cdbb

Centre for Digital Built Britain

CDBB Week 2019

Posters Presented during the Summer Research Showcase,

12 September 2019

St Catharine's College, Cambridge

UNIVERSITY OF CAMBRIDGE

Collaborate with us

engagement@cdbb.cam.ac.uk

www.cdbb.cam.ac.uk

@CambridgeCDBB

cdbb

Centre for Digital Built Britain

From Norm to Swarm: development of a Balanced Scorecard for evaluating Automation in Construction

Benefits to UK Government and policy-makers (UKG), construction industry: i.e. contractors and clients (UKCI), IT/tech companies (ICT), education and research institutions

Assessing and optimising the performance of digital construction projects is essential to achieve a sustainable and efficient construction industry

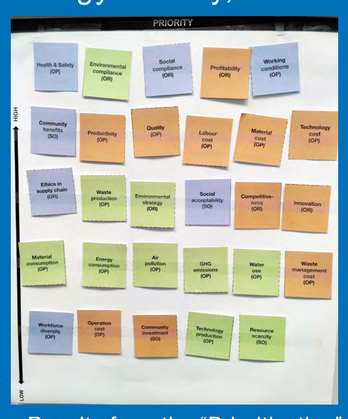
- Dr Isolda Agustí, Whole-Life Performance Lead, Construction Innovation Hub.

Summary

The adoption of digital technologies in construction (e.g. BIM or robotics) shows great potential to transform the way we currently plan and construct the built environment. Construction organisations expect an increase of productivity, efficiency, quality and safety, as well as a reduction of costs, emissions and waste. Yet a lack of management tools and standards to evaluate automation and set business strategic improvement drivers is hindering wider adoption in the construction industry. The aim of the project is to deliver a Balanced Scorecard (BSC) to support the adoption of automation in the UK building industry by delivering a framework to evaluate automated construction processes from a holistic perspective (financial, social, and environmental). The BSC is co-created with industry and is based on a set of hierarchic

Key Performance Indicators (KPIs) that will help construction organisations to set improvement targets to achieve their long-term strategy. Finally, the BSC is tested through the evaluation of a case study of 3D printing with aerial robotics provided by the EPSRC-funded project Aerial Additive Building Manufacturing.

TOWARDS CONSTRUCTION 4.0: A collaborative workshop on the future of automation.



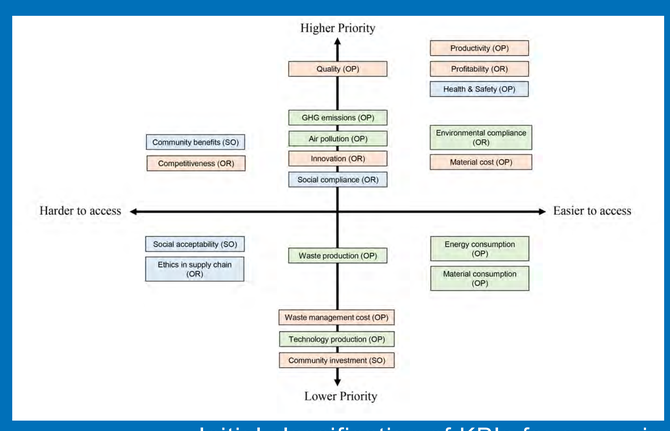
Results from the "Prioritisation" workshop exercise

Impact and Value

- The BSC will raise awareness and interest in automation in construction and provides a realistic vision of the impact of digital technologies and processes.
- The BSC will support the sustainable implementation of automated technologies in major UK construction projects, which will improve commercial competitiveness and productivity, while ensuring the well-being of the natural environment and citizens
- The BSC will establish minimum performance requirements for automated construction processes and technologies, which will serve as a base for the production of standards in automation in construction.
- The BSC will guide decision-making during the transition to digital economy, e.g. improving ways in which data is collected and assessed.
- The BSC will create new partnerships between industry and academia.
- The BSC will establish new knowledge of automated construction processes and technologies, which can be transferred to research and education programmes in UK institutions.

Key Findings

- The proposed Balanced Scorecard (BSC) model uses KPIs from the three dimensions of sustainability at three assessment levels, which provide a holistic understanding of the impact of automated construction processes and facilitates a new pathway for achieving sustainability in buildings.
- The hierarchic organisation of indicators according to priority supports management teams in decision-making regarding the adoption of automation and in defining relevant issues to be targeted and optimised in the organisation.



Initial classification of KPIs for assessing automation in construction.

- Overall, the BSC shows that traditional out-turn measures (e.g. Productivity, Quality and Profitability) tend to dominate thinking in construction organisations.
- The model also shows that the priority of indicators related to compliance of regulations is intermediate and the majority of environmental and social indicators tend to be deemed lower priority than economic indicators.
- The development of the BSC based on industry stakeholders' views ensures the applicability of the framework for assessing the performance of automation in the industrial context.
- The evaluation of a case study confirms the effectiveness of the BSC model by highlighting the relevant data to be measured and transferred throughout the value chain (design-construct-operate-maintain) of the organisation.

Long-term Vision

- The BSC will help clients, business and policy makers to assess impacts and shape decisions based on whole life value.
- The final goal of the project is to facilitate the implementation of digital and automation technologies in construction to improve productivity, while ensuring the well-being of the environment and society.
- This project is the starting point of an extended performance evaluation framework applicable to a broader range of innovative construction projects. This standardised framework will be developed in line with similar industrial and governmental initiatives, such as the work of the Construction Leadership Council. Dr Isolda Agustí will continue this work in the Whole-Life Performance workstream of the Construction Innovation Hub.

Next Steps

Submission of a scientific publication describing the development of the Balanced Scorecard to the journal Automation in Construction

Research Acknowledgements: The research project "From Norm to Swarm: development of a balanced scorecard for evaluating automation in construction" is funded by the Centre for Digital Built Britain (CDBB), under InnovateUK grant number RG96233. The authors would like to thank Dr Mirko Kovac and Pisak Chermprayong from the Aerial Robotics Lab at Imperial College for providing the data of the case study. Moreover, they would like to extend their sincere gratitude to Prof Guillaume Habert from ETH Zurich, Prof Robert Stuart-Smith from University of Pennsylvania and the industry participants, who took part in the workshops in March and June 2019.

UNIVERSITY OF CAMBRIDGE

Contact: Jacqueline Glass
Professor in Construction Management,
University College London,
j.glass@ucl.ac.uk

https://www.ucl.ac.uk/bartlett/construction/people/professor-jacqui-glass

UCL

Collaborate with us

agement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

Centre for Digital Built Britain

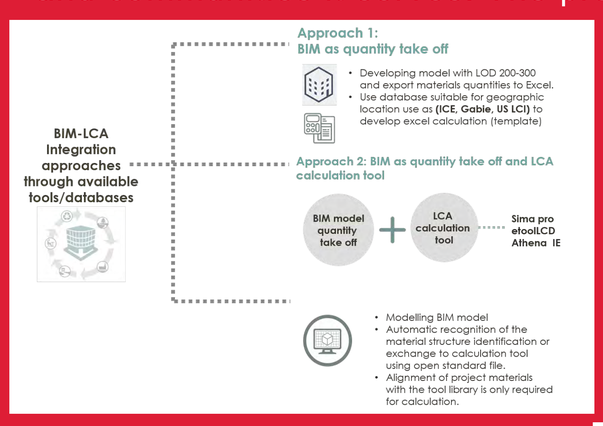
Digital Energy Estimation Tool (DEET)

Benefits to developers, architecture firms, designers, housing associations, facilities managers

“Collaborated with leading regional architecture firm with the aim of developing a parametric BIM ready tool that address is CDBB research topics of Sustainbility , exploiting of exiting tools and techniques and leverage data and information”

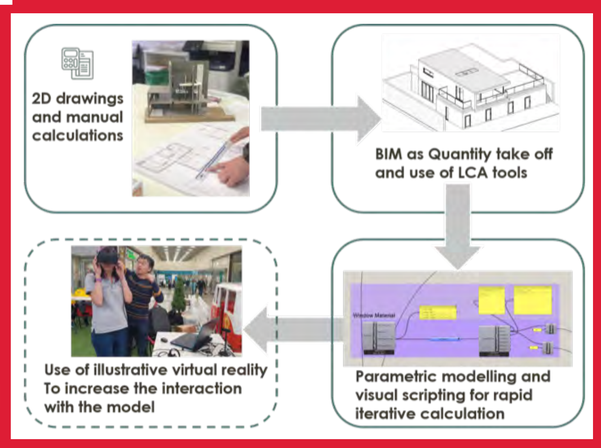
Summary

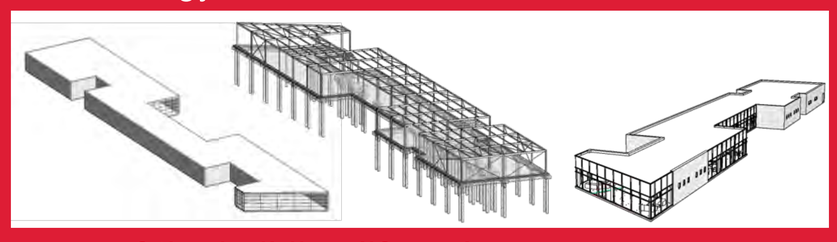
In this research project the research team has developed a unique parametric design-based methodology for estimating total energy use in a building utilising BIM (Building Information Modelling) frameworks and protocols. Results from the work have indicated that embodied energy can be much more significant in the first few phases of the buildings life cycle, and material selection can be addressed within a parametric model. In addition the project had a unique multidisciplinary research approach to show how technologies such as BIM and virtual reality can be used to communicate the message of addressing the overall aims of CDBB in enhancing the performance of the built environment and the cities and communities it serves. The project achieved the development of data rich 3D construction templates that addressed more efficiently the decision making potential of BIM processes. A final outcome of the work was the realization of how such aspects such as energy and carbon in the built environment assets can be visualized with virtual reality to give it greater acceptance.



Key Findings

- Widening understating of embodied energy and its impact on the Built Environment within a building can vary in their contribution to embodied energy, and certain material can be classified as energy hotspots
- A framework has to be developed for measuring embodied energy impact as not all components can be measured
- Embodied energy contribution can play an important role in the first few years of the building lifecycle
- Established and adopted a framework to identify the parameters that can actually be measured
- Within a single parametric model whole energy - both operational and embodied - can be analysed and can potentially be analysed in VR environments





Impact and Value

- Using carbon data of assets to make future cities and BIM a possibility
- Development of datacentric approaches for material selection in construction based on energy and carbon
- Key tool to deliver carbon reduction objectives of 50% as part of construction 2025 strategy

Long-term Vision

- Development of Digital Carbon Twin of Built Environment assets
- New approaches to material selection using BIM and dashboards for smart buildings
- Develop long term benchmarks for Embodied energy and Carbon for built environment
- Applying Virtual Reality principles
- Development of the parametric model so it enables real time Carbon as well as energy capture
- Develop the DEET as a synergy between Information management framework to deliver the governments targets of zero carbon by 2050.

Next Steps/Further Work

- Development of a full systems that uses VR linked to devices which enables energy and carbon estimation in real time
- Development of the parametric model so it enables real time Carbon as well as energy capture
- Develop the DEET as a synergy between Information management framework to deliver the governments targets of zero carbon by 2050.

Acknowledgements: The research team at Northumbria university would like to give a special thanks to the early career research programme 2018 run by the CDBB. The supply of examples and real case studies from the Built Environment sector that made the provision of actual plans and drawing possible by BDN limited, White Frog training, Ryder Architecture and Elliott Architects

UNIVERSITY OF CAMBRIDGE

Contact: Zaid Alwan
Architecture and Built Environment
Faculty of Engineering and Environment
Northumbria University
zaid.alwan@northumbria.ac.uk

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

Centre for Digital Built Britain

Information Resilience in a Digital Built Environment (DBE)

Benefits to: Chief Information Officers, Project Managers

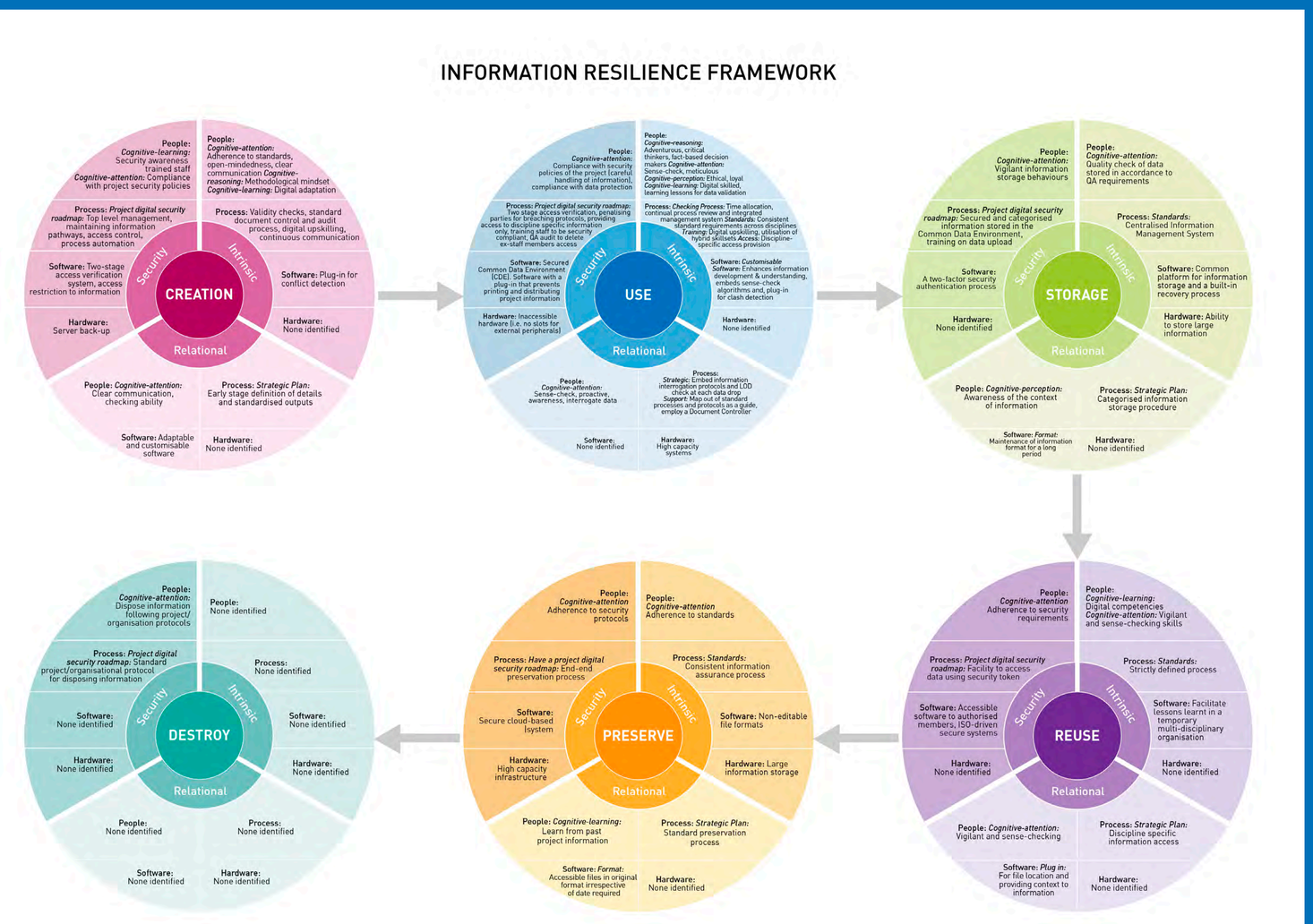
“Capabilities and Requirements for ensuring the resilience of information in the digitised Architecture, Engineering, Construction and Operations (AECO) sector are crucial to the Centre for Digital Built Britain’s (CDBB) agenda.”

Summary

Information is the underpinning driver in the Digitised Built Environment and crucial to the Centre for Digital Built Britain’s agenda. Threats to information affect the intrinsic, relational and security dimensions of information quality. Therefore, the DBE requires capabilities of people, and requirements of the process, software and hardware for threat prevention and reduction. The aim of this research is to develop an information resilience framework which outlines the capabilities and requirements needed to ensure the resilience of information throughout its lifecycle; creation, use, storage, reuse, preserve and destroy.

Key Findings

The findings highlight the need for people’s (stakeholder) competencies and behaviours which are driven by cognitive abilities such as attention, learning, reasoning and perception. Furthermore, process’ requirements such as embedding validation check process, standard requirements for Level of Detail, digital upskilling, among others, were identified. Additionally, identified software requirements include its ability to be customised to meet the project needs, detect conflicts and provide context of information. Finally, hardware requirements encompass facilitating backup, having a high capacity system and being inaccessible to peripherals.



Impact and Value

- The developed IR framework is intended to maintain and enhance information quality in the midst of threats and help assets to be managed more effectively over their extended lifecycles.
- IR is central to the collaborative digitised asset development process in the Built Environment and therefore it is necessary to identify the capabilities and requirements needed to enable adequate decision making and planning.
- IR contributes to the capability and requirements for Smart Construction and Digital Design Agenda in the Construction 2025 (Gov.uk, 2013 & 2017) and the Data and Information - ‘Data provenance and quality towards maintaining social values embodied in the data against threats’ (numbers 13 and 14, under CDBB Focus areas)

Next Steps

This research will be further extended to the development of a decision-making assessment tool to measure capabilities and requirements in the entire lifecycle of built assets.

Research Acknowledgements

This research was funded by the Centre for Digital Built Britain, under InnovateUK grant number RG96233. We thank professionals from Skanska and other Architecture, Engineering, Construction and Operations disciplines for providing insights and expertise that greatly assisted the research. We would also like to show our gratitude to the practitioners from Manufacturing, Library Service, Healthcare and Software Development industries for their recommendations to DBE.

UNIVERSITY OF CAMBRIDGE

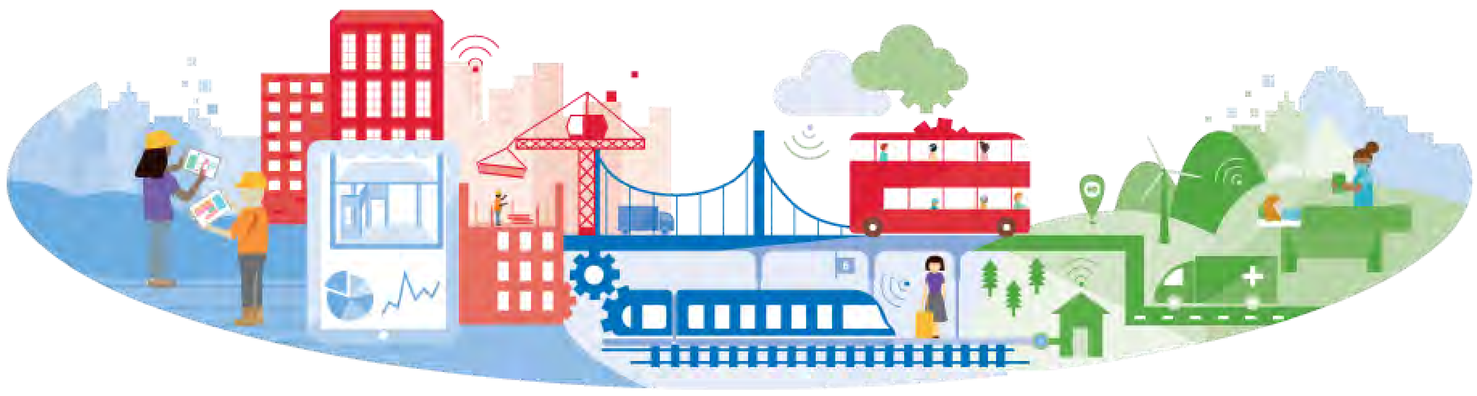
Dr Karen Blay
k.b.blay@lboro.ac.uk

Loughborough University

Collaborate with us
engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain



Aerial Swarm Robotics for Active Inspection of Bridges

Benefits to society, digital, construction, complex integrated systems, data and information

"Taking the robots from research labs to a challenging real world is an important step to achieving the Centre's mission to deliver a digital built Britain"

– Dr Shan Luo, Director of the smARTLab, University of Liverpool

Summary

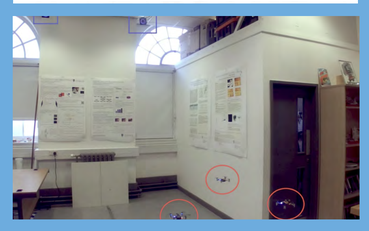
This project proposes a solution to the problem of maintaining the infrastructure of bridges and other structures. Bridges can have hazardous environments that are hard for humans to reach, making the labour intensive inspection and maintenance process ineffective. However, this task may have the potential to be done by autonomous systems. In this project we aim to create a coordinated aerial swarm system to inspect the cracks in the bridge structures, improving the monitoring coverage and efficiency. With strict constraints of the environments and mutual interference, the development of such multi-UAV system for bridge inspection is challenging. We have achieved the following objectives of the project: Agile coordination and collision avoidance for aerial swarms (WP1); Image based bridge defect detection and assessment (WP2); System integration and validation (WP3).

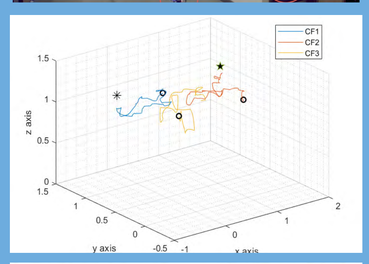
Key Findings

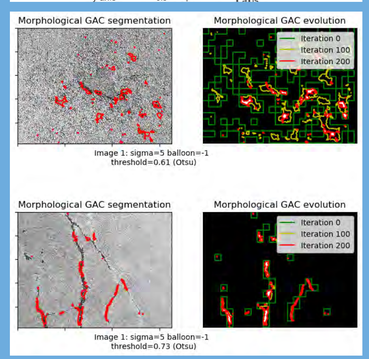
1. Our proposed FFPSO algorithm can reduce the number of collisions to zero effectively. As shown in theTable here, PSO has a much larger number of crashes than any other algorithm given that it has no collision avoidance mechanism. Both PSO-CA and FFPSO-GRAV never result in any crashes whereas FFPSO-LIN only results in very few on average.
2. Real drone test. The experiments in the real environment were performed using the FFPSOLIN algorithm on a swarm of 3 Crazyflie 2.0s shown to the right. As illustrated to the right, experiments show that the FFPSO works effectively on a real MAV swarm.
3. Crack detection. Both of the improved initial sets in all CNNs show good accuracy to find the edges of the cracks shown in the images here. Dilation of the images helps to connect regions that are part of a continuous crack but harshly hinders the progress of the Active Contours (ACs) since there is a limited amount of iterations we can do quickly. The AC results ultimately depend on the accuracy of the CNN, if it is not accurate then neither will the ACs.

4. Real bridge inspection. These images show snapshots of the footage taken from a Parrot Bebop 2, showing a real bridge and its structure.

	Algorithm			
Number of Drones	PSO	PSO-CA	FFPSO-LIN	FFPSO-GRAV
2	1.704	**0**	2.274	**0**
3	62.476	**0**	0.05	**0**
4	134.758	**0**	0.044	**0**
5	198.004	**0**	0.018	**0**
6	256.418	**0**	0.028	**0**
7	258.894	**0**	0.024	**0**
8	224.106	**0**	0.022	**0**
9	244.658	**0**	0.012	**0**
10	234.614	**0**	0.038	**0**







Impact and Value

1. The project aims to develop an autonomous system using digital technologies (robotics, AI and data analysis) for monitoring the health of bridges and other structures, which contributes to guarantee the safety and well-being of the people of Britain.
2. It has explored the implications of a digital built Britain for mobility and transport. The project creates a bridge inspection system that ensures the safety and structural integrity of bridges. It contributes to avoiding personnel and economic losses due to collapses of bridges lack of inspection and monitoring.
3. It has explored the exploitation of existing or emerging tools, technologies and techniques and their role in delivering a digital built Britain;
4. It has explored ways to leverage data and information to deliver a digital built Britain.
5. It has explored the commercial challenges and opportunities of a digital built Britain.

Long-term Vision

Taking the findings in this project, we are confident to see in the future that autonomous systems can be deployed to survey, detect and repair defects in the city infrastructures. It will monitor the structural integrity of bridges and flag any potential issues, helping to avoid the tragedies like the Morandi bridge collapse. In addition, it will take the human inspectors from the hazardous inspection and maintenance environments.

Next Steps/Further Work

1. Decentralised FFPSO. In future work, the FFPSO algorithm will be converted into a fully decentralised algorithm in which the global best can be propagated to all individuals of the swarm without the use of a central server.
2. Fully autonomous aerial swarm for bridge inspection. A fully autonomous system that consists of a swarm of aerial robots equipped with embedded systems and sensors will be developed to inspect the bridge actively
3. Contact based bridge inspection robot swarm. In addition to the visual inspection, contact based (with tactile sensors) robotic inspection system will be developed to monitor the city infrastructures in further details (a larger grant will be submitted to the EPSRC or Innovate UK).

Acknowledgements: **This work incorporates results from the research project "Aerial Swarm Robotics for Active Inspection of Bridges" funded by the Centre for Digital Built Britain, under InnovateUK grant number 90066.**

UNIVERSITY OF CAMBRIDGE

Contact: Dr Shan Luo
Dr Shan Luo,
shan.luo@liverpool.ac.uk;

Lauren Parker,
Lauren.Parker@liverpool.ac.uk.

UNIVERSITY OF LIVERPOOL

smARTLab

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Reinventing Renting:
The use of digital technology in housing for ‘generation rent’

Benefits to tenants in the private rented sector, property developers, technology providers, housing providers, government, tenants in the private rented sector, landlords

“An increasing number of people in the UK have no choice but to live in rented housing. If we can unlock the potential of digital technologies to improve the sector, we could improve the lives of thousands of households.”

- Dr Gemma Burgess, Cambridge Centre for Housing and Planning Research

Summary

The private rented sector has grown dramatically in recent years. The percentage of people aged 25 to 35 renting in the private rented sector increased from 27% in 2007 to 46% in 2017. Digital technology is increasingly being used to facilitate greater access and convenience, efficiency in management, and sense of community.

This research aims to:

- understand how digital technology is being used to improve the rental experience in different types of housing
- understand the technology being provided to landlords and tenants in traditional buy to let housing
- investigate new models of housing such as ‘build to rent’ and ‘co-living’
- understand how tenants engage with digital technology

Impact and Value

This research provides an overview of how digital technologies are transforming different parts of the private rented sector. This research has the potential to inform future housing and technological developments, and to shape policy in this area.

Photo Credit: Co-Living Spaces

Key Findings

- New digital technology has the potential to transform three key areas of renting: access to properties, management of properties, and lived experience.
- The research shows that digital innovation is being used most commonly for access (finding a rental property). There is increasing use of digital services by landlords for managing their rented properties, but there is so far less impact on lived experience, e.g. using digital platforms to communicate with landlords, or using apps to spilt bills with house mates.
- Barriers to adopting technology and digital innovation by residents in the private rented sector relate to three main areas: knowledge about available technology, willingness to use it and issues of trust and data privacy.

Long-term Vision

The long term vision is for digital technology:

- to reduce costs and make access to the private rented sector easier for tenants, particularly because these tend to be households with low incomes;
- to make management of properties easier and therefore improve the quality and state of repair of the rented housing stock, which is currently the worst tenure for quality and energy efficiency;
- to improve the experience of living in the private sector as, although renting is growing as a tenure, tenants express relatively high levels of dissatisfaction.

Next Steps

The sector needs to address issues of trust and data privacy if use of digital technology is to be adopted more widely by tenants in the private rented sector. There is currently no end-to-end digital platform that meets all the needs of landlords and tenants.

Research Acknowledgements

We would like to thank the participants interviewed during this research.

UNIVERSITY OF CAMBRIDGE

Contact: Dr Gemma Burgess
Acting Director
Cambridge Centre for Housing and Planning Research
glb36@cam.ac.uk
https://www.cchpr.landecon.cam.ac.uk/
Twitter: @CCHPR1

Cambridge Centre for Housing & Planning Research

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

The governance of digital technology: Implications for the city-scale digital twin

Benefits to local authority users (city planning and management), urban planners, urban modellers, smart city delivery companies, activist community groups

"We don't have access to the model...At the end of the day, most things come down to judgement and you can't challenge people's judgement, you can criticize it, but you can't formally challenge it... I think what we have to do is just enlighten people, particularly councilors, in some cases council officers, to help them make better decisions"

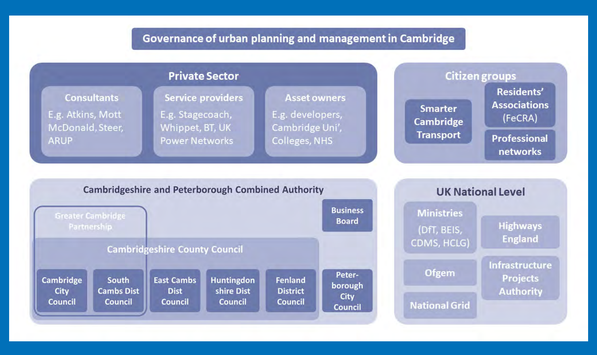
- Citizen Activist, Cambridge

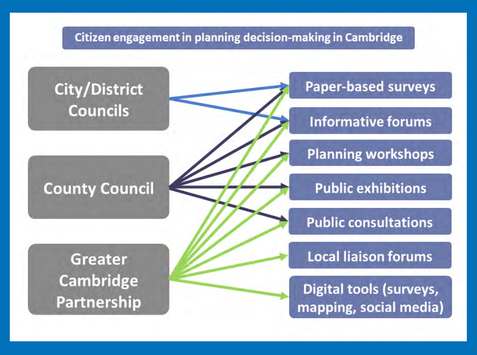
Summary

The study investigates how **existing governance systems** – both in terms of their structural and cultural characteristics – influence the **design** and **implementation** of **city digital twins** (i.e. a realistic digital representation of urban assets, processes and systems).

Moving towards city digital twins as evidence for decision-making in urban planning and management will have implications for urban governance and modelling. First, it contributes to more a more **effective** use of evidence through enabling a **better understanding** of **cross-cutting problems** and the **communication** of data-driven decisions. Second, by supporting the development **in-house modelling capabilities**, commissioning will be become **more time and resource efficient**. Third, broader **accessibility** improves the **democratic quality** of evidence-informed decision-making through **enhancing transparency** and **accountability**.

Thus, to harness the benefits offered, the design and implementation of CDTs needs to consider how currently existing local governance systems **function** and **use modelling outputs** as **evidence for decision-making**, as well as **grounded citizen participation** and **feedback**.





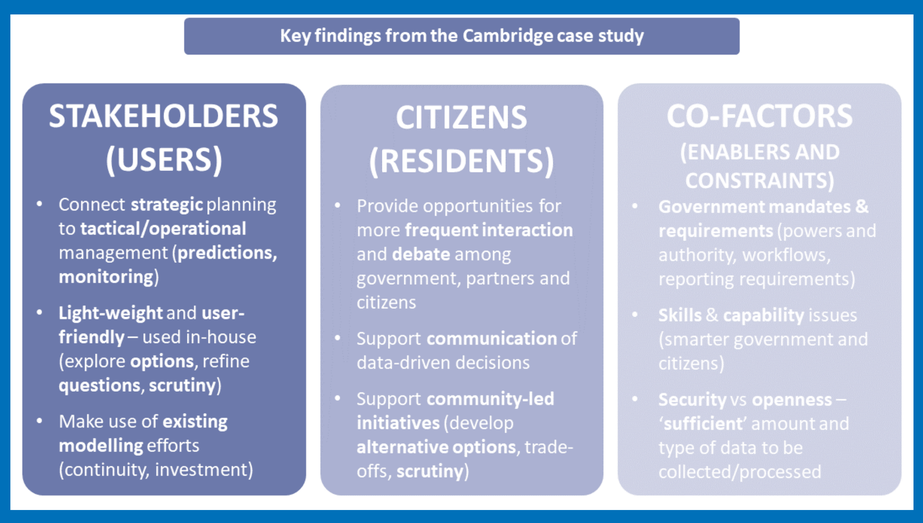
Next Steps

Future Steps	2019		2020				2021		
	Q3	A4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Context: in-depth analysis of CDTs from different cities to understand generalisability									
Competence: identifying skills and capability gaps for successful CDT implementation									
Experimentation: new research project including real-world case studies and implementation (Cambridge Biomedical Campus, Northern Fringe East- subject to funding)									

Long-term Vision

- Embedding the significance of research on socio-technical processes to assess impact of digital tools in local contexts.
- Connecting, expanding and re-defining experiences of city digital twins across countries to form a global knowledge network of new generation urban modelling for 'smarter' city planning and management.

Key Findings



Conclusions:

1. There is an apparent need for **participation and better collaboration mechanisms** and across the governance landscape based on **systemic interdependencies** and **pressing problems** situated at the nexus of governance structures and processes.
2. 'Black box modelling' and siloed evidence base **limits comprehensive responses** and negotiations of accountability relationships and responsibilities; and **increases difficulties for engaged citizens** to be heard.
3. Cambridge citizens will continue to be engaged, and **developing inclusion strategies** throughout the modelling process will **decrease re-planning costs** and **negotiation time**; and **increase trust** in the value of modelling evidence.
4. Public scrutiny in Cambridge has increased in the past years with the **manifestation of economic growth on citizens' everyday lives**, and will continue to demand **evidence-based policy-making** using **traditional** and **new methods**.

Research Acknowledgements

Investigators:

Dr Ajith Parlikad, Institute for Manufacturing, University of Cambridge;
Dr Jennifer Schooling, Centre for Smart Infrastructure and Construction, University of Cambridge

Research Assistants:

Ms Nicole Badstuber and Dr. Noura Wahby, Centre for Smart Infrastructure and Construction, University of Cambridge

Twin research project:

Dr Li Wan and Mr Tianren Yang, Centre for Smart Infrastructure and Construction, University of Cambridge

Local Authority partners:

Smart Cambridge, Cambridge City Council, Greater Cambridge Partnership

UNIVERSITY OF CAMBRIDGE

CSIC Cambridge Centre for Smart Infrastructure & Construction

smart CAMBRIDGE

Contact:
Dr Timea Nochta, Centre for Smart Infrastructure and Construction (CSIC), Department of Engineering, University of Cambridge

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Co-Evolving Built Environments and Mobile Autonomy for Future Transport and Mobility

Benefits to: city planners, developers, governmental policy makers.

“What would an autonomous vehicle’s dream city look like?”

Summary

Autonomous navigation and automated mobility are hard problem that are compounded by the unpredictability and dynamics of urban environment. As we re-think and re-design our built environments, we have the unique opportunity to transform them so that automated mobility systems a can perform efficiently and robustly. The main idea behind this project is to tackle the challenges of autonomous navigation and automated mobility by explicitly considering the coupling of the autonomous vehicles with the environments that they operate in.

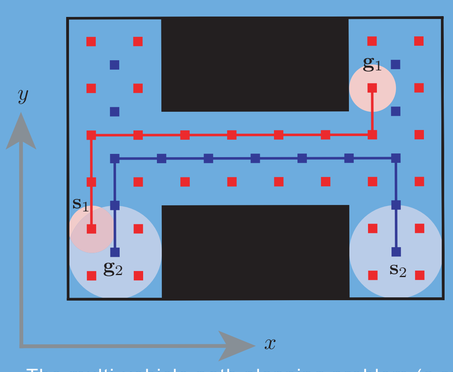
Outline

Our approach is to pose the built environment as a design variable, and to jointly optimize mobile autonomy. Our goal is to support mobile autonomy through re-designs of the built environment; in particular, we are interested in how its morphology, topography, and technological enhancement aid us in this endeavor.

Key Findings

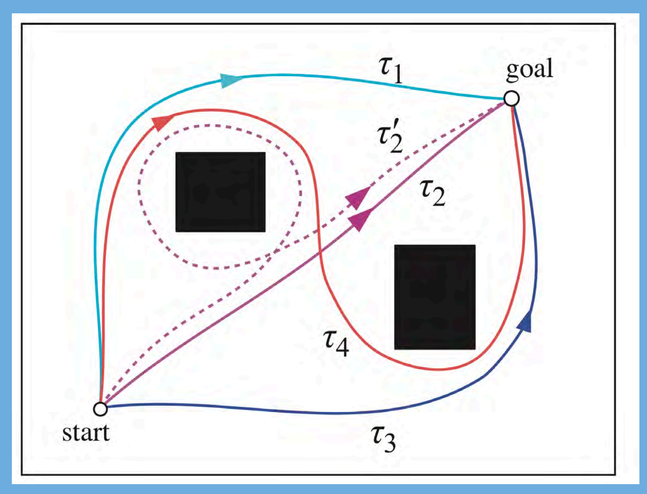
Our research highlights include the following insights:

1. We were able to expose the tight coupling between a vehicle’s mobility constrains and the topography of the built environment. Also, we showed that by explicitly considering this relationship, we are able to improve navigation performance. This is a milestone result that provides a fundamental new understanding of navigation in cluttered environments [1].



The multi-vehicle path planning problem (a red vehicle and a blue vehicle both compete for the narrow corridor space)

2. We were able to show that exploiting redundancy in transport networks is an effective approach to reducing waiting times in mobility systems. Importantly, our results also indicate an interesting connection between robustness and diversity: the paths selected by our mobility assignment algorithm tend to be more diverse, and correlate with better performance. This insight can be applied to the design of transport networks, where measures must be taken to provide redundant and diverse travel paths that connect same start and goal locations, in order to increase transport efficiency. This is a milestone result that provides guidance towards the planning, design and routing of road networks [2].



Impact and next steps:

Our ultimate aim is to provide actionable recommendations for city planners. Towards this vision, we are developing metrics that quantify how ‘difficult’ a given built environment is, from the point of view of trajectory planning and mobile autonomy. We are also developing methods that actively propose the modifications that a built environment needs to undergo.

Research Acknowledgements

Research collaborators:Jiayi Zhao, Subhrajit Bhattacharya, Wenying Wu

References

[1] W. Wu, S. Bhattacharya, A. Prorok, "Multi-Robot Path Deconfliction through Prioritization by Path Prospects", IEEE Robotics and Automation Letters (R-AL), under review

[2] A. Prorok, "Resilient Assignment Using Redundant Robots on Transport Networks with Uncertain Travel Time", IEEE Transactions on Automation Science and Engineering, under review.

UNIVERSITY OF CAMBRIDGE

Dr Amanda Prorok

University Lecturer
Department of Computer Science and Technology
University of Cambridge
www.proroklab.org

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Future cities in the making overcoming barriers to information modelling in socially responsible cities

Benefits to: national, regional and local policy makers, civil servants, urban planners, infrastructure planners, project investors, technology innovators, citizens

"Overcoming barriers to information modelling for planning will address problems of collaboration and coordination. If done responsibly, this can help communities unlock the value of data to support sustainable and inclusive city management"

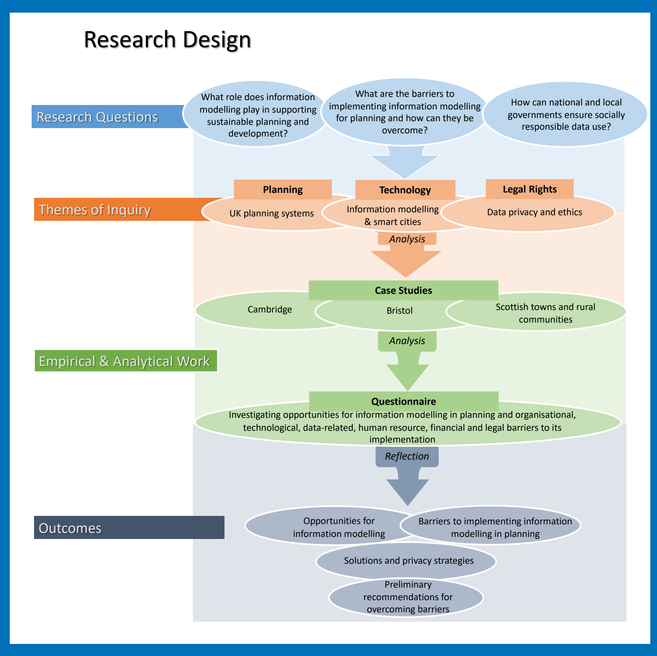
Dr Franziska Sielker, Department of Land Economy,University of Cambridge

Summary

This project probed the relationship between Building Information Modelling (BIM) and the planning system. BIM is a set of digital tools, processes and standards used to capture and store data associated with a construction project so it can be used collaboratively by everyone working on the project and those responsible for the assets' subsequent operation. We selected three main case studies to explore information modelling in different governmental, socioeconomic, and planning contexts, and our research was informed by 40 stakeholder interviews, policy analysis and a stakeholder questionnaire. Specifically, the research addressed three questions:

1. What role can information modelling play in supporting better planning outcomes?
2. What are the barriers to its uptake in the planning system and what steps can be taken to overcome these barriers?
3. What are the ethical and legal considerations governments must address as public spaces become more digitalised?

Barriers fall generally into one of six categories: organisational, data-related, technological, human resource, financial and legal; however, barriers tend to be interrelated, and so overcoming them will require a coordinated approach:



Examples of barriers to digitalisation and implementing information modelling for planning

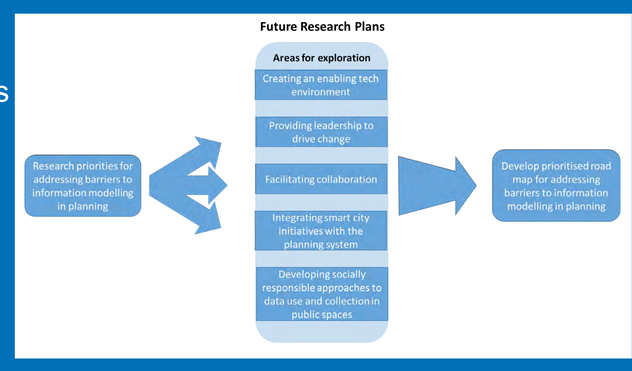
Organisational	Technological	Data-related
Lack of collaboration between governmental departments and bodies	Contract lock-in with certain technology platforms or providers	Necessary data is difficult to access
Fragments government structures	Lack of standardisation in tools and protocols	Data is not of good quality
Unclear data-sharing arrangements	Lack of customisable tools	Data is not validated
Unclear information about existing data sets	Non-interoperable software systems	Data is not standardised
Political disagreement	Need for hardware upgrades	The level of detail in BIM is too high
Lack of leadership support	Path dependency based on legacy systems	Insufficient data storage capacity
Lack of awareness from politicians		
Human Resource	**Financial**	**Legal**
Lack of in-house expertise	Software costs	Uncertainty around what can legally be shared
Lack of training	Hardware costs	Time-consuming nature of getting legal approval for sharing
No time to get up to speed	Data storage costs	Insurance and liability concerns
No time for implementation processes	Training costs	GDPR and other data privacy laws and regulations
Differences in expertise among collaborating parties	Cost of hiring right personnel	Restrictions around who can store public data and where it can be stored

Key Findings

- The barriers to information modelling in planning are also barriers to effective data use in local government, so overcoming these barriers can help advance digitalisation efforts across local government.
- Tighter links are needed between smart city initiatives and planning departments, as currently these areas of local government are not well integrated, even though both areas are active in planning the future of communities.

Next Steps

- Having identified the barriers, next steps focus on development of recommendations and integrated actions to encounter the barriers.
- Support the development of pilot cases for strategic smart city planning using BIM light and digital twins.



Impact and Value

- This research identified the barriers to implementing information modelling for local authorities, which has the potential to put built environment data to use for public benefit, linking public planning policy with technological developments.
- This research highlights the need for a new data management paradigm that can extract value from data while protecting citizens' right to privacy and to the city.

Long-term Vision

The long-term vision for this project is three-fold:

1. Open up planning systems to successfully integrate data flows from the built environment to plan for a sustainable future. This is not just about building out hardware and software systems; this is about using the strategic function of planning to bring together insights from different sectors and departments to collaboratively plan for the future.
2. Integrate smart city planning with the planning system: In communities that are pursuing smart city initiatives, those responsible for smart city strategy tend to be isolated from planners. The smart city strategists and the planners are both responsible for planning for a sustainable future, and these two functions should be aligned to ensure successful outcomes.
3. Support the government in leading the drive towards socially responsible data use in the built environment: There is currently no definitive model to follow for how governments should protect residents' privacy while also extracting benefit from data flows.

Research Acknowledgements: Thanks to all interviewees and stakeholders who contributed their time and expertise to this project.

UNIVERSITY OF CAMBRIDGE

Dr Franziska Sielker

Department of Land Economy
University of Cambridge
fs421@cam.ac.uk.
www.planningfuturecities.org

DEPARTMENT OF LAND ECONOMY
Environment, Law and Economics

Planning Future Cities

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Toward Blockchain-enabled Construction Supply Chains: Potential, Requirements and Implementation

Benefits to public and private clients, housing associates, councils, procurement, tendering and contract managers, project managers, developers and investors, higher and lower tier contractors.

"Simply going digital is not helpful. Trust is an issue (in the AEC industry). It (Blockchain) might make some companies go digital due to increased trust."

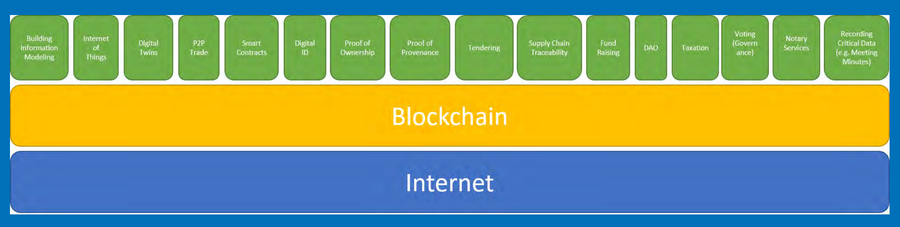
– Senior Consultant. AEC Industry

Impact and value:

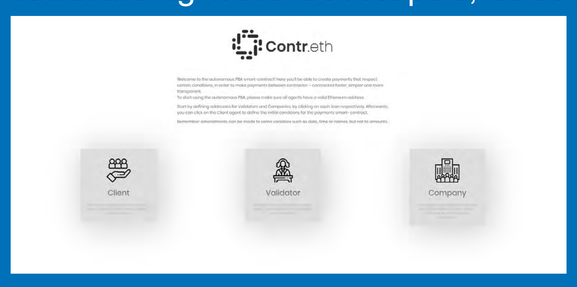
- Identifying various Blockchain opportunities, risks/barriers and key implementation parameters for AEC supply chains
- Creating three working mock models for Blockchain-based tendering, payment, and fundraising for projects and assets.
- Collecting feedback for the implementation of the models from industry actors, Blockchain developers and academics
- Raising awareness of the subject among and collecting feedback from practitioners through a workshop.

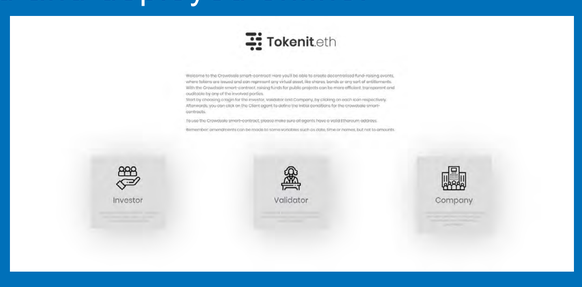
Key Findings

- Blockchain will increase trust, transparency and inclusiveness in the industry.



- The need for trust will not disappear with Blockchain but shift focus to correct data inputting.
- The conventional multi-party transactions can be streamlined with Blockchain to save to time and costs.
- There are many challenges; lack of knowledge and awareness, legal and contractual frameworks, not streamlining internal processes with Blockchain etc.
- Three Blockchain based models on payments, tendering and fundraising were developed, coded and deployed online:





- The models were generally found of high value. However, there are also issues like changing the payment/money control culture in the industry, streamlining internal processes for the models, compliance with regulations and standard contracts etc.
- The workshop attendees expect more research on real-use cases, increasing knowledge of Blockchain, identifying critical project information to be Blockchained etc.

Summary:

The project investigated the value and implementation parameters for Blockchain in AEC supply chains. After a detailed literature review on the use of Blockchain in different industries, 33 interviews were conducted with subject experts. A large list of Blockchain application opportunities as well as critical points for the implementation and different actors' (e.g. government, clients etc.) roles were identified for the AEC industry. Of the identified application opportunities, three Blockchain based models on Project Bank Accounts/payments (https://contract-eth.herokuapp.com/), reverse auction (https://auction-eth.herokuapp.com/) and asset tokenization (https://token-eth.herokuapp.com/) were developed, coded and deployed online for demonstration and industry engagement purposes. The models were validated through three focus group studies conducted with contractors, clients, Blockchain developers and academics. Finally, an industry/research workshop was held on the subject with 28 participants in June 2019 to demonstrate and validate the findings, and to raise awareness of the subject.

Next Steps:

- Integrating the feedback from the focus groups and workshop into the models
- Implementing the developed models in real project(s) creating the use case.
- Conducting implementation work or case study on BIM/Blockchain integration.

Long-term Vision:

- Linking the models with digital passports (ID) on Blockchain
- Identification of macro and micro-level requirements for the penetration of Blockchain in the AEC industry
- Identification of key project or asset information/document types to be Blockchained over project life-cycle.
- Understanding the change requirements for Blockchain in the current procurement systems and standard contracts
- Investigating the potential for Decentralised Autonomous Organisations (DAO) in the AEC industry

UNIVERSITY OF CAMBRIDGE

University of HUDDERSFIELD
Inspiring tomorrow's professionals

isl

Contact:Dr Algan Tezel
Senior Lecturer,
University of Huddersfield,
A.Tezel@hud.ac.uk,
https://pure.hud.ac.uk/en/persons/algan-tezel

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

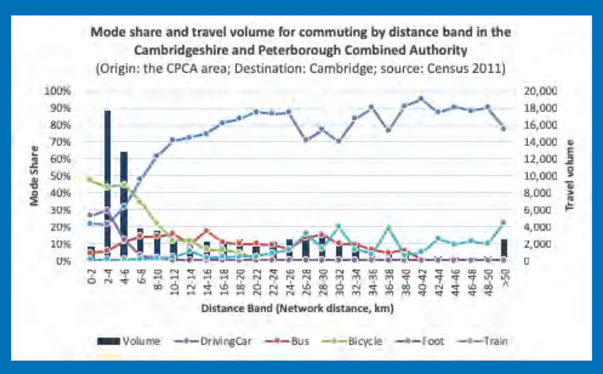
Centre for Digital Built Britain

A City-Level Digital Twin Experiment for Exploring the Impacts of Digital Transformation on Journeys to Work in the Cambridge Sub-region

Benefits to urban planners, transport and energy infrastructure planners, local policy makers

Summary

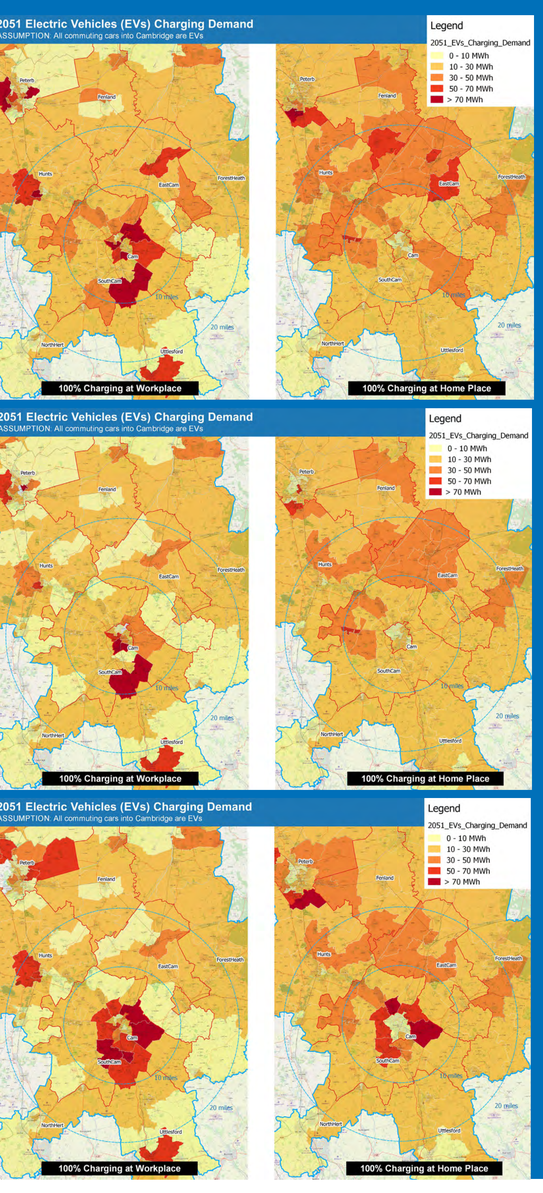
The 'digital twin' represents one of the latest technical trends for smartening our cities. However the roadmap to develop a city-/national-level digital twin is not yet clear. This project represents a timely effort to explore a policy-oriented strategy for developing a city-level digital twin prototype for the Cambridge sub-region, with a particularly focus on journeys to work. The investigation of past trends in journeys to work is reported, and the analytical capability of the twin model is demonstrated through two digital scenarios (teleworking and EVs charging demand). Initial feedback from local authrotities suggests that the city-level digital twin has a great potential for bridging professional/ disciplinary silos in city and infrastructure planning and management. The project is nothing but a small step towards the ambition of creating a national digital twin for the UK infrastructure. It is expected that more and more empirical evidence will be gathered to establish a new body of knowledge for leveraging and regulating the power of digital twins. As a reflection of the project, a series of propositions are proposed for guiding the future research on city-level digital twins.

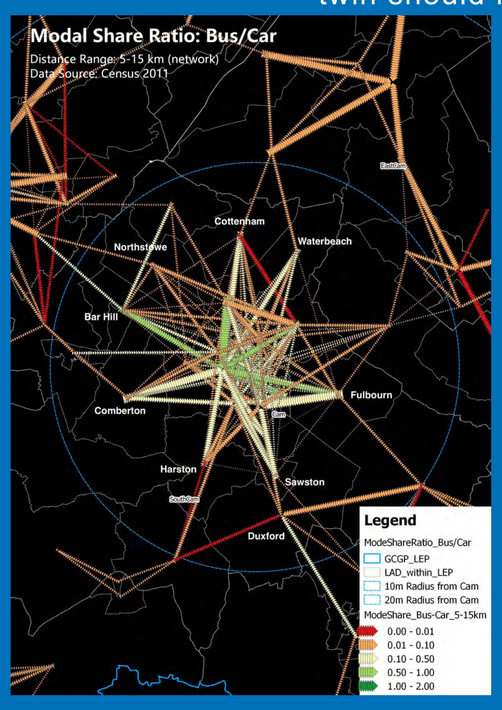


Topic 1: mode choice in the Cambridgeshire and Peterborough Combined Authority

Next Steps

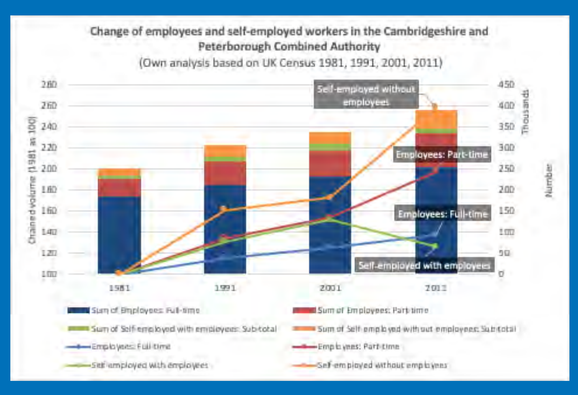
- Further developing and applying the digital twin prototype to support the planning and management of major development initiatives in Cambridge through case studys in collaboration with local authorities, key stakeholders and citizens;
- Collecting feeback on the design, use and conmmunication of the digital twin tool and developing preliminary guidelines for city-level digital twin development;
- Exploring a new competence framework for city managers.



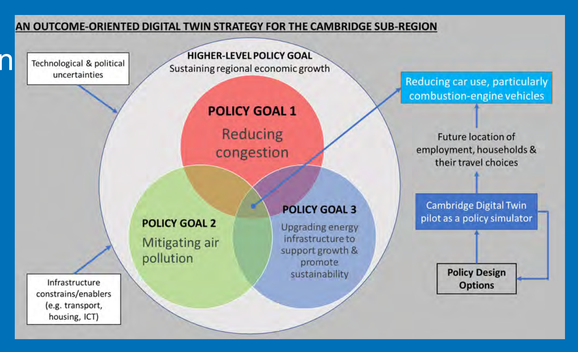


Key Findings

Proposition 1: The upscaling from an engineering digital twin to a city-level digital twin is not straightforward. For a city-level digital twin application to be useful and the associated discussion to be meaningful, key dimensions of a city-level digital twin need to be articulated pertaining to the purpose, boundary, context and resolution of specific digital twin as well as the interdependences among twin models.



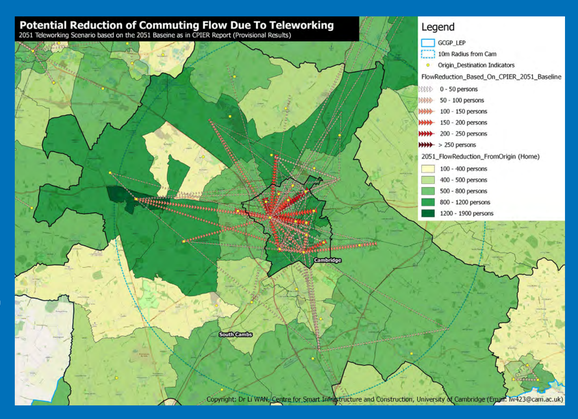
Proposition 2: Digital twin development is a progressive process; the digital twin and the social system that creates and uses it must co-evolve with each. On the one hand, our existing knowledge about cities and societies defines how well we could development and use a city-level digital twin. On the other hand, artificial intelligence (AI) may eventually become comparable to or even surpass human intelligence in terms of knowledge production and decision making.



Proposition 3: Real time is a relative term. The temporal scale of the digital twin should reflect the rate of change of the subject in reality.

Proposition 4: To advance the city-level digital twin agenda, digital twin applications should be focused on enabling more frequent and effective feedback loop between the twin model, policy makers, stakeholders and the public. New interface needs to be explored which can translate data analytics into cogent narratives targeted to various stakeholders.

Proposition 5: A realistic use of a city-level digital twin is to identify system-level risks and inefficiencies of policy interventions and to foster cross-disciplinary/ professional collaboration, as opposed to providing a singular model-based optimization.



Research Acknowledgements

The project is funded by the Centre for Digital Built Britain. The project is hosted by the Cambridge Centre for Smart Infrastructure and Construction (CSIC) at Department of Engineering, University of Cambridge. Dr Li Wan would like to thank the following people for their kind support and guidance to the project: Dr Jennifer Schooling, Dr Ajith Parlikad and Dr Ying Jin. Contributions from Dr Timea Nochta on the governance of city-level digital twins are much appreciated. Dr Li Wan would also like to thank Dan Clark and Gemma Schroeder from the Cambridgeshire County Council and other council colleagues for their kind support and feedback for developing the Cambridge digital twin prototype. The administrative support from Tianlei Wu and Jemma Andrews is gratefully acknowledged. A spatial disaggregation module is developed in collaboration with Dr Roberto Murcio, Dr Richard Milton and Prof Michael Batty from the Bartlett Centre for Advanced Spatial Analysis, UCL. The development of the web-based digital platform is supported by the Zentrope.

UNIVERSITY OF CAMBRIDGE

Contact: Dr Li Wan

Department of Land Economy,

University of Cambridge

lw423@cam.ac.uk

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Automated Checking of Regulations and Requirements Managment in Healthcare Design

Benefits design teams, professionals in charge design assessment, software developers, policy makers

"The challenges facing construction and the built environment will require greater collaboration between all parts of the industry and academia, particularly in the area of sustainability and improved whole life value. Community Health Partnerships are currently supporting HEI's in a number of areas which it is hoped will result in improved value in healthcare design and delivery."

Julian Humphreys, Community Health Partnerships

SUMMARY

BIM can support the automation of design assessment with regards to regulation compliance, and its use for modelling information contributes to the visualisation and organisation of requirements data. The practical adoption of automation can support transparency and consistency for designers and regulatory bodies. This research proposes recommendations for the adoption of automated checking of regulatory compliance in the design of healthcare facilities.

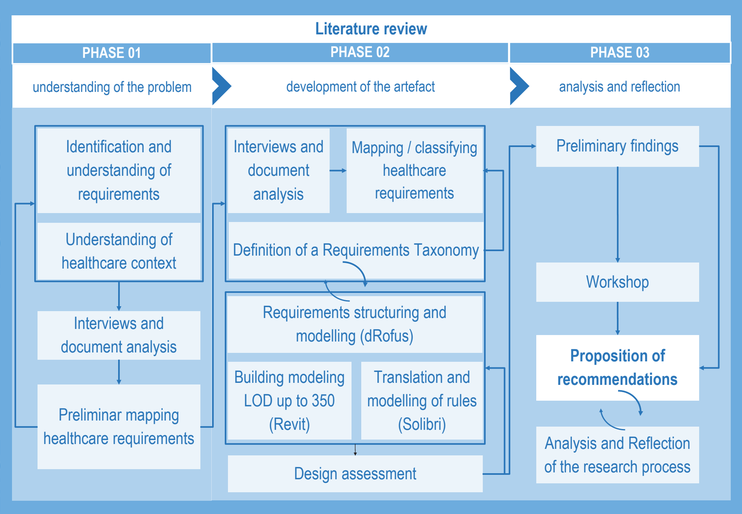
Main findings include an evaluation of the information content of existing healthcare regulations towards automation; and the need of a hybrid approach for assessment was identified. The hybrid approach should support the automation of objective requirements, but also address subjective requirements through human inputs.

Acknowledgements: We are grateful to Community Health Partnerships, Solibri and Hospital das Clinicas de Porto Alegre for their collaboration. We also would like to thank all other stakeholders and companies which supported the research enabling site visits, interviews and meetings

KEY FINDINGS

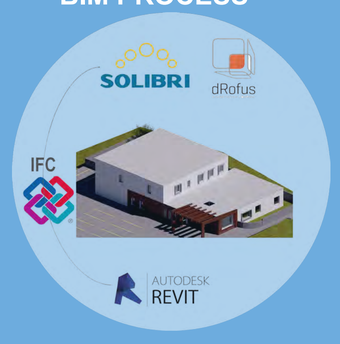
- The UK has over 100 healthcare design regulations or guidance; requirements are often described through **complex and subjective expressions**, creating difficulties for automation
- The proposed taxonomy describes how regulations should be written to enable, in the future, an **easier automation of quantifiable requirements and a reduction of subjectivity**
- Existing regulatory requirements that can be translated into logic rules for automated checking have **low and medium logic complexity**, which is beneficial for automation
- Need to adopt automated checking at **different design stages** to avoid non-compliance and rework
- Subjectivity can be: **Natural** - requirements contents cannot be translated into an objective sentence e.g. design flexibility; or **Artificial** - created by humans and hence could be presented objectively e.g. accessibility
- Need for a **hybrid approach**: automation is suitable for objective requirements; subjective requirements needs to be addressed through semi-automated approaches

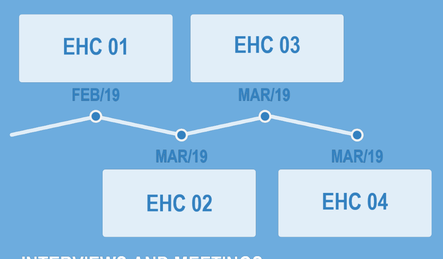
RESEARCH METHOD



SOURCES OF EVIDENCE

BIM PROCESS

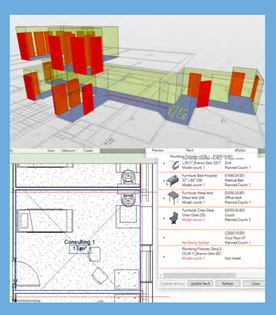




INTERVIEWS AND MEETINGS

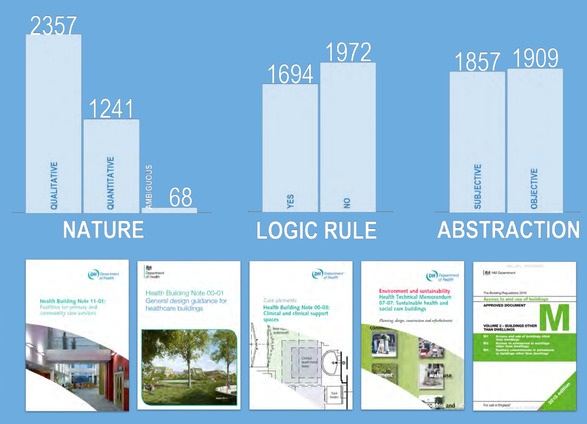
4	10	4	8
HC 01 MEETINGS	SEMI-STRUCTURED INTERVIEWS	OPEN INTERVIEWS	HC 01 PROJECT MEETINGS

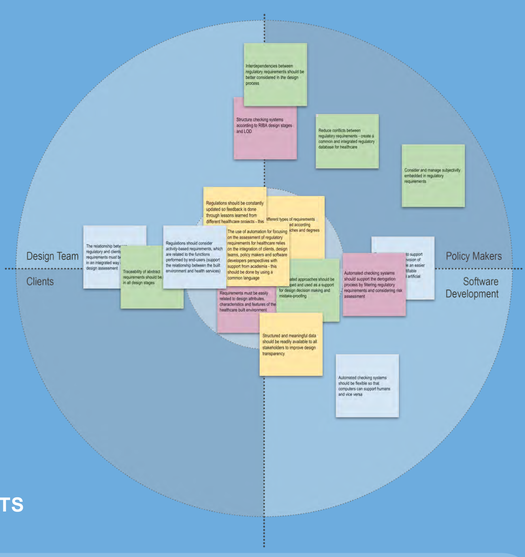
APPLICATION OF SOLIBRI AND DROFUS



- Regulatory requirements were inserted in Solibri, modelled and checked against the building model.
- Solibri was successfully used to verify requirements related to areas, components, corridor dimensions.
- The spaces, equipment and furniture planned in dRofus were connected to the building model, making requirements explicit during the design process.

ANALYSIS OF REGULATIONS





IMPACT AND VALUE

- More structured, reliable, easier and faster compliance checking
- Better understanding of compliance needs and clarity about rules for automated checking
- Support the revision of regulations so automation can be more easily implemented in the future

LONG-TERM VISION

- Need to update healthcare regulations to enable automation of quantifiable requirements according to the proposed taxonomy
- A support system which automatically checks regulatory compliance during design development and supports decision making of subjective requirements

NEXT STEPS

- Analyse other regulations according to the proposed taxonomy for further validation
- Better understand links between regulatory and clients requirements, in terms of prioritisation and conflicts
- Explore design support systems and mistake-proofing using the regulatory framework as a basis
- Further explore the need for subjectivity in regulations

RECOMMENDATIONS

FOR AUTOMATED CHECKING OF REGULATIONS AND REQUIREMENTS IN HEALTHCARE DESIGN

- **Policy makers** should avoid artificial subjective elements in regulatory texts, ensuring objective and quantifiable sentences are included in the revision of regulations. There is a need to consider if any subjectivity should exist within the regulatory framework, as it can cause design errors and rework, and challenge attempts to automate the process.
- **All stakeholders** should manage the subjectivity embedded in the regulations by using a common language.
- **Designers** and policy makers should organise requirements in a common, structured and integrated database. Clients should provide constant support and inputs to this database.
- **Designers** and software developers should better consider the integration of regulatory and clients requirements and systems to enable such integration.
- **All stakeholders** should envisage the use of the regulatory framework as a support tool towards mistake-proofing rather than a mistake-finding mechanism.

UNIVERSITY OF CAMBRIDGE

Collaborate with us
engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

Contact: Prof Patricia Tzortzopoulos
Professor, School of Art, Design and Architecture,
University of Huddersfield, HD1 3DH, UK.
P.Tzortzopoulos@hud.ac.uk
https://research.hud.ac.uk/institutes-centres/idl/

University of HUDDERSFIELD
Inspiring tomorrow's professionals

Centre for Digital Built Britain

Analysing Systems Interdependencies Using a Digital Twin

Benefits to asset managers, infrastructure owners and operators, commissioning managers, data-scientists working in major infrastructure projects or operations, and/or digital twin engineering.

“Working with Tideway, we brought research on theoretical work on modelling techniques and model integration into dialogue with leading practice to develop new ways of analysing systems interdependencies in the digital twin”

-Professor Jennifer Whyte, Centre for Systems Engineering and Innovation, Imperial College London

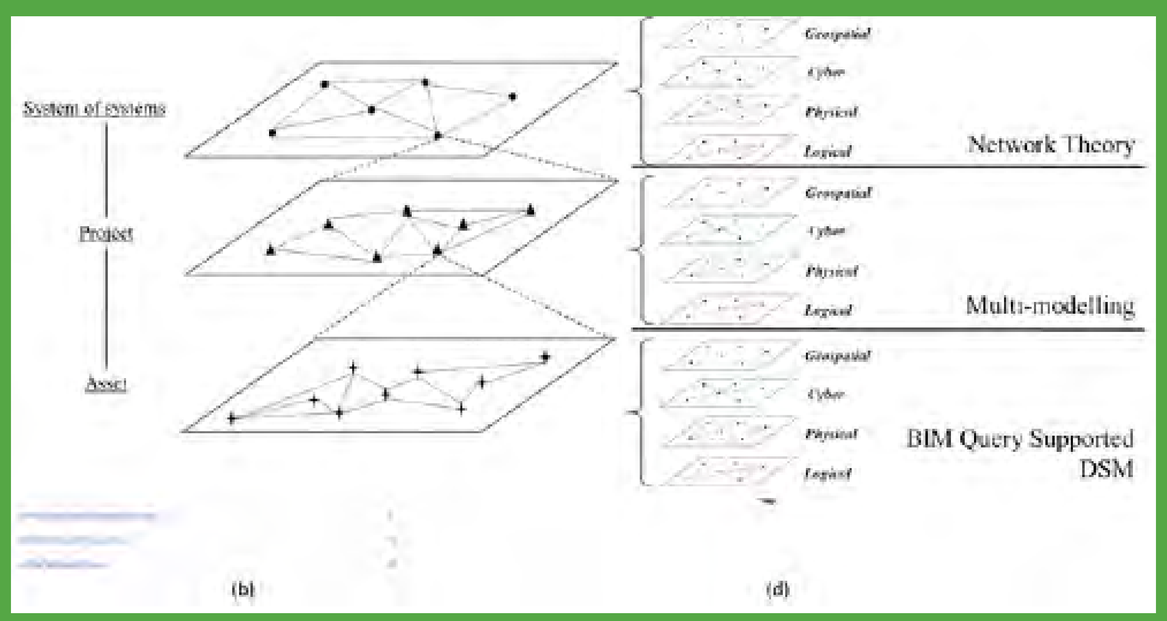
Summary

Examines the potential to combine analytical methods (e.g. BIM query, network analyses and multi-modelling), demonstrating use of a digital twin to generate new insight into systems relationships and interdependencies.

Aim: To understand how articulate the extent to which a digital twin can be used to generate new insight into systems relationships and interdependencies.

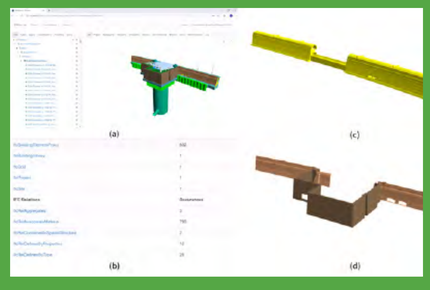
Objectives:

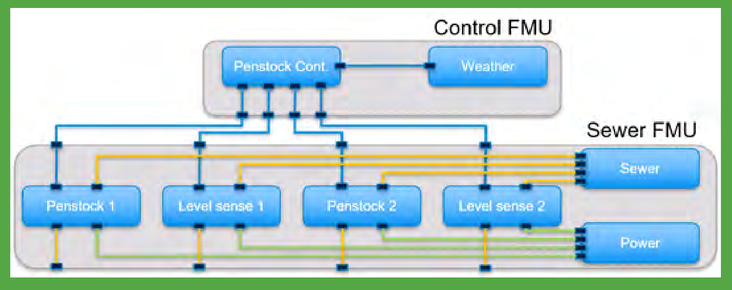
1. Identify and rank the importance of critical interdependencies emerging in Tideway, both in the infrastructure system and in the enabling production system;
2. Develop new approaches to identifying critical interdependencies in time for decision makers on the project to make decisions by linking digital data; and
3. Articulate, across different scales, the utility of and practical barriers to the use of different analytical approaches in relation to practical problems and use cases faced in delivery.



Key Findings

1. Critical interdependencies: qualitative understanding of interdependence both delivery and operations.
2. Application of modelling approaches in BIM query supported Design Structure Matrices, multi-modelling and network analysis to infrastructure projects.
3. Use cases for different analysis approaches: decision trees to articulate, across different scales, the utility of and barriers to the use of different analysis approaches.





Impact and Value

- Informs work on the digital twin including the Digital Twin hub set up by the Digital Framework Task Group (DFTG).
- Provides decision trees for practitioners to understand scenarios in which network analyses, multi-modelling and BIM query may be useful.
- Provides steps towards a framework through which digital approaches can be implemented and potentially integrated, and a model for how industry and researchers can work together on this.
- Identifies new research directions for the use of linked data and sensitivity analyses as well as the potential to use modelling techniques at different scales in observatories.

Next Steps/ Further Work

We plan to examine combinations of these modelling approaches across scales and also the combination of multi-modelling and linked data approaches.

Long-term Vision

The long-term ambition is to build the tools that decision-makers need to understand infrastructure system interdependencies within and across project boundaries, where these analyses provide information to decision-makers in time to make decisions on the project.

Acknowledgements: We are grateful for the input of Tideway, particularly Dr Sian Thomas, Dr Patrick Owen and Peter Vale, who commented on this report. We also acknowledge the input of Dr Giuliano Punzo from the University of Sheffield for input in the delivery of the project, and of Mark Enzer and Professor Mark Girolami for reviewing near-final drafts of the final report.

Imperial College London

Professor Jennifer Whyte
Professor Nilay Shah
Dr Long Chen
Dr Filip Babovic
Dr Akeem Pedro

Newcastle University

Professor John Fitzgerald
Dr Ken Pierce
Dr Carl Gamble

The University Of Sheffield.

Professor Daniel Coca
Professor Martin Mayfield
Dr Cristian Genes

Contact: Prof Jennifer Whyte
Director
Centre for Systems Engineering and Innovation,
Imperial College London,
j.whyte@imperial.ac.uk,
www.imperial.ac.uk/csei @CSEI_Imperial

UNIVERSITY OF CAMBRIDGE

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Open ML Training Data For Visual Tagging Of Construction-specific Objects (ConTag)

Benefits to infrastructure owners, asset owners, researchers

Summary

ConTag has generated open datasets for visual machine learning (ML) specific to the construction industry. ML technology has enabled a revolutionary leap in many digital economies generating growth in activity and business mainly for the ITC sector. Part of the growth is generated through sharing of IP, knowledge, tools and datasets. We want to adopt this approach for the digital construction sector. ConTag provides visual and 3D training datasets for training deep neural networks (DNNs) and provides weights for pre-trained networks. The research output is to support visual tagging of assets from reality capture data. Such automatically generated semantic information can be used to generate or populate digital twins in the example scenarios. The first dataset is a collection of fire safety equipment typically found in indoor environments. The dataset contains the classified images, per-pixel label images and bounding box data for object detection. The second dataset is a synthetic 3D point cloud of an outdoor urban street scenario. The dataset contains the point cloud data and per-point label data.

Impact and Value

We have generated SynthCity an open, large-scale synthetic point cloud. We release this dataset to help aid research in the potential use for pre-training of segmentation/classification models on synthetic datasets. Impact of such research outcomes are in the automated tagging of urban assets. Owners or stake holders in urban infrastructure can take stock, monitor change and generate digital twins through automatically classified reality capture data.

In addition we have generated FireNet an open ML training dataset for visual recognition of fire safety equipment. We release this dataset to kick-start further ML developments in both academia and industry and as a seed point for collaborative research. Impact of such research outputs is in the automatic asset tagging for fire safety equipment form (mobile phone) imagery. Building owners or asset managers can populate digital twins with this automatically generated tagging information.

Next Steps

FireNet has been designed as a ML training dataset for experimentation and therefore fulfills multiple machine learning scenarios (classification, object detection, sematic segmentation). The dataset itself is not big enough to train a modern DNN from scratch. It is intended as a domain specific dataset to refine pre-trained standard architectures. There is a remaining class imbalance and a small number of images that were not successfully labelled. As part of a continuous maintenance to the dataset we are exploring options to revisit the remaining images.
SynthCity has been designed primarily to be used for semantic per-point classification. Whilst this is useful for a range of applications, currently the dataset does not contain instance IDs for individual object extraction. With SynthCity being an ongoing project we plan to implement this in future releases.

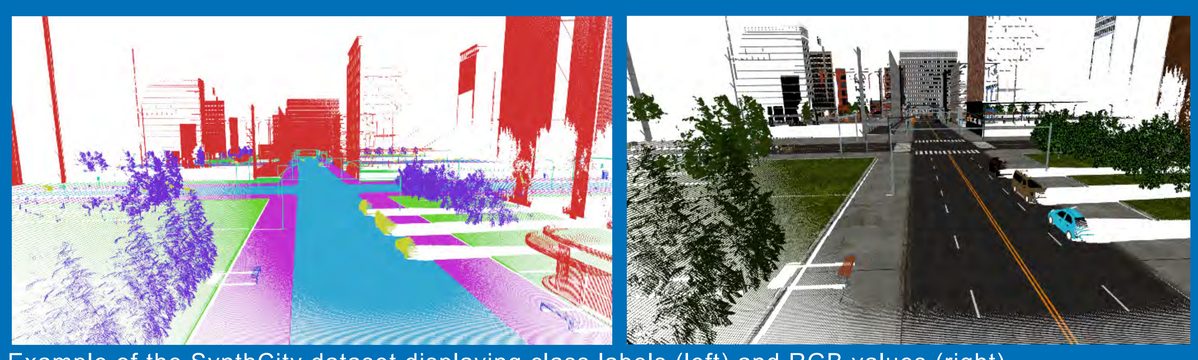
Research Acknowledgements:
David Griffiths, Fabio Panella, Victor Melatti

Key Findings

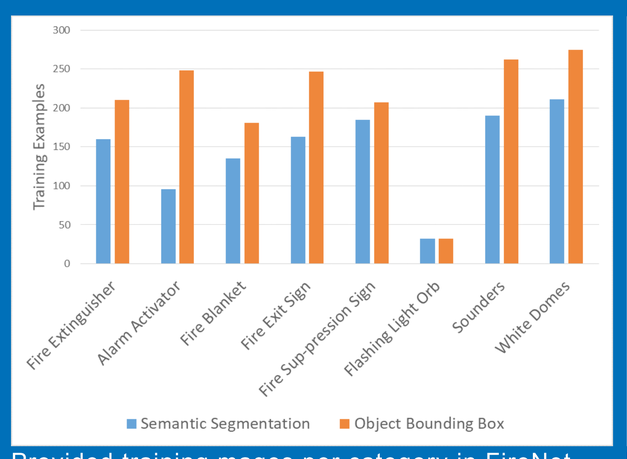
We explored crowd-sourcing of semantic labels for technical equipment in images. We have shown that even relatively small teams can generate relevant sized datasets with a quick turn-around. Our tool chain has proven successful and we are able to generate further domain specific datasets with future collaboration partners.

Example of the FireNet dataset: image with classification label, object with bounding box and segmented object (left to right).

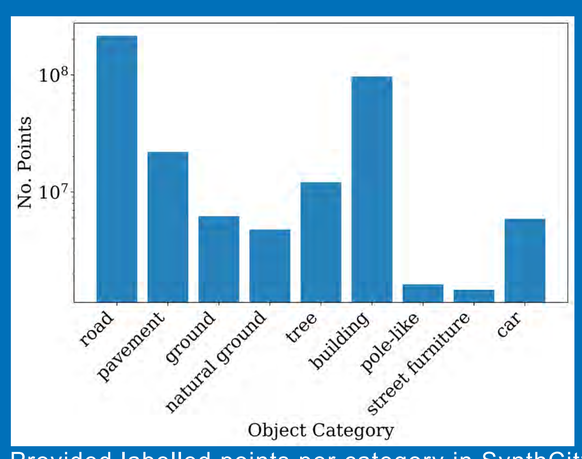
Per-point 3D segmentation requires highly skilled users and manually generating perfect labels for even the most advanced users is non-trivial. We argue an ability to generalise from synthetic data to real world data is immensely beneficial to the community as a wealth of existing synthetic 3D environments exist. The primary purpose of our dataset is therefore to offer an open dataset to aid further research assessing the potential of synthetic datasets for pre-training Deep Neural Networks (DNNs) for automatic point cloud labelling.



Example of the SynthCity dataset displaying class labels (left) and RGB values (right).



Provided training mages per category in FireNet



Provided labelled points per category in SynthCity

Long-term Vision

We expect this shared and open datasets to kick-start further ML developments in both academia and industry. It is intended as a seed point for collaborative research.

UNIVERSITY OF CAMBRIDGE

UCL

UCL ENGINEERING
Change the world

Contact: Jan Boehm
Associate Professor, UCL
j.boehm@ucl.ac.uk
https://www.ucl.ac.uk/civil-environmental-geomatic-engineering/

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Immediate (Integrated Management of Margins through Evaluation, DesIgn, Analysis, Tracking and nEgotiation)

Benefits to: NHS Hospitals, Estate Directors, Estate Managers, Estate Officers, Building Service Consultants, Building Service Designers and Providers, Energy Managers.

“if you look at the culture … within the public sector, buildings generally I think, there is a fear of getting it wrong, which is so extensive, that the level owed to the design or overcapacity, that goes into these schemes is crippling”

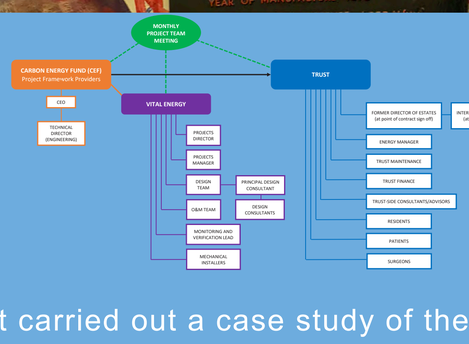
- Estate Director, NHS

Summary

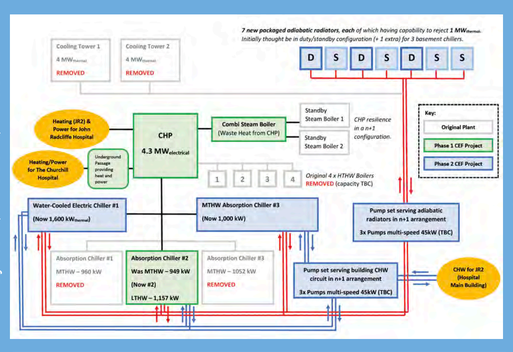
Over-engineering of systems is an often hidden source of inefficiency in building systems within building service systems. It significantly increases their design, installation and running costs, and reduces the sustainability of the system. The project carried out a case study of the CHP and the chiller installations at the Oxford John Redcliff hospital, a recent PFI project.

While the system studied during the project makes considerable savings compared with the antiquated boiler system it was replacing, different stakeholders realised that their system was overdesigned, but could not quantify the amount, or cost the overdesign. Stakeholders are not aware of the rationale behind the upgraded specification of the system, intended for much greater demand than that which transpired, and consequently the margins remain, and are not challenged. The case study illustrated how a previously rational decision can ultimately lead to an oversized system.

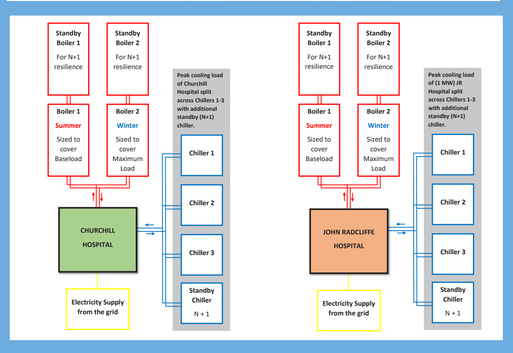
The project analysed the causes of overdesign arising from the way building service projects are specified and procured and developed insights that can inform the decision making and management of building service projects. It also developed recommendations for designing flexible building services with suitable margins.



CHP Network Diagram - Original System, Phase 1, Phase 2



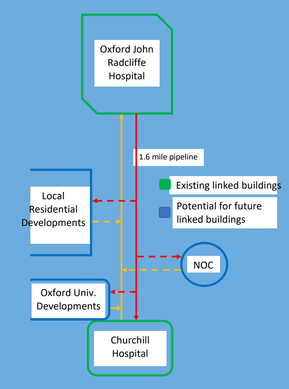
CHP Network Diagram - Alternative Design without Power Generation



Impact and Value

Oversizing building services:

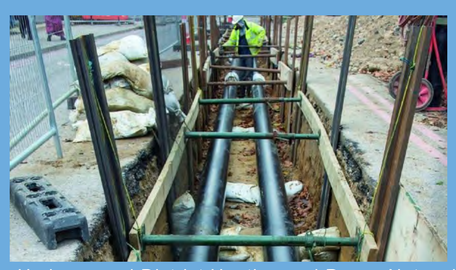
- considerably increases initial capital costs and long-term running costs
- negatively affects sustainability through excess energy use
- excess heat produced is frequently vented to the atmosphere, rather than harnessed for other purposes



Pipework Link - Basic Diagram

Key Findings

- Building service systems can be very oversized
- The size of new system often based on the capacity of existing systems, rather than on need
- The rationale for the system architecture and size is often lost
- Resilience requires some system duplication - this may be reduced by solutions from outside the system
- The language of making “savings” from a new system, against specified base lines, can obscure significant overdesign



Underground District Heating and Power Network

Next Steps

1. A proposal is planned to address
   - Decision making processes in the NHS including an analysis of the risks that need to be considered for resilience
   - Modelling and visualizing margins on interconnected parameters
   - Capturing and managing data related to current and future energy, water and heating needs.
2. Developing sizing guidelines for the building services in the NHS
3. Predicting the future energy use of hospitals based on estimates of patient care trajectories, climate data and environmental requirements, and medical equipment use.
4. Developing system architectures for flexible and upgradable building service systems

Long-term Vision

The long term vision is to contribute to adequately sized and interconnected systems of systems for providing energy, heating, cooling that,

a) utilize capacity by combining different types of systems, that can be brought on-line as required, from non-critical parts of the system or from external sources;

b) and which can be upgraded easily through a modular architecture.

Research Acknowledgements: Professor Andrew Geens, Head of CIBSE Certification; Professor Fiona Daly, National Sustainability and EFM Workforce Lead NHS Improvement

UNIVERSITY OF CAMBRIDGE

Contact: Dr Claudia Eckert

Professor of Design
Department of Engineering and Innovation
The Open University
claudia.eckert@open.ac.uk

Darren Jones, Open University, darren.jones@lowco2.eu

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Co-Creating a City-Scale Digital Strategy and Framework: A Systems and Co-production Approach

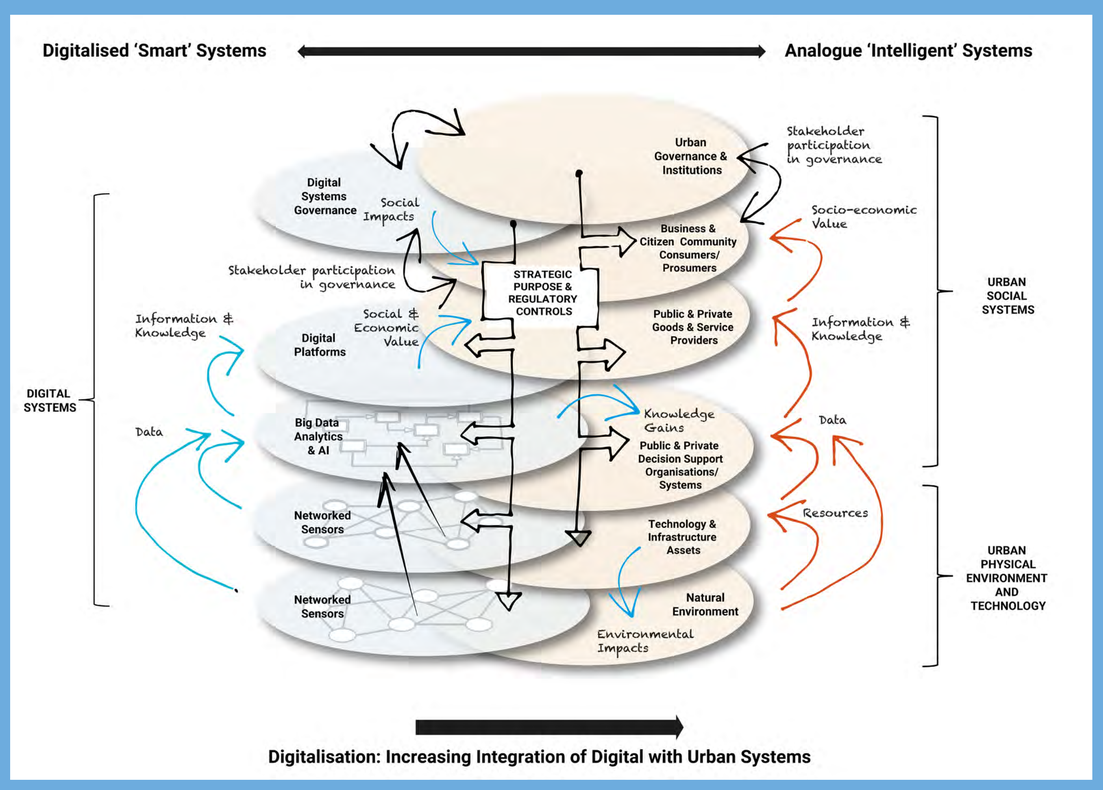
Benefits to national government, local governments in cities, towns, counties and combined authorities, public and private sector digital/ technology/information officers, 'Smart' and 'Digital' city consultants, infrastructure owners and operators, local enterprise partnerships

"When focused on facilitating positive experiences that are city-led, applied technology can produce better social outcomes and inclusive growth. As long as people are at the heart of the solution, digital technology has the potential to address intractable challenges within the city"

- Marvin Rees, Mayor of Bristol, 12 September 2019.

Summary

Digital technologies have the potential to unlock major social and economic change for the World's rapidly growing urban populations, creating value through more liveable, healthy and environmentally sustainable cities. However, this can only happen if city leaders are empowered to make intelligent and informed strategic choices governing how digital systems are commissioned, installed and operated. This pilot study has investigated how collaborations between public authorities, private business and other city stakeholders may be used to enhance and share the benefits of digital transformation across UK towns and cities. Through a mix of interviews, workshops, and attendance at working group meetings, we've investigated how government in the UK's cities, towns and counties are planning for digital transformation and the challenges they face.



Long-term Vision

- Digitalisation of urban areas is challenge-led, focused on citizen and planetary health needs.
- Cities and town authorities have developed and trusted digital governance.
- A 'digital social contract' balances rights of businesses to profit from digital technologies with need to resource digital public goods.
- Digitalisation and technology adoption is integral to city-wide strategic planning and supported by 'living laboratory' approaches and city testbeds.
- Developed networks within urban areas facilitate collaborative innovation between businesses, public sector, citizen groups and communities.
- Strong city-to-city and city-to-town networks facilitate knowledge exchange on digital transformation and sharing of innovation risks.

Key Findings

- Co-creation of digital strategies: effective digitalisation strategies emerge from strong, engaged local networks including public-private partnerships and community groups.
- Conceptual framework for digital transformation: digitalisation requires layers of sensors, data analytics, digital platforms and governance to be integrated with existing 'analogue' city systems. Opportunities to create value and manage risks arise at the interfaces between layers. Successful digitalisation requires a balanced progress across all layers.
- Maturity models indicate strategic planning is evolving, with significant variations in capacity and organisational readiness of local authorities to lead and shape digitalisation
- Long-term, spatial transformation of UK cities and towns: as 'smart' technologies are scaled, digitalisation will transform the social and physical organisation of towns, cities and rural areas. Business models that prioritise digitalisation of areas with only the highest commercial returns risk 'cherry-picking' and entrenching socio-economic inequalities.
- Privacy, security, public acceptance and trust: not just issues of regulatory compliance, but are a strategic challenge when setting service levels, accessibility and digital inclusion. A related challenge is to deliver 'socially responsible' innovation to cities and towns.
- Sharing digitalisation gains: a new 'digital social contract' could be developed that balances the rights of technology businesses to profit from digitalisation, with the need to develop digital public goods, e.g. open data portals, new digital governance and sensor networks.
- Challenges local authorities face include: 1) public sector deficit in digital skills; 2) gaps in science and data adversely impacting trusted leadership; 3) weaknesses in capacity of public-private leadership networks to co-create a shared vision tailored to local needs, assets and opportunities; and additionally 4) insufficient access to investment and technologies outside major cities.

Next Steps

- Develop toolsets to support and integrate digital planning into programme management and operational activities, including coproduction skills.
- Investigate potential for more formalised research, learning and knowledge-sharing institutions and practices, focussed on provision in follower towns, counties and rural areas.
- Investigate policy options around concept of a new 'digital social contract' between private enterprise, public authorities and citizens.

Impact and Value

- Improved understanding of challenge areas and barriers Local Authorities face to planning and co-leading on the digitalisation of cities and towns;
- Creating more liveable and sustainable urban areas by aligning digitalisation with community needs at all scales from city to local neighbourhoods;
- Opportunities to harness and realise socio-economic and environmental benefits of digitalisation, including human health and well-being and planetary health;
- Increased public trust and confidence in digital transformations through co-produced strategies.

Research Acknowledgements

Freyja Lockwood (Bristol City Council), Julie Snell (CEO, Bristol is Open), Dr Neil Carhart, Dr Helen Manchester and Dr Lyndsay Grant (Co-Investigators, University of Bristol)

UNIVERSITY OF CAMBRIDGE

University of BRISTOL

Contact: Dr Ges Rosenberg
Research Fellow
Department of Civil Engineering
University of Bristol
email: ges.rosenberg@bristol.ac.uk
telephone: 07776 131 594
twitter: @GesRosenberg linked-in: Ges Rosenberg

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

A Two-step Clustering Framework for Locally Tailored Design of Decarbonizing Residential Heating

Benefits to local authorities, policy makers, urban planners

“Integrated analysis of data across diverse dimensions will enable more effective implementation of energy technologies in cities”
-Ruchi Choudhary, Data-centric Engineering Program, Alan Turing Institute

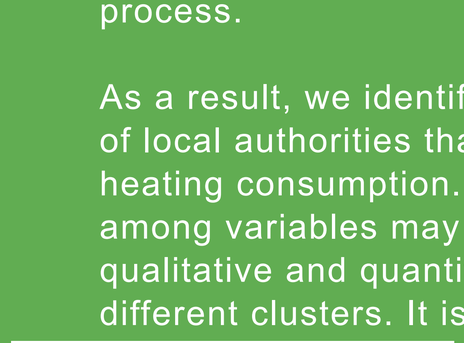
Summary

We present a two-step clustering framework of high-dimensional data involving socio-demographic, physical, and economic features of districts across London. The framework takes the advantage of the aligned design of statistical geographical boundaries and different characteristics of various clustering algorithms to provide enlightening hidden patterns and policy implications at multiple resolutions both numerically and geographically without including the target variable and geographical information in the modelling process.

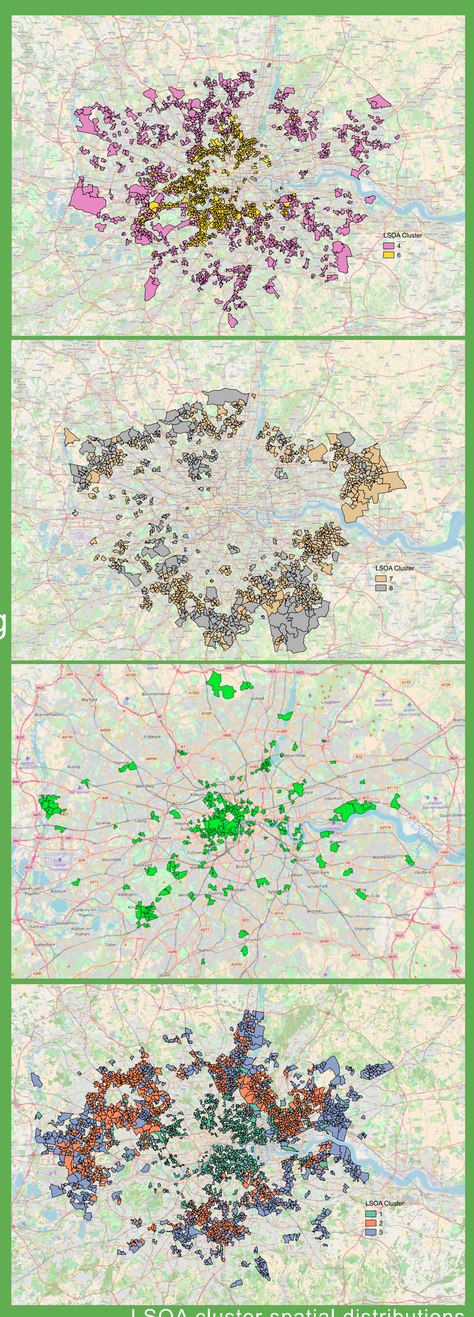
As a result, we identify distinct groups of local authorities that share patterns of heating consumption. The relationship among variables may vary in both qualitative and quantitative aspects in different clusters. It is of great help to perform cluster analysis that includes all approachable information and to look into the differentiated characters among generated clusters before designing or executing their policies.

We have also performed network analysis to further categorised residential built environment based on their energy efficiency properties. Depends the understanding of building for future improvement on building energy efficiency.

Cluster densities of domestic gas consumption in GLA



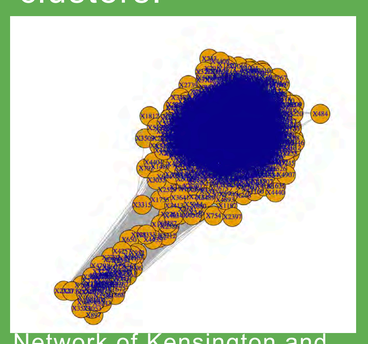
Dendrogram of the LAD clusters



LSOA cluster spatial distributions

Key Findings

- It is not enough for urban planners and policy makers to consider the targeted areas as a whole. The relationship among variables may vary in both qualitative and quantitative aspects in different clusters.


Network of Kensington and Chelsea residential buildings

- We generated 8 LSOA clusters that have decomposed the full density of domestic gas consumption into eight different sub-densities with each has its own characteristics without including the gas consumption information in the model.
- The combined characters across 22 dimensions in each cluster provides unique energy efficiency related policy indications.
- The Local Authorities that lies in the same cluster (or sub-cluster), especially the ones that are locally adjacent, may pursuit closer collaborations.

Impact and Value

- Master-planning tools to support locally tailored implementation of energy policies in UK cities.
- These will help us understand why certain energy policies are more or less successful than others, geographically, socially, and physically.
- It will also enable sustainable infrastructure planning that is aligned with UK’s carbon targets and is, at the same time, locally robust.

Long-term Vision

In the long-term, we aim to develop an integrated standard procedure that combines state-of-the-art statistical models to help local governments/planners to understand the targeted area at various resolutions and in a more comprehensive view.

Next Steps

- Further develop the framework to incorporate situations when the accessibility of data is limited
- Comparing the energy consumption patterns among cities/areas at different scale with the proposed methods
- Combining information at both macro and micro level in the modelling to provide evidences more robust and comprehensive evidences

Acknowledgements: This project is in partnership with Centre for Smart Infrastructure & Construction and Data-centric Engineering Program at the Alan Turing Institute.

UNIVERSITY OF CAMBRIDGE

The Alan Turing Institute

CSIC Cambridge Centre for Smart Infrastructure & Construction

Contact: Mingda Yuan
Dr Ruchi Choudhary
Department of Engineering
University of Cambridge
UK

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Digitisation of Requirements, Regulations, Standards and Compliance Checking in the Built Environment

Benefits to building/Asset owners/managers, design professions, regulatory bodies, local and national government, building control officers.

"The D-COM network in their initial findings have shown the need for this work to happen and indeed the positive response to compliance checking shifting from a manual endeavour to once that is supported by computer driven automation allowing a swifter and more integrated process. There is a mutualism between compliance checking and digital workflows and now is the time to make it happen."

David Philp, AECOM & CIOB Trustee and Chair of CIOB Digital Technologies Specialist Interest Group

Summary

The entire lifecycle of the built environment is governed by a variety of regulations, requirements and standards. These requirements range from contractual, project brief, legislative, to environmental. The checking of compliance against these is a complex task that is currently performed on a manual basis thus is highly resource intensive. So far there has been no meaningful adoption of automated compliance checking, which can bring tangible advantages including increased efficiency and a reduction in costs. This opportunity presents a clear need for further research in this area. Thus, D-COM was established to better understand how the built environment can take advantage:

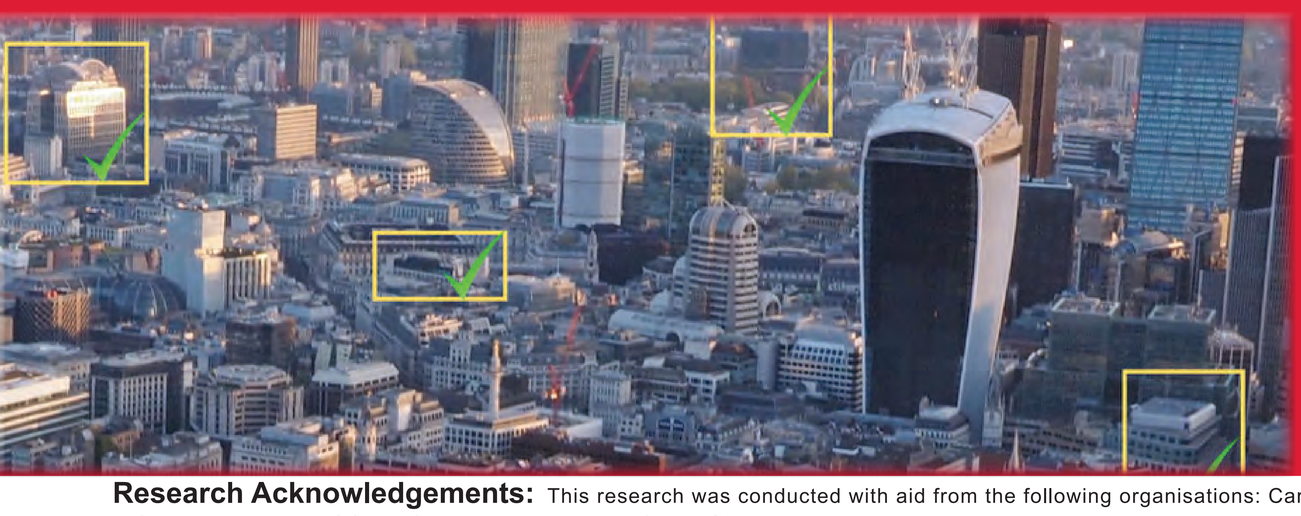
- Conducting a detailed landscape review of applicable industrial and academic developments.
- Consulting with stakeholders.
- Developing a research roadmap for achieving digitisation of built environment regulations
- Defining the capabilities required to deliver this roadmap
- Analysing the results to produce a future research roadmap.

Key Findings

The overarching insights from the D-COM network activities are:

- There is an appetite for automation.
- There were caveats and suggestions, that automation should have human oversight.
- current research landscape revealed that there are ad hoc solutions that have many limitations

The findings painted an overwhelmingly positive response to transforming the built environments existing compliance system they give confidence that the industry can achieve a level of automation checking by 2025 and expressed the importance of considering political, commercial and technological factors along the journey.

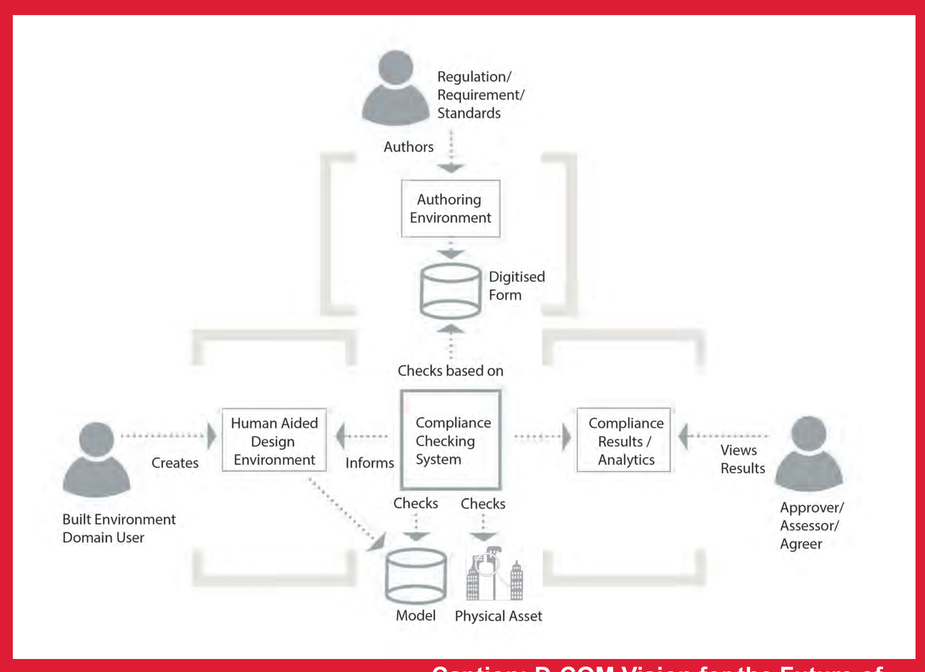


Impact and Value

- Gathered significant data regarding the appetite of the industry for the adoption of automated compliance checking
- Proposed a roadmap for the adoption of digitisation of compliance checking.
- Primary value is stimulation of research and discussion in this area
- Ability of the D-COM network to act as a focal point and hub in this activity.

Long-term Vision

The D-COM future vision for regulatory compliance is a new modern approach, driven by the paradigm shift of "human aided design" where the human guides the computer in developing designs to meet legislative requirements. In this paradigm, both designs and physical assets automatically checked against regulations, requirements and standards. Enabling delivery of a safer and more efficient digital built Britain.



Caption: D-COM Vision for the Future of Regulatory Compliance

Next Steps

To build industry confidence and work towards the target of mass scaling automation checking in 2025, D-COM proposed the following future steps as part of its roadmap.

Stakeholder engagement: catalogue and prioritise regulations.

Piloting: develop rules alongside a common language and demonstrate working approach.

Industrialisation: build a product or process to meet majority of needs, trial and test.

Scaling: develop audience specific training and guidance, establish methods for user feedback and continually refine.

Research Acknowledgements: This research was conducted with aid from the following organisations: Cardiff University – Dr Tom Beach; Process Innovation Forum – Raj Chawla; AEC3 – Nick Nisbet; MACE – Dr Marzia Bolpagni; University of Central Lancashire – Dr Abdulkadir Ganah; Bryden Wood – Rosemarie Andrews; Northumbria University – Dr Claudio Benghi; Solibri

UNIVERSITY OF CAMBRIDGE

Contact: Dr Tom Beach
Cardiff University
Beachth@cardiff.ac.uk
http://www.dcom.org.uk
@dcom_network

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Housing Digital Built Britain Network

Benefits to house builders, planners, local and central government, mortgage providers, warranty providers, home owners and tenants

Summary

The aims of the Housing Networks were:

1. To propose the capabilities needed for the UK to deliver and benefit from digital built Britain and identify the enabling research to deliver those capabilities;
2. To describe the state of the art and leading-edge practice today, and;
3. To build communities of people interested and able to participate in future research, demonstrator and pilot projects.

The Network identified the four following broad capabilities as priority:

1. Using digital innovations to meet the housing and care challenges of an ageing population.
2. Developing digital innovation and better use of data in the planning system.
3. Digitising housing production through off-site housing manufacture.
4. Ensuring better housing governance, maintenance and management through use of data and digital technologies.

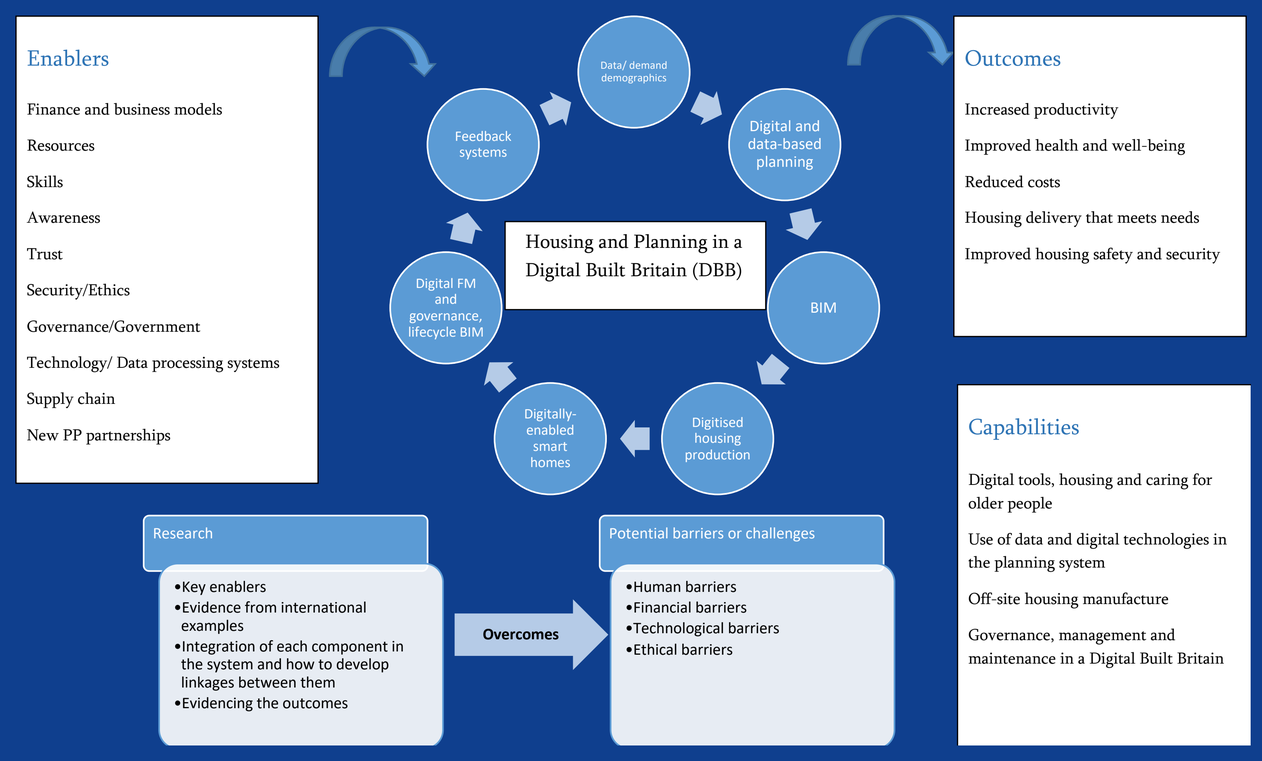
Impact and Value

Housing sits at the heart of many wider social issues, and it will sit at the heart of the development of a Digital Built Britain (DBB). Delivering a DBB is not simply about technological solutions to make supply and maintenance more efficient, it is also about understanding how those solutions and efficiency gains interact with wider social policy issues to address UK housing inequalities.

Long-term Vision

The long term vision is for sustainable, safe, affordable housing to be delivered for all households in a digital built Britain.

Key Findings



Next Steps/Further Work

The Housing Network identified that further research is needed:

- On the interrelationships between housing demand, planning, off-site housing, management and the digital agenda.
- To develop an evidence base of the benefits of digital innovation and investment.
- To understand the current market, identify those organisations investing in digital innovation, understand their innovations and scale, their supply chains and the use of data and business models.
- To improve data security and ethics.
- New forms of data collection and digital innovations are a governance challenge in housing and need further consideration.
- A cross-cutting area for further research is the identification of inequalities and potential unintended consequences of digital innovation.
- Understanding the human barriers. There are clearly a wide range of non-digital barriers to the implementation of digital innovation. These include issues of trust, awareness, skills, education and training and resources. Further research would help to identify how to overcome such challenges to ensure that the benefits of digital innovation in housing are realised.

Research Acknowledgements

We thank all members of the Housing Network for their input.

UNIVERSITY OF CAMBRIDGE

Contact: Dr Gemma Burgess
Acting Director
Cambridge Centre for Housing and Planning Research
glb36@cam.ac.uk @CCHPR1
https://www.cchpr.landecon.cam.ac.uk/

Cambridge Centre for Housing & Planning Research

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Vision Network: Augmented Reality and Virtual Reality for Digital Built Britain

Benefits to designers, contractors, consultants, asset managers, infrastructure owners, operators, authorities

"The work carried out by the Vision Network provides valuable insights about the factors that drive and limit the adoption of AR and VR technologies in construction, and it identifies a clear future R&D agenda to improve adoption."

- Manuel Davila Delgado, Associate Professor, UWE Bristol

Summary

The Vision Network, a mix of academics and industry experts, conducted a study into the levels of adoption of Augmented Reality (AR) and Virtual Reality (VR) technologies in the UK's Architecture, Engineering, and Construction (AEC) sectors. A mixed research method was used to analyse the collected data, and to identify and prioritise R&D opportunities.

AR and VR have the potential to change all types of visual communications dramatically. AR and VR are of great and broad interest in the UK. Huge benefits can be gained in the manufacturing and construction sectors, but the levels of adoption and commercial solutions are not well developed. The Vision Network conducted granular study to obtain a defined picture of the current adoption landscape and to identify R&D opportunities that will accelerate the adoption of immersive technologies in the AEC sectors.

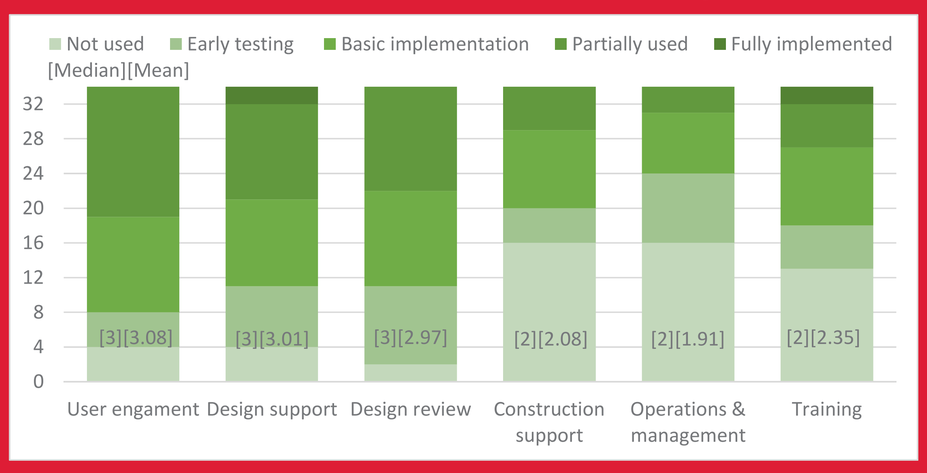


Figure 1. Levels of adoption of Virtual Reality by use case in the AEC sector

Impact and Value

- Provides a detailed overview of the use and research capabilities of AR and VR in the UK.
- Provides an indication of the levels of adoption of AR and VR in the UK's AEC sectors.
- Explanation of the main factors that limit and drive adoption, which could be used as the basis to develop mitigating actions.
- Defines the capabilities that should be developed to achieve the DBB vision.

Next Steps/Further Work

An R&D roadmap must be developed to drive market adoption of immersive technologies. The R&D activities should focus on developing the identified hardware and software capabilities, the required standards to ensure interoperability, and developing the new skills required for market adoption. In addition, the R&D activities should bridge the gaps between the current state of using immersive technologies in the construction sector and the new vision of the future built environment in short-term and long-term frameworks.

Key Findings

- The level of adoption of AR and VR in the UK's AEC sector is low. A level of adoption index was defined to provide a quantitative indication of adoption levels. The adoption index for VR in the UK AEC sector is 2.5 out of 5, and for AR is 1.5 out of 5. Five represents full adoption and 1 not used.
- Most of the companies have tested immersive technologies at some capacity, but they have not integrated the technologies into their regular workflow.
- The level of adoption, research, development, and maturity of VR is higher than AR. Around 90% of the research projects on immersive technologies are focused on VR. AR should be given priority in a future research agenda.
- Six main use-cases were identified for the use of AR and VR in the AEC sector: (1) Client/Public Engagement, (2) Design Support, (3) Design Review, (4) Construction Support/Progress Monitoring, (5) Operations and Management, (6) Training.
- The major perceived benefit for adoption is that immersive technologies will improve communication and reduce ambiguities. They are not perceived as technologies that will greatly improve productivity.

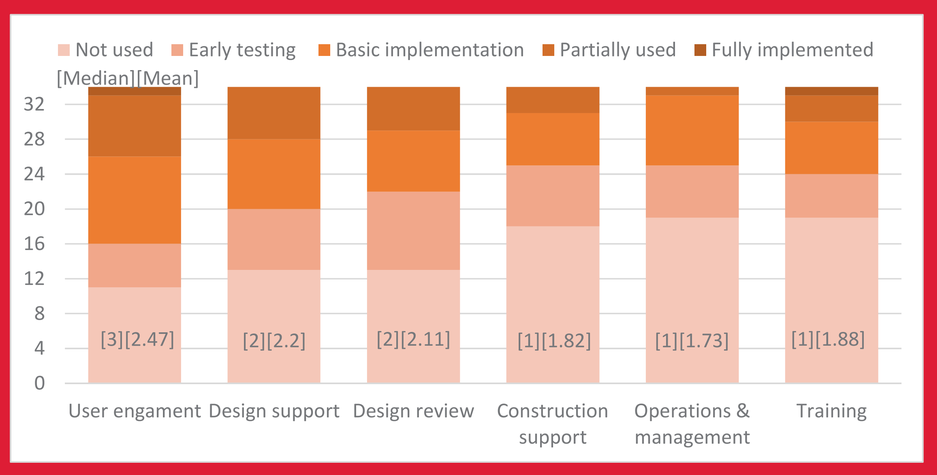


Figure 2. Levels of adoption of Augmented Reality by use case in the AEC sector.

Long-term Vision

The main limitation for adoption is that AR and VR technologies are regarded as expensive and immature technologies. To tackle these issues, R&D efforts should be focused on developing technologies for the specific requirements of the construction industry. R&D should address non-technical issues as well. Detailed cost-benefit studies and real-life demonstrators have the potential to showcase the benefits and improve the reputation of the technologies. Improvements in project delivery and providing new and better services are the main drivers for adoption. R&D efforts should focus on developing approaches that boost and showcase these factors.

Acknowledgements: Vision Network Core Members: Manuel Davila, UWE Bristol; Tom Beach, Cardiff University; Stéphane Côté, Bentley Systems; Peter Demian, Loughborough University; Andrew Gamblen, Willmott Dixon; Amer Hijaz, A&H Group; Andrew Jordaan, Mott MacDonald; Mac Muzvimwe, Arcadis: Hasan Omar, A&H Group; Hadeel Saadoon, Coventry University Estates; Mohammad Samie, Cranfield University; Zakwan Skaf, Cranfield University

UNIVERSITY OF CAMBRIDGE

Contact: Manuel Davila
Associate Professor
Big Data Enterprise and Artificial Intelligence Laboratory
University of the West of England Bristol
manuel.daviladelgado@uwe.ac.uk
https://people.uwe.ac.uk/Person/ManuelDaviladelgado

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Evolve or Die

Transforming the productivity of Built Environment Professionals and Organisations of Digital Built Britain through a new, digitally-enabled ecosystem underpinned by the intelligent mediation of competence supply and demand

Benefits to the variety of stakeholders that comprise the ecosystem of the Digital Built Environment

"The productivity problems of the construction sector and wider built environment are likely to be as much a manifestation of the failures relating to the mediation of competence supply and demand as the failures relating to the flow of purpose driven information."

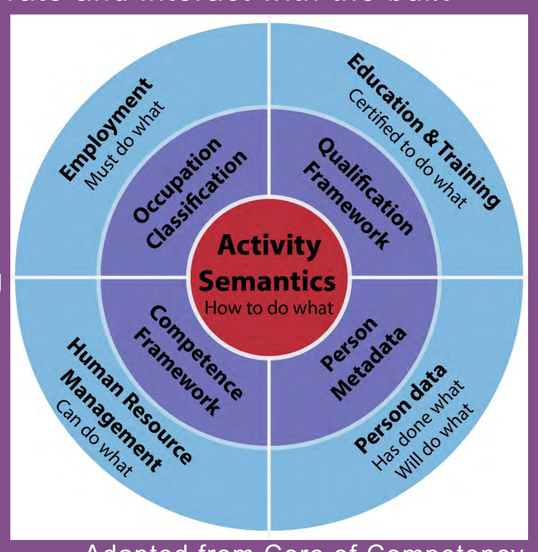
-CDBB Pedagogy & Upskilling Netowrk

Summary

The Pedagogy and Upskilling Network (PUN) is a network of collaborators for the Centre for Digital Built Britain (CDBB) drawn from research, practice, and other areas, and contribute to their work by exploring how we create and support a digitally enabled, agile, competent and ultimately, productive workforce. The outcomes of the network provide the key questions that need to be addressed if Digital Built Britain (DBB) is to both provide return on investment and succeed as the catalyst for evolving the manner in which we conceive, plan, design, construct, operate and interact with the built environment.

Impact and Value

Establishing a community of people and determining the foundational questions and providing recommendations for taking this essential area forward; making it more centre stage of the productivity agenda and the sector's response to the Grenfell disaster.



Adapted from Core of Competency [© Interlates, see Zhao, 2017a]

Long-term Vision

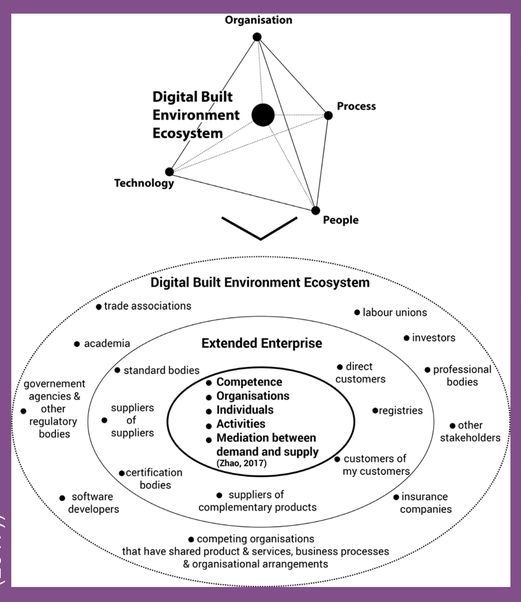
We need to imagine incentivising an ecosystem of competency management that all stakeholders work together in coopetition to capture, infer, interpret, specify, integrate, accredit, apply, use, monitor and evolve competence as a working asset just like any other asset. But in a consistent, objective, explicit and scalable manner with end2end transparency and traceability. Then only can we truly oversee competency assurance across the system and raise the bar on competences and reduce imbalances.

Next Steps

- Moving this agenda forward by growing the community and building a case for the digitisation of competency data and knowledge to be incorporated in the efforts of the various working groups such as responses to Grenfell, Digital Framework Task Group, IRG Steering Group on Competencies for Building a Safer Future, Transforming Construction agenda, etc.; winning hearts and minds.
- Researching and validating the proposition that an ecosystem of competency management approach can effectively contribute to the improvement of the productivity of people and organisations in the built environment.
- Defining the capabilities and infrastructural requirements for an ecosystem of competency management that enables competence to act and flow as the currency (just like water) of the labour market and develop a roadmap and a sustainable operating model.

Key Findings

- Central to productivity are people; the competency of the current and future workforce, which need to be treated as a working asset just like any other asset in the built environment.
- The purposeful language of Dame Judith Hackett concerning competence, competent, competency, and competency assurance has not been fully adopted by the sector.
- Competence is not just about competence frameworks; there are other sources of knowledge of competence as well as competency data (unstructured and distributed), which we also need to digitise. Competence does not currently act as the unifying currency of the labour market. Occupations are used as a proxy for demand and qualifications as a proxy for supply, which is no longer granular or multi-dimensional for the dynamic world of work.
- There is increasing overlap of competences across sectors, activities, professions and trades, roles, disciplines, etc. and this will only increase with automation, digitalisation and increased regulation. A new model for the post-professional society is required.
- Boosting productivity also comes from the effective mediation of competency demand and supply; skills imbalances are linked to low productivity.
- An ecosystem of competency management can facilitate the mediation of competency demand and supply in DBB; a people-centred community platform that connects all the inter-dependent stakeholders in coopetition within and across sectors, occupations, and disciplines. A digital marketplace facilitating and mediating supply and demand of data, information, and knowledge about competences, occupations and roles, disciplines, upskilling and learning, qualifications, certification, standards, regulations and policies.
- The upskilling/reskilling of people and their competencies is simply the evolution (acquisition, application, appreciation and depreciation) of one competency profile to another; one off static qualifications or certifications are no longer fit for purpose
- Upskilling must be competency-based and granular enough to address change to work duties and activities, and how work is done; across all dimensions of competence.
- Lifelong learning must be relevant to competency demand and the evolving competency needs of individuals.



Proposed alternative to People: Process: Technology (Figure on ecosystem is adapted from Moore (1997) and the concepts on an ecosystem of competency mediation between demand and supply are adapted from Zhao (2017))

Acknowledgements: Expressed thanks to members of the network for their commitment, dedication, and valued contribution and an extended special thank you to Debbie Carlton for her passionate interest and the sharing of her extensive knowledge.

University of Salford MANCHESTER

UNIVERSITY OF LIVERPOOL

BAF BIM Academic Forum

UNIVERSITY OF CAMBRIDGE

Contact: Professor Jason Underwood

Professor Digital Built Environments & Construction ICT,
University of Salford,
j.underwood@salford.ac.uk,
https://www.salford.ac.uk/built-environment/our-staff/sobe-academics/jason-underwood

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

CDBB Network: Methodologies for planning complex infrastructure under uncertainty

Benefits to Infrastructure planners, policymakers, researchers

"If we are to transform and improve Britain's built infrastructure we need to understand the complex interdependencies of multiple systems that make it work. Fundamental to this is modelling that recognises complexity and uncertainty."

- Gordon Masterton, Prof of Future Infrastructure at the University of Edinburgh, and former President of the Institution of Civil Engineer

Summary

Infrastructure investments are typically capital intensive with long lifetimes. Larger projects also have public and private stakeholders and take years to develop and build. Investment decisions are thus intrinsically made under great uncertainty against a complex planning background.

This Network has taken an interdisciplinary approach to understanding:

- The state-of-the-art in use of modelling support for infrastructure planning decision making, both in industry and policy, and in research;
- Needs of the practitioner community for research and innovation on methodology;
- The research communities which must be engaged to achieve these needs, and methodologies which might be applied to the challenges arising from the community.

The network has worked through literature review; in-depth discussions with key individuals; an online survey; and two scoping workshops (the first on innovation and capability needs, the second on how the research community can support these needs).

Key Findings

1. Need for enabling work on stakeholder needs and state-of-art to support design of full projects in some areas
2. A more nuanced understanding of success and failure will support rational policy debate
3. Importance of two way communication between decision makers and analysts for common understanding of needs and evidence
4. The importance of sufficient resource for analysis to support strategic planning
5. Making relevant data more widely accessible will support both better decision making and research
6. Design of funding structures is key to developing the right interdisciplinary collaborations for innovation work

Impact and Value

Bringing new analysis methods to planning practice will improve project delivery

Next Steps/Further Work

- Identify companies and government units who wish to work together on infrastructure projects in the area of the network.
- Particular emphasis on developing means of integrating new analysis methods into business-as-usual, starting from current skills and practices

Long-term Vision

Researchers and practitioners working together on innovation for the benefit of society.

Acknowledgements:

The Network thanks the many individuals who took part in the survey and discussions.

UNIVERSITY OF CAMBRIDGE

The Alan Turing Institute

Contact: Dr Chris Dent
Reader in Industrial Mathematics
(University of Edinburgh) and Turing Fellow (Alan Turing Institute)
chris.dent@ed.ac.uk

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB

cdbb

Centre for Digital Built Britain

Network FOuNTAIN: Network For ONTologies And Information maNagement

Benefits to all stakeholders (users of BIM, CDE, Digital Twin platforms)

"When it come to Information Management, it's not a question of too much or too little standardisation. It's a question of standardising the right things for a particular purpose."

- Workshop 0 leader, Matthew West, Director, Information Junction

Summary

The vision of the Network is for all stakeholders in digital built Britain (DBB) to be able to meet their information needs. The Network undertook five workshop activities between July and December 2018, in order to establish the capabilities required under various Information Management (IM) themes.

The first workshop sought to establish the scope of "IM". The second and third workshops focused on ontologies and reviewed the variety of standards currently available. The fourth workshop explored system requirements; it identified three modes of consuming information and the corresponding software requirements for each mode. The three modes identified are: Search & Retrieval, Browsing & Expiration and Information Delivery. The fifth workshop focused on business models and concluded that the capability was needed to identify and derive business value from IM.

The Network set out a research agenda required to deliver those capabilities. Fundamental research is needed to formulate a process of establishing the appropriate scope of standardisation for IM at project, organisation and industry levels. This research needs to unfold in the context of emerging related international standards.

Key Findings

Workshop	Issues Discussed	Capabilities
Workshop 0: Scope of Information Management	Information Management Landscape, Information Management Maturity.	Capability to gauge Information Management maturity.
Workshop 1: Ontologies	Variety of ontologies, standardisation vs. flexibility.	Capability to establish the appropriate scope of standardisation, and to design or extend existing ontologies in general.
Workshop 2: Cataloguing Information	Delphi Survey to achieve expert consensus on most suitable, adaptable and complete ontology and project process to be used for cataloguing information in DBB. There was no full consensus, but Uniclass-2015 stood out as a candidate.	Capability to develop current classification systems, schema and frameworks, Uniclass-2015 in particular, to maximise the potential to share data, in ways that make best use of current skills and investments
Workshop 3: System Requirements	Search & Retrieval, Browsing & Exploration, Information Delivery as models for information consumption in DBB.	Capability to develop fit-for-purpose software which enables stakeholders • to query information reositories visually or using natural language • to explore information repositories based on current models (such as Uniclass-2015) • to interrogate information repositories automatically using ontology-based tools, and • to set information delivery schedules based on industry and project protocols
Workshop 4: Business Models	The need for a process model for delivering business value through Information Management.	Capability to identify and derive business value from Information Management.

Impact and Value

- Our vision is for all stakeholders in a digital built Britain to be able to meet their information needs.

Long-term Vision

- The emergence of Digital Twins and projects such as the Data & Analytics Facility for National Infrastructure (DAFNI) of the UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC)make the work of Network FOuNTAIN extremely important. The team are working hard to enable their findings to inform these long-term initiatives.

Next Steps/Further Work

- Further research is needed to establish a method for determining the appropriate level of information standardisation at project, firm and industry levels. The team is exploring further research opportunities.

Acknowledgements:

Network Team:
- Peter Demian (Leader), Steven Yeomans (Co-ordinator),
- Danny Murguia-Sanchez (Research Assistant)
- Workshop Leaders:
- Matthew West, Information Junction (Wkshp 0)
- Prof Stuart Barr, Newcastle University (Wkshp 1)
- Dr Tom Beach, Cardiff University (Wkshp 1)
- Dr Steven Yeomans, Loughborough University (Wkshp 2)
- Dr Peter Demian, Loughborough University (Wkshp 3
- Dr Mohamad Kassem, Northumbria University (Wkshp 4)

Network Members:
- Julian Buhagiar, Building Research Establishment
- Lawrence Chapman, TempleGate Projects Ltd
- Dr David-John Gibbs, HKA
- Rollo Home, Ordnance Survey
- Andrew Jordaan, Mott MacDonald
- Dr Marianthi Leon, Robert Gordon University
- Jamie Mills, Xylem (BIM4Water)
- Joseph Murphy, Loughborough University, High Speed Two (HS2) Ltd
- Andrei Popa, Project Centre Ltd
- Ian Rush, Data and Process Advantage Ltd
- Hadeel Saadoon, Coventry University
- Cristina Savian, Glider Technology Ltd
- Martin Simpson, University of Liverpool (UKBIMAlliance)
- Graeme Tappenden, Lingwell Consulting Ltd
- Paul Turney, Network Rail
- Dr Ying Wang, University of Surrey

UNIVERSITY OF CAMBRIDGE

Contact: Dr Peter Demian
Reader in Building Information Management,
Loughborough University
Twitter: @petedemian

Collaborate with us

engagement@cdbb.cam.ac.uk
www.cdbb.cam.ac.uk
@CambridgeCDBB