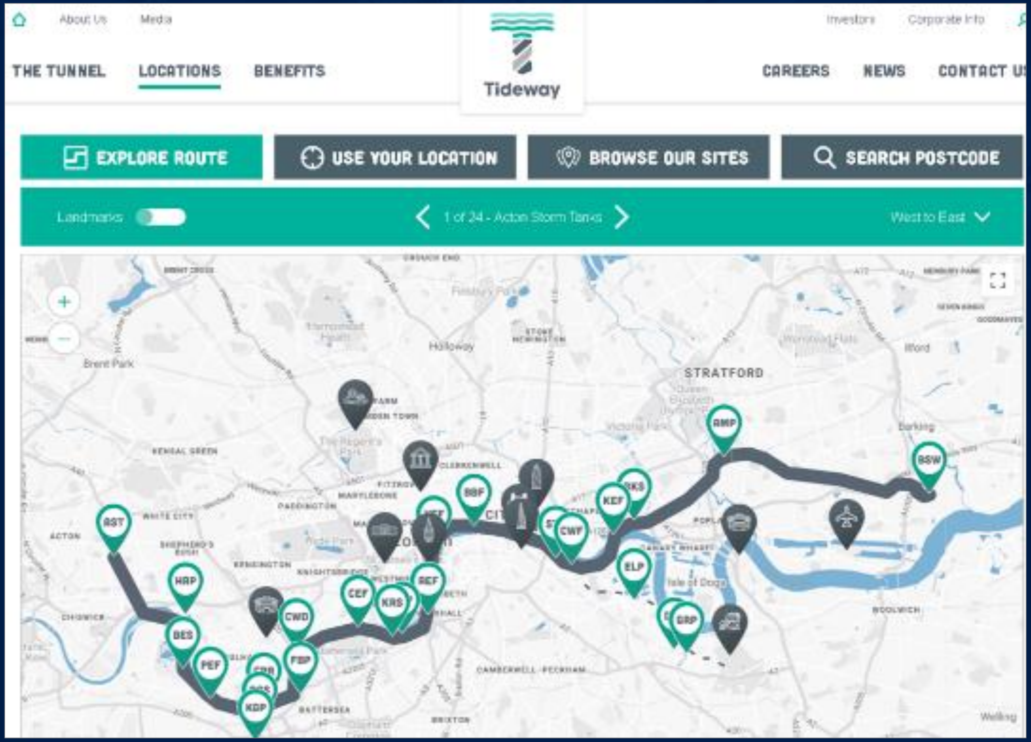


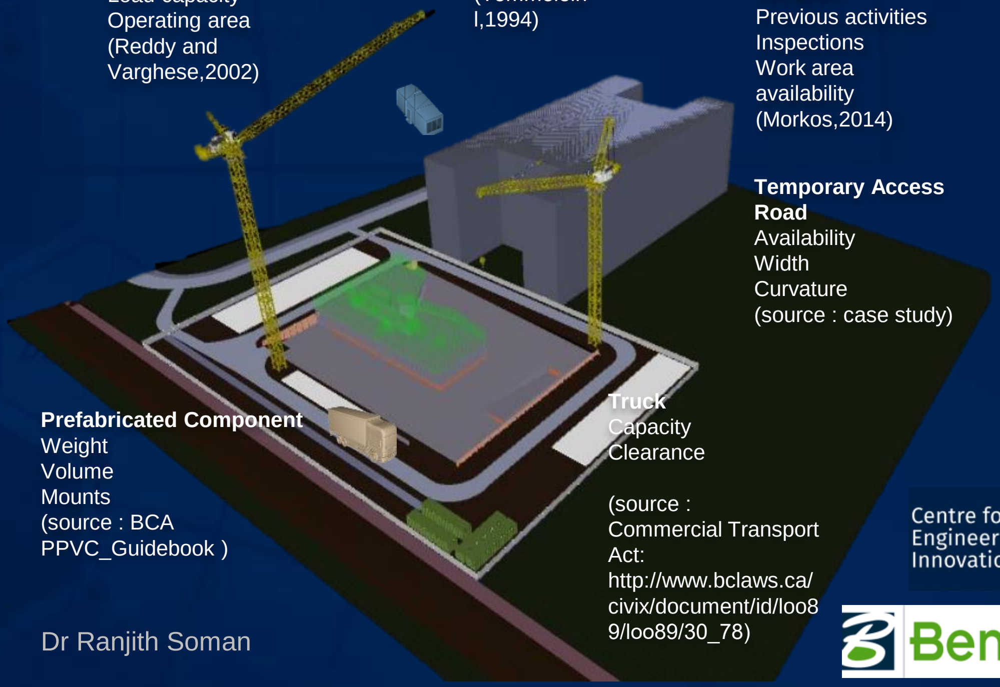
Interdisciplinary Design Reviews using the 3D Mobile Visualization Environment (3D-MOVE), Crossrail Innovate 18 Project, with Laura Maftei and Dragana Nikolic

Crossrail, £14.8bn+ (26.8bn+ AUD) Completion expected 2021

Imperial College London

Digital Twin

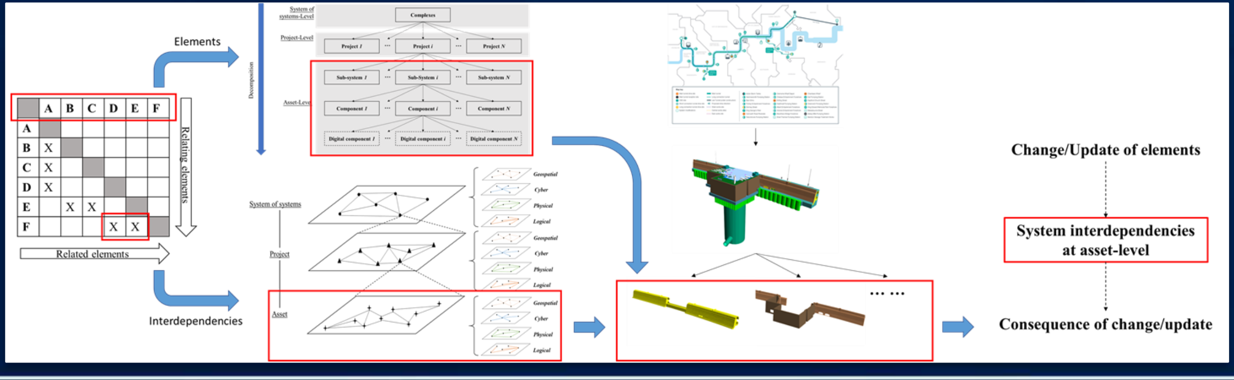




Dr Ranjith Soman

Centre for Systems Engineering and Innovation

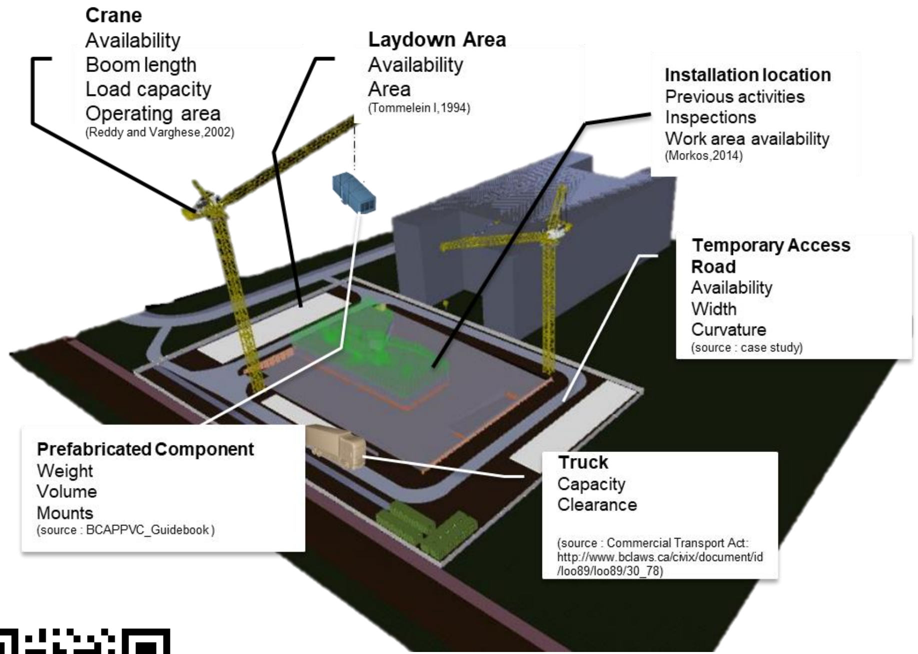
Bentley

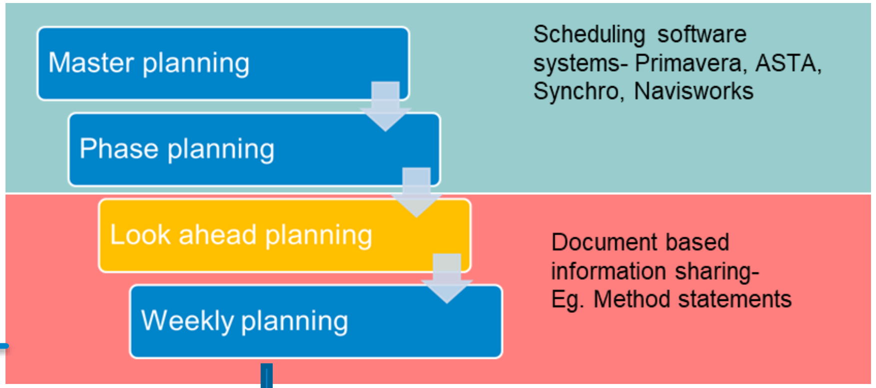


Tideway, £4.2bn+ (7.62bn AUD), Completion expected 2025

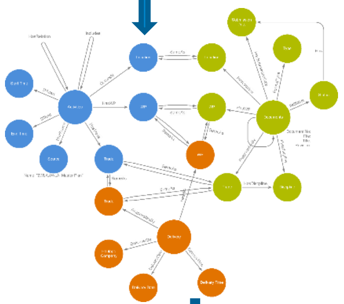
Imperial College London

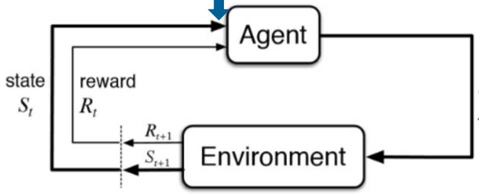
Linked-data based constraint modelling and checking for AI assisted look-ahead planning

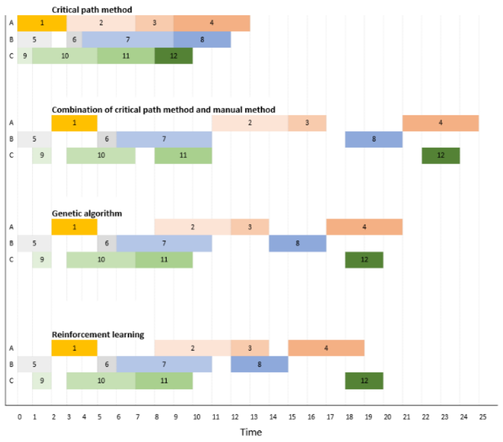




How to embed this to an information model for AI?



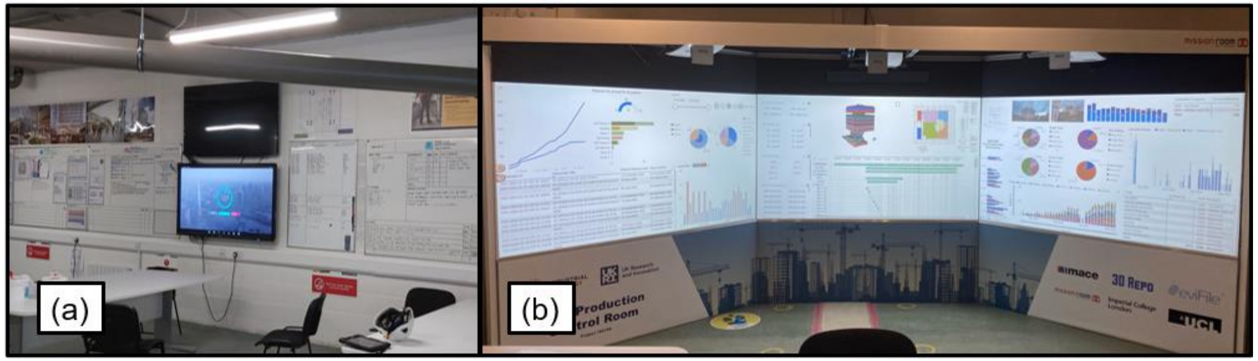




Soman, R. K., Molina-Solana, M. and Whyte, J. K. (2020) 'Linked-Data based Constraint-Checking (LDCC) to support look-ahead planning in construction', Automation in Construction, 120(July), p. 103369. doi: 10.1016/j.autcon.2020.103369.

Visualization of linked data

Construction production control room



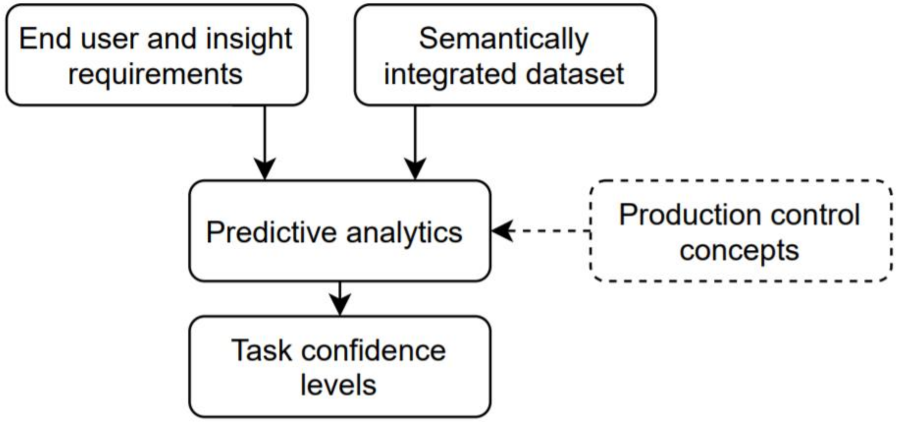


Figure 7: Predictive analytics workflow

VENTURA - Virtual decision rooms for water neutral urban planning

Project Analytics

Propose collaborations in area of project analytics:

- Decision support systems and production control rooms
- Prospective identification of systems interfaces in digital engineering data
- Constraint modelling in scheduling and project controls
- Modelling of carbon in recycling and clean energy projects
- Analyses of stakeholder engagement strategies in complex projects
- Modelling resilience building and disaster management projects
- Visualisation and monitoring of sub-contractor performance

An A-Z of Scholars in the **School of Project Management** with research interests in **Project Analytics**

Dr Fatima Afzal

Dr Mehdi Rajabi Asadabadi

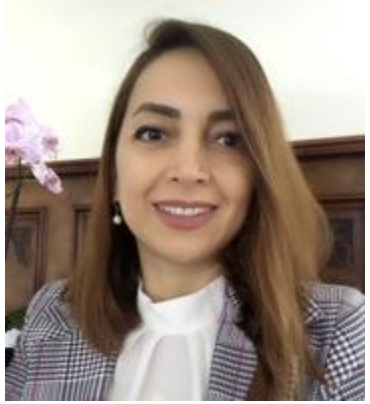
Dr Ken Chung

Dr Ali Eshhraghi

Dr Petr Matous

Dr Nader Naderpajouh

Dr Mahshid Tootoonchy



Dr Shahadat Uddin

Professor Jennifer Whyte

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