Cambridge Centre for Housing & Planning Research

Final Report: Analysing the social context to transforming construction through digital innovation and offsite construction

Dr Kwadwo Oti-Sarpong
Dr Reyhaneh S. Shojaei

March 2022

UNIVERSITY OF CAMBRIDGE

Dr Kwadwo Oti-Sarpong[1] & Dr Reyhaneh S. Shojaei[2]
Cambridge Centre for Housing & Planning Research
Department of Land Economy
University of Cambridge
19 Silver Street
Cambridge
CB3 9EP

[1] ko363@cam.ac.uk
[2] rss64@cam.ac.uk

Tel 01223 337118

www.cchpr.landecon.cam.ac.uk

Cambridge Centre
for Housing &
Planning Research

Cambridge Centre for Housing & Planning Research

Contents

1. Executive summary 1
2. Background 5
3. The research project 7
4. Research findings, outputs, and impact 9
5. Recommendations 19
6. Conclusion 23
7. References 25
8. Acknowledgements 27

Cambridge Centre for Housing & Planning Research

1. Executive summary

This report summarises the key contributions from the research project '*Analysing the social context to transforming construction through digital innovation and offsite construction*'. This research is part of the Centre for Digital Built Britain's (CDBB) work at the University of Cambridge within the Construction Innovation Hub (CIH). The study contributes to achieving CIH impacts related to information management, as well as to the development of skills and capabilities and to fostering the effective collaboration needed for the effective adoption and use of digital technologies and modern methods of construction.

The UK's government has sought to tackle the problems that have faced the construction industry, including the delivery of projects over time and over budget and the high level of carbon emissions, for nearly thirty years. A mix of policy initiatives has been used to address many of these problems and policy changes have become increasingly led by technology. More recent efforts by the government have focused on driving greater use of digital technologies - Building Information Modelling (BIM) and manufacturing approaches, such as offsite manufacturing (OSM) - to address the construction industry's problems and transform it into a sector that is able to efficiently deliver built assets at faster speeds, lower costs, and with reduced greenhouse gas emissions. Across several policy documents, the government has shown its commitment to use public sector procurement as a tool to drive industry actors to embrace the use of BIM and OSM by making their use mandatory for projects which have ministries, departments and arms-length bodies as their clients.

Despite the initiatives rolled out to push the greater use of BIM and OSM, the key expected outcomes for a transformed construction industry are still to be realised. This is in part due to the fact that, to date, technocentric views that have dominated policy and academic discussions. Transforming construction is not simply about the development and optimisation of technical artefacts, it is also about people and organisations. In comparison to overcoming the multi-level social, cultural, economic and wider contextual challenges to the success of any technology-led change agenda, technological change is relatively easy to achieve,

Against this backdrop, this research analysed the key social, cultural and behavioural factors inhibiting BIM and OSM uptake in the UK construction industry and thus holding back transformation across the construction supply chain. Underpinned by the six key objectives, the research aims made it possible to offer solutions for tackling the factors inhibiting project delivery in the construction industry.

The aim and objectives were achieved by working closely with the early adopters of digital innovations and new manufacturing-based business models in order to deliver transferable knowledge useful for the housing sector as well as the broader construction sector. Following a mainly qualitative approach, extensive data was gathered through interviews with government representatives (e.g., Homes England), industry and project delivery partners, as well as from relevant policy, company and project documents (for case studies). Participation from industry partners was critical for exchanging knowledge, understanding skills and capacity development needs, and for identifying processual changes and best practices from exemplar organisations to inform how the key objectives and outcomes under the transformation agenda could be realised.

Findings from the research project show that:

1. The UK construction industry has not attained the level of maturity needed to facilitate the widespread adoption of OSM and BIM, and this is reflected in the prevailing industry practices that sustain the industry's reluctance to embrace innovations.

2. The multi-level inhibitors to the greater uptake of BIM and OSM in the UK construction industry can be grouped into six main categories, namely: people, culture, goals, technology, process and procedure, and infrastructure factors. Regardless of their classification, these inhibitors are underpinned by sociological factors that have little rooting in the technical aspects of either BIM or OSM.

3. Exemplar construction firms in the UK have made progress in overcoming the inhibitors they faced and have successfully adopted BIM and OSM for internal and project-related tasks. These exemplar firms all have six enablers in common: leadership and management committed to championing and driving the process of change; a digital transformation strategy with realistic objectives; a 'growing together' approach to building a capable supplier network; trust-based relationships with clients; prioritisation of training and skills development initiatives for employees; and robust structures for effective collaboration and communication.

4. The UK construction industry can learn from countries such as Sweden, Germany, Japan and Singapore, all of which have achieved greater use of OSM for new housebuilding. Key lessons from these countries show that driving greater use of OSM requires a country-wide assessment to identify strategic natural and human resources, and to obtain a critical understanding of the institutional factors impacting the actors operating in the wider construction industry. This understanding can be honed to achieve the desired outcomes with strong government support through funding for

academic research, industry demonstrator projects and targeted grants for building projects using OSM.

5. To ensure that the sought-after improvements in the UK construction industry are realised, the development of a robust assessment framework is indispensable when evaluating the performance of projects delivered using MMC (e.g., OSM) and BIM, and assessing the extent to which the industry is shifting towards more manufacturing-led approaches. The development of such a framework should be underpinned by quantitatively establishing how the metric of premanufactured value (PMV), recently embraced by the government, relates to existing project performance metrics. Following this, a standardised data collection framework can be developed and used by industry actors to collate their project data, creating the robust assessment framework needed for benchmarking across the industry.

6. The realisation of policy objectives linked to the industry transformation agenda requires a co-evolution of the overarching structures, rules of practice and established norms among industry actors. Achieving this coevolution requires the government, as a strong player, to sustain the development of a significant innovation like the current CIH-led product platform programme and align infrastructure delivery pipelines with it. This will create the much-needed momentum to trigger the widescale adoption of digital and manufacturing innovations.

Altogether, the research findings contribute to achieving CIH impacts related to information management (with an emphasis on the implementation of the UK BIM Framework), as well as skills and capabilities development and ways of fostering effective collaboration for an effective adoption and use of OSM. Furthermore, the findings contribute world-leading knowledge in academic research about industry transformation through the greater adoption and use of OSM and BIM.

The research findings have been reported in various outputs for a range of audiences, including government representatives, MMC experts, industry collaborator groups and the public. As a research project focused on generating impact, the findings have facilitated knowledge exchange and been used to create meaningful interactions and impact pathways with industry, policy and academia. Impact has been realised through three well-received reports and industry guidance papers, over a dozen industry-focused presentations and seminars, two major online public engagement events at the University of Cambridge, eight academic publications, and a number of guest lectures to cohorts of undergraduate and postgraduate students and researchers at world-leading academic institutions in the UK.

Based on the research findings, seven key recommendations are put forward for construction industry policymakers and executives of construction firms.

Recommendations for policymakers:

1. Align procurement policy with innovation drive for greater BIM and OSM use;
2. Coordinate multi-faceted initiatives to sustain the momentum for industry transformation;
3. Support training and upskilling initiatives through subsidies or grant funding with a focus on SMEs;
4. Establish a central digital knowledge sharing platform that is accessible to firms operating in the construction industry to facilitate cross-industry learning.

Recommendations for construction industry firms and their executives:

1. Develop a digital and manufacturing technology transformation strategy that sets out realistic objectives in plain language and with clear and achievable targets;
2. Prioritise employee skills training and competency development, offering in-house or externally sourced training as appropriate;
3. Work with supplier networks to improve or build capabilities in using BIM and OSM for projects through a 'growing together' approach.

These recommendations are complementary and require close collaboration from these two groups of stakeholders if the vision of a transformed construction industry is to be achieved. The successful implementation of the recommendations by policymakers and industry players through coordinated efforts will grow the impact of this research and sustain the improvements already being realised from the industry transformation initiatives implemented by the UK government since the launch of the Industrial Strategy in 2018.

2. Background

The UK construction industry has been criticised for several decades for problems including poor performance, low productivity and unsafe work practices, as well as for delayed projects and for delivering projects over budget (Farmer, 2016; HM Government, 2018). Both government and industry reports suggest that the performance of the UK construction industry lags behind that of comparable economies in the G7 (CIOB, 2016), with productivity rates averaging 27% lower than that of the wider national economy since 1997 (HM Government, 2018). Partially attributed to the industry's lack of innovation and fragmentation, these problems impact the ability of both the government and private sector to deliver social and economic infrastructure (e.g., schools, commercial buildings, housing) rapidly, cost effectively and to the desired levels of quality (IPA, 2019). The challenge for the government and industry stakeholders, therefore, has been to find ways of transforming the industry in order to deal with these problems by improving productivity, safety, timely delivery and cost-effectiveness.

The drive to transform the UK construction industry has been an imperative of the government for nearly three decades (Latham, 1994; Egan, 1998; HM Government, 2013) and remains so (HM Government, 2020). The industry is a significant contributor to the overall national economic output, adding ~£100billion to the value of the economy in 2020 (ONS, 2020). Employing 9% of the UK's total workforce (IPA, 2019), the operations of the construction industry affect every person in the country (HM Treasury, 2020). Therefore, according to HM Government (2018, p.3), ensuring that the industry is transformed into one that can 'build new homes in weeks - and even days - rather than months; that can deliver new buildings at a third of the cost; that can provide affordable, energy efficient homes' is important if the targets of reducing construction and whole lifecycle costs by over a third and delays of construction projects and greenhouse gas emissions by half in 2030 are to be achieved.

To achieve these visions of a transformed construction industry, there has been a gradual shift of government-led reforms over the past three decades to improve the industry – from management-focused approaches that sought to gel the industry together by promoting collaborative practices, to technology-centred initiatives (Oti-Sarpong & Burgess, 2020). More recent efforts towards industry transformation by the UK government focus on changing the industry's practices from 'traditional' approaches to 'modern' methods of construction (MMCs), with the uptake and use of manufacturing approaches and digital innovations at the forefront of this. In particular, offsite manufacturing (OSM) and Building Information Modelling (BIM) have been at the centre of the transformation drive (HM Government, 2018), with the recent addition of a platform approach for design for manufacture and assembly (P-DfMA)

(IPA, 2019; CIH, 2021). Government Construction Strategies (Cabinet Office, 2011; IPA, 2016), Industrial Strategies (HM Government, 2013; 2018) and a Construction Leadership Council (CLC)-backed review of the sector's labour model (Farmer, 2016) all emphasise driving industry transformation through greater adoption and use of modern methods of construction (MMC) and digital innovations.

However, in policy and academic circles, discussions about driving transformation in the construction industry have been dominated by technocentric views that seek to optimise the digital and manufacturing innovations put forward as panacea to the industry's ills (Papadonikolaki et al., 2022; Ehwi et al., 2022). Transforming construction is not merely about developing a robust technical artefact – which is deemed relatively easy to achieve, in comparison to overcoming social, cultural, economic and wider context challenges that are often the significant non-technical inhibitors to successful technology-led transformation (Oesterreich and Teuteberg, 2019).

For a holistic understanding of how to achieve the widespread adoption and use of digital innovations and offsite manufacturing as part of attempts to transform the UK construction industry, a critical examination of these non-technical dimensions, from a social science perspective, is essential. This research informs how the expected outcomes from the government-led industry transformation agenda and the Construction Innovation Hub's (CIH)[1] key objectives can be achieved. It focuses on delivering insights for shaping the policy environment, in line with the UK government's construction ambitions (including those for housing) for driving and measuring the benefits of using MMC and digital approaches construction to improve social housing. It worked closely with industry to understand industry and client needs and to support the evidence base for the adoption of innovation and inform the development of the new capabilities needed to deliver innovation at scale. Furthermore, digital skills are seen as key to increasing productivity and improving social, economic and environmental outcomes as part of the industry transformation agenda. In collaboration with representatives of the government (e.g., Homes England), industry and our project delivery partners, the research also focused on generating insights that can help to embed the skills and knowhow necessary to allow the greater uptake of digital skills in the construction industry.

[1] This research forms part of the Centre for Digital Built Britain's (CDBB) work at the University of Cambridge within the Construction Innovation Hub (CIH) which brings together world-class expertise from the Manufacturing Technology Centre (MTC), BRE and CDBB to transform the UK construction sector. The Construction Innovation Hub is funded by UK Research and Innovation through the Industrial Strategy Fund.

3. The research project

3.1. Aim and objectives

Informed by social science theories, this research analysed the key social, cultural and behavioural factors which are inhibiting BIM and OSM uptake in the UK construction industry and which are holding back transformation across the construction supply chain for project delivery. It aimed, ultimately, to offer solutions to tackle them. To this end, the research objectives were to:

1) Establish the state of the nation in terms of the adoption of BIM and OSM, and the industry's maturity in embracing these innovations;
2) Identify individual, organisational and wider industry barriers to the greater uptake of BIM and OSM;
3) Describe how local exemplar construction firms are achieving successful adoption and use of BIM and OSM internally and on projects with their supplier network;
4) Draw out learning for the UK from international practices that lead to the greater use of BIM and OSM for construction project delivery in different jurisdictions;
5) Outline key considerations for developing a robust framework for effectively assessing the use of modern methods of construction as part of industry transformation;
6) Develop a multilevel understanding for tackling the multifaceted social, cultural and wider industry factors that are currently holding back the realisation of a transformed construction industry.

Pursuing the aim and objectives of the research involved working with the early adopters of digital innovations and firms implementing new business models of a manufacturing approach to construction, to deliver transferable knowledge useful for the housing sector as well as the broader construction industry. The research focused on BIM and OSM, as part of modern methods of construction (MMC), because these are the two key innovations currently underpinning the government-led transformation of the UK construction industry (Oti-Sarpong & Burgess, 2020). The use of BIM has been mandated for all publicly funded construction projects since 2016 (IPA, 2016), and has become the basis for the adoption of other advanced technologies in the construction sector, according to the IPA (2019). The government has also adopted, through a series of policy decisions, a position that gives a 'presumption in favour of offsite construction across capital programmes where it represents best value for money' (HM Treasury, 2017, p.38). Accordingly, the Government has decided to use its procurement power, as described in The Construction Playbook, to demand the greater use of MMC such as OSM in order to drive the transformation of the construction industry (HM Government, 2020).

3.2. Research design and methods

The research followed a qualitative approach using exploratory interviews and case study designs. Undertaking the research through such designs allowed for a deep exploration into the non-technical inhibitors to the adoption and use of BIM and OSM in firms and across supplier networks on projects. In total, 72 interviews were conducted (circa 104 hours in total), and 10 project and firm case studies were examined.

Data were gathered from multiple sources. These comprised published academic, industry and policy papers related to digital innovations and offsite manufacturing, company and project documents, and through semi-structured interviews[2]. Collecting data for the study benefitted from the participation of a combined total of over 70 industry practitioners working for client, contractor, consultant, manufacturer and sub-contractor firms in the UK and engaged in the delivery of a mix of social and economic infrastructure, including housing. The practitioners represent 20 different firms in the construction supply chain who are research partners on this project. Participant selection for the research took account of individuals' roles and place within the hierarchy of their organisations to ensure representativeness across operative roles and low, medium and top level managerial/executive roles for other firms in the UK construction supply chain. The cross-cutting nature of research participants ensured that the insights gathered were representative of the wider state of affairs regarding the adoption and use of BIM and OSM among firms operating in the construction supply chain. Participation from these industry partners was critical for exchanging knowledge, understanding skills and capacity development needs, and identifying processual changes and best practices from exemplar organisations in order to inform how the key objectives and outcomes under the transformation agenda could be realised.

Given the qualitative nature of the research undertaken, all data gathered were cleaned, anonymised, coded and analysed by content, thematic or theory-led analysis, using NVivo v.12.0 computer-aided qualitative data analysis software. In most cases, coding was led by the data and not predetermined, in order to allow the data to 'tell the story' (Creswell, 2002; Saldaña, 2016).

[2] In-person interviews were conducted before the UK's coronavirus pandemic lockdown began, and virtual interviews were held after lockdown restrictions came into force in England in March 2020.

4. Research findings, outputs, and impact

4.1. Findings

In addressing the overarching research aims and objectives, the research offers findings that are of relevance for practice and policy in relation to the ongoing transformation agenda for the UK construction industry. More specifically, the findings contribute to achieving CIH impacts related to information management (with an emphasis on the implementation of the UK BIM Framework), as well as to the development of skills and capabilities and to fostering the effective collaboration necessary for the effective adoption and use of OSM and other forms of MMC. Furthermore, the findings also contribute to frontier knowledge in academic research about industry transformation through the greater adoption and use of OSM and BIM.

The sections that follow summarise the study's key findings, as detailed in various other outputs.

4.1.1 State of the nation: industry maturity and the uptake of digital innovations and offsite manufacturing

The UK construction industry is regarded by practitioners, policymakers and academic research as not having attained a level of maturity needed to facilitate the widespread adoption of OSM and BIM and drive rapid transformation, as envisaged by the government[3].
This low maturity is reflected in the prevalence of industry practices that sustain a reticence to the adoption of innovations. The overarching structures, rules of practice and established norms among actors (e.g., clients, contractors, consultants, planning authorities, technology vendors) that currently govern the UK construction industry continue to promote adversarial relations, supplier networks are developed based on broken-down work packages where the lowest bid wins, and processes of construction remain heavily labour-intensive and are performed in situ. Furthermore, lending facilities are more aligned to supporting projects that

[3] For a detailed read, please refer to:
Oti-Sarpong, K. (2019). *Offsite manufacturing, construction and digitalisation in the UK construction industry-state of the nation report*. Centre for Digital Built Britain.
https://www.cchpr.landecon.cam.ac.uk/system/files/documents/state_of_the_nation_osm.pdf
Shojaei, R. (2019). *Understanding the socioeconomic inhibitors to the take up of digital innovation in construction industry-state of the nation sector report*. Centre for Digital Built Britain.
https://www.cchpr.landecon.cam.ac.uk/system/files/documents/son_digital_innovation.pdf

use 'tried and tested' conventional building techniques and they are only now beginning to embrace funding projects delivered using MMC[4].

Such configurations are at odds with the use of BIM and OSM, which require early integrated team formation [5], collaboration and willingness to cooperate in long-term strategic relationships and as such need to be tackled using a mix of coercive and incentivising policy instruments.

4.1.2 Individual and organisational barriers to the greater take up of digital innovations and offsite manufacturing

Viewed through a sociotechnical lens, the key individual and organisational barriers to greater uptake of BIM and OSM among UK construction supply chain firms can be grouped into six categories. These are: people, culture, goals, technology, process and procedure, and infrastructure factors[6, 7].

The multi-faceted nature of these factors is captured in Figure 1.

[4] For a detailed read, please refer to: Oti-Sarpong, K and Burgess, G (2020) *Offsite Manufacturing and Construction Industry Transformation: A Multi-Level Sociotechnical Transitions Perspective* In: Scott, L and Neilson, C J (Eds) Proceedings of the 36th Annual ARCOM Conference, 7-8 September 2020, UK, Association of Researchers in Construction Management, 475-484.

[5] Oti-Sarpong, K., & Burgess, G. Undertaking building projects using offsite manufacturing: Exploring the role of a systems integrator through a complex product systems model. (Under review) in *Journal of Construction Management and Economics*.

[6] Shojaei, R. & Burgess, G., Non-technical inhibitors: Exploring the adoption of digital innovation in the UK construction industry (Under review) in *Journal of Technological Forecasting and Social Change*.

[7] Shojaei, R., Oti-Sarpong, K., & Burgess, G. Leading UK construction companies' strategies to tackle BIM training and skills challenges. (Under review) in *International Journal of Construction Education and Research*.

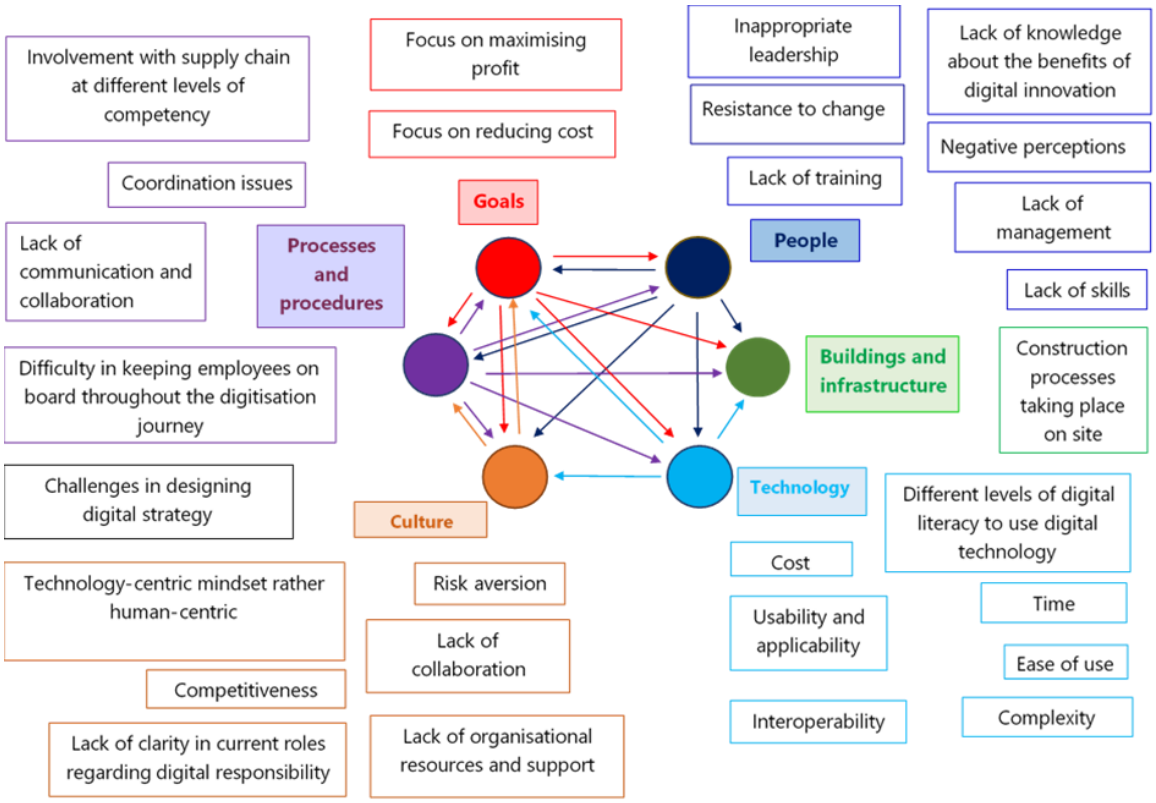


Figure 1: Sociotechnical inhibitors to greater uptake of BIM and OSM among UK construction firms

The six factors all have sociological roots. For example, different levels of digital literacy in the use of technology are a technological inhibitor, but the attitudes and preferences of the actors involved in the construction sector are a human-centric inhibitor. The extent to which each of these groups of individual and organisational barriers is important in construction firms is shaped by their role in the supply chain network, organisational values, priorities, digital maturity and the type of clients they work with (public/private), as well as the nature of the projects they deliver (e.g., scale, sector).

4.1.3 How industry exemplars are achieving successful adoption and use

Despite the widespread inhibitors identified to be holding back the adoption and use of BIM and OSM, it is promising to note that some construction firms in the UK offer examples for how these barriers can be successfully overcome. Across the practices of five leading main contractor firms in the UK, six important enablers were identified as being essential to successfully achieve the adoption and use of BIM and OSM internally and on the building projects executed with their supplier networks. The firms in question all had:

1) *Leadership and management committed to championing and driving the process of change*

Whilst managers focused on operationalising the vision for a changed firm, leaders were involved with creating the vision and building a supportive environment that placed value on employee suggestions. As an overarching enabling factor, committed leadership in construction firms is ultimately critical to a successful digital transformation strategy and should be developed accordingly[8].

2) *A digital transformation strategy with realistic objectives*

From the firms studied, a successful transformation strategy is geared towards establishing new routines and practices and creating a new organisational culture in a step-by-step manner, with a focus on people, processes, routines and technology. Accordingly, a strategy that achieves change uses simple language to communicate the goal of transformation; gives employees a sense of 'shared ownership' in what is to be achieved; is consistent and can be repeated across the firm; considers the needs of employees when introducing new technologies, techniques and processes; and provides the necessary internal support structures for implementation (e.g., training and support for staff, appropriate software). Creating such a strategy first involves an assessment of a firm's existing digital capabilities and competencies, benchmarking them against those of potential competitors to determine future actions for improvement[9].

3) *Adopted a 'growing together' approach in building a capable supplier network*

A 'growing together' approach involves main contractors equipping their subcontractors with the necessary relevant technical and organisational capabilities to help them work seamlessly using the same software, tools and ways of thinking in relation to BIM and OSM. This supportive approach involves resource investment by main contractors by hosting workshops, training sessions and company visits to learn about capability challenges and to offer training support to suppliers. In doing this, firms have uncovered the training needs of their suppliers and consequently offered

[8] Leadership and management training resources are available in the UK through the Supply Chain Sustainability School: https://www.supplychainschool.co.uk/

[9] For a detailed read, please refer to:
Oti-Sarpong, K. & Shojaei, S. (2021*). Industry guidance: successful adoption and use of BIM and OSM*. Centre for Digital Built Britain. https://www.cdbb.cam.ac.uk/news/publication-industry-guidance-successful-adoption-and-use-bim-and-osm
Shojaei, R.S., Oti-Sarpong, K. and Burgess, G. (2022), *Enablers for the adoption and use of BIM in main contractor companies in the UK*, Engineering, Construction and Architectural Management. https://doi.org/10.1108/ECAM-07-2021-0650

bespoke assistance to address these needs. The 'growing together' approach has proven to be particularly useful for contractors who set out to make the transition to using BIM and OSM with their supplier network, building on working relationships that have developed over the years.

4) *Built trust-based relationships with clients*
As key project players, clients are able to drive innovation, but obtaining their buy-in is crucial. To build a trust-based relationship that will facilitate the use of BIM and OSM for project delivery, firms need to prioritise honest communication and provide reliable information about the inherent risks and benefits associated with digital innovation. They need to be consistent about meeting agreed expectations from their use, having mutual respect for values, and maintaining a good reputation by adhering to contractual requirements. Building trust this way is important for working with both private and public sector clients.

5) *Implement training and skills development initiatives for employees*
Such initiatives comprise offering in-house training as part of an intra-organisational strategy for tackling employees' skills and training variations and needs. Providing training for both general competencies and role-specific skills ensure that each individual employee receives appropriate training and is equipped with the necessary skills to function within teams and on projects using BIM and OSM. The exemplar companies provided four types of BIM-related training: broader digital literacy training, tailored training, role-specific training and collaboration, and communication training. These companies all had one significant feature in common: their views on BIM and OSM related skills were not limited to technical design and software skills. Instead, human factors, soft skills training, including systems thinking, collaborative skills and communication were all considered to be important. To tackle the issue of varying competencies and ensure teams work productively, the companies in question provided bespoke training, modifying processes and adopting new digital tools for internal or project tasks as employees progress.

6) *Robust structures for effective collaboration and communication*
The adoption of BIM and OSM is dependent on collaborative working across the different professional disciplines engaged on a project, which in turn requires cooperation and clear communication between parties. Using BIM and OSM is incompatible with traditional methods of organising and sharing information (i.e., using physical files). Building relevant robust structures involves embracing digitally enabled data capture, storage and sharing, integrated ways of thinking around the processes of design, manufacturing, and on-site assembly and/or construction.

Effective structures are reliant on using interoperable software platforms to reduce the likelihood of conflicts and enhance collaboration, using cross-functional teams with structures that promote collective creativity in problem solving and encourage employees to take initiative when working with new tools, technologies or when implementing new processes.

4.1.4 Achieving greater use of digital innovations and offsite manufacturing: international policy findings

The UK construction industry can learn from how other countries have achieved greater use of OSM, for new housebuilding in particular. International learning from seven selected countries (Japan, Sweden, Singapore, Germany, USA, Canada and China)[10] shows four context-specific typologies that drive greater use of OSM to build new housing. These different typologies are characterised by varied influences of government leadership, reliance on advanced technology, industry actors (e.g., developers, manufacturers and construction firms), and the exploitation of human and natural resources.

The key lessons from these countries are as follows:

Undertake a country-wide evaluation of resources and capacity

Prior to embarking on a national strategic plan to increase the use of OSM in construction, governments and industry stakeholders should undertake a country-wide resource evaluation with researchers in order to obtain a critical understanding of the institutional factors impacting the actors operating in the wider construction industry. Identifying the structure of the existing housebuilding industry, in which a mix of institutional pressures exist or could be honed to yield the desired impact, the range of existing or planned policy-backed initiatives designed to generate specific pressures (e.g., demonstrator projects, financial incentives, mandate-driven obligations), and the available resources that can support firms to adopt and use OSM are all key to shaping a successful strategic plan that will lead to the achievement of targets linked to the widespread adoption of OSM.

Capitalise on existing sources of institutional pressures

Achieving greater use of OSM for building new housing necessitates capitalising on the existing sources of institutional pressures (e.g., government demand, mandates) and the

[10] These countries have been identified as having achieved greater use of OSM to build new housing (see: Savills, 2020; BCG, 2019) in Oti-Sarpong, K., Shojaei, R. S., Dakhli, Z., Burgess, G., & Zaki, M. (2022). How countries achieve greater use of offsite manufacturing to build new housing: Identifying typologies through institutional theory. *Sustainable Cities and Society*, https://doi.org/10.1016/j.scs.2021.103403

available resources (e.g., technological capacity, skilled labour, finance) in a country. Government, regulators, industry associations and environmental interest groups play a crucial role in the use of direct and indirect forms of pressures to catalyse these interactions. Pressures to drive greater OSM use can be achieved through institutionalising rules and regulations guiding component standardisation, implementing government interventions (e.g., mandates, financial incentives, awareness creation programmes and pilot exemplary projects), and through the enforcement of sustainable practices.

Provide funding to support OSM adoption and use

Governments provide funding to promote the use of OSM through three main ways: i) general research and development funding to support innovative research and experimental applications to find new ways to optimise production processes and engineer new materials; ii) targeted grants for OSM-built housing that meets high energy efficiency standards; and iii) direct funding for construction firms and component manufacturers to enable them to acquire machinery and deploy manufacturing-led solutions for project delivery.

4.1.5 Achieving industry transformation: Key considerations for developing a robust assessment for the use of modern methods of construction

To understand the progress made in terms of the UK construction industry transformation initiatives, a robust assessment framework is necessary[11]. Developing such a framework will help evaluate the performance of projects delivered using MMC (e.g., OSM) and BIM, and the extent to which the UK construction industry is shifting towards more manufacturing-led approaches. To this end, the UK government has embraced premanufactured value (PMV) as a performance metric for evaluating housing and other building projects. Whilst PMV is important, it cannot be prioritised over existing project performance measures (e.g., sustainability targets, time, budget, safety) that have long existed in the construction industry, given that the industry is slow to embrace systemic change. The importance of developing a robust evaluation metric to effectively assess the use of MMC cannot be disputed for two key reasons. Firstly, quantitatively establishing how PMV relates to existing project performance metrics will open the door to creating a standardised but easy-to-access data gathering framework that can be consistently applied to all building types to collate industry-wide metrics. Secondly, educating the industry about how to delineate PMV-related project tasks from those that are not, and about the primary objectives for the introduction of PMV, is critical to ensure that best practices are implemented in delivering projects using MMC.

[11] Oti-Sarpong, K., Shojaei, R., Dakhli, Z., Burgess, G., & Zaki, M. (Under review) in *Journal of Construction Engineering and Management* (for Special collection on Modular construction/Off-site construction)

4.1.6 A multilevel understanding for achieving a transformed construction industry

The initiatives implemented in the UK to drive BIM and OSM adoption and use for construction industry transformation are yet to produce all the key performance goals envisaged in policy. A multi-level analysis of initiatives implemented to drive BIM and OSM adoption shows that the current trajectory of developments has limited potential to create any significant step changes that would lead to industry transformation. Top-down government initiatives[12] to create a demand push for the widescale use of BIM and OSM as well as industry-led 'bottom-up' attempts by industry actors (e.g., a £75m investment by Goldman Sachs in the use of OSM for housing provision), and contractors establishing manufacturing factories and the formation of joint ventures (e.g., Laing O'Rourke, Legal and General and Touchstone) are largely discrete. These efforts are therefore limited in terms of their ability to cause the kind of significant changes needed for industry-wide transformation to materialise.

Realising any meaningful industry-wide transformation is linked to the co-evolution of overarching structures, rules of practice and established norms among actors (e.g., clients, contractors, consultants, planning authorities and technology vendors) who presently govern the construction industry and keep it 'locked-in' with configurations that are not oriented to allowing the widespread adoption of OSM and BIM. It is, however, promising that public procurement and planned infrastructure delivery pipelines (e.g., for housing) are gradually being aligned with the policy ambitions[13] and technological developments[14] designed to create the needed momentum for widescale adoption of digital and manufacturing innovations.

In summary, the research findings above highlight the need for: the government to support the development of new skills framework by the CITB and public tertiary institutions; the establishment of industry benchmark strategies based on exemplar organisations; and deepened and sustained collaboration across different types of firms, with public bodies and academia. These needs are key for achieving a transformed construction industry in the UK, in line with CIH target outcomes, and call for concerted action from construction firms, industry policy makers and the government.

---

[12] Examples include commissioning of a £253m 1,680 capacity resettlement prison by the Ministry of Justice; the Department for Business Innovation and Skills giving a £22.1m grant to Laing O'Rourke for the development of offsite manufacturing solutions; and a £7.39bn Homes England affordable housing programme with delivery partners across the country (see: Oti-Sarpong & Burgess, 2020)

[13] HM Government (2020). *The Construction Playbook: Government Guidance on sourcing and contracting public works projects and programmes*. Cabinet Office: London

[14] CIH (2021). *Platform Programme: The Road to the Rulebook*. Construction Innovation Hub: UK.

4.2. Outputs and impact

The findings from the research conducted have been widely disseminated for impact, and the diverse range of outputs below showcase this. In particular, the research has created meaningful interactions and impact pathways within industry, policymaking and academia, and facilitated knowledge exchange within them.

4.2.1 Reports and Industry Guidance

Two reports discussing the state of the nation regarding OSM and BIM adoption respectively, and an industry guidance report describing how leading contractor firms implemented six key enablers and were able to successfully adopt and use BIM and OSM were published on the Cambridge Centre for Housing and Planning Research and the Centre for Digital Built Britain websites. These reports were well-received and have been accessed by different industry stakeholders and academics – both local and international – since their publication. The industry guidance was co-created with input from industry partners. Since its publication, the guidance has been accessed and viewed over 560 times by both practitioners and academics.

4.2.2 Industry-focused presentations

To broaden the reach of the knowledge produced, researchers engaged with industry practitioners by presenting insights at various meetings. Fourteen invited lectures were held, discussing emerging and published findings from the research with industry groups, including the Construction Leadership Council, BIM4Housing Group, UK Institution of Structural Engineers, and their sub (working) groups. Output from the research has guided considerations in BIM4Housing to create a working group focused on Collaboration and Communication for BIM.

4.2.3 Public engagement

The 2021 Cambridge Festival[15] was used to further disseminate knowledge from the research to the wider public using a bespoke online video [16] about the gains from OSM for housebuilding, and an online quiz that sought to test the public's view and knowledge of houses built using OSM. Combined, both outputs have received nearly 170 engagements from the public. Part of the knowledge from the research also contributed to a journalistic article

[15] The Cambridge Festival 2021: Interactive new story about the 2021 festival.
[16] CCHPR Cambridge Festival 2021 video submission: Tackling the housing crisis by transforming construction

about the use of offsite-built micro homes to tackle homelessness, published in The Conversation UK. This has reached nearly 1300 online engagements.

4.2.4 Academic outputs

Findings from the research are also reported in eight peer reviewed academic publications in top journals and presented at three world-leading conferences and published in their proceedings. A paper on 'Tackling the housing crises through digital innovation and offsite manufacturing' was published with the Cambridge Bennett Institute as part of their Industrial Strategy for Tomorrow Policy Paper series. Overall, these outputs have drawn nearly 2,200 engagements (including 330 downloads) from academics and students all over the world. Publishing in top-tier journals and conferences demonstrates the robustness, reliability and credibility of the research project and the findings produced. Furthermore, these publications helped increase the visibility of the world-leading research undertaken.

As part of the academic outputs, knowledge from the research was shared through invited visiting and guest lectureships in universities across the country and internationally. Part of the research findings informed guest lectures delivered to cohorts ranging from experienced postgraduate students to undergraduates studying for degrees related to the built environment in six universities. These institutions include the: Cambridge Institute for Sustainability Leadership and Jesus College (University of Cambridge), Innovative and Industrial Construction group (ETH Zürich, Switzerland), Department of Real Estate & Construction (University of Hong Kong), Building & Real Estate Department (HK Polytechnic University), Kingston University (UK) and Birmingham City University (UK).

5. Recommendations

5.1 For Policymakers

5.1.1 Align procurement policy with innovation drives to achieve transformation goals

Achieving a transformed construction industry requires coordinated effort, with the alignment of initiatives at the micro (firm and project), meso (industry) and macro (wider socio-cultural and economic) levels. Public procurement should focus on significant innovations for BIM and OSM use. The product platform under development for the delivery of built assets by government departments, ministries and arms-length bodies holds the potential to be a central innovation that could create the much-needed momentum to trigger fundamental changes towards the realisation of industry reform goals. This development should be sustained through a well-coordinated plan, involving both government and industry stakeholders, to ensure that the push for greater BIM and OSM use is met with a commensurate pipeline of projects that will demand their use. Developing such technological innovations should be complemented with a public sector procurement strategy that will explain, for example, how the government's stance in The Construction Playbook will be implemented in practice. These steps are essential for aligning what are currently discrete efforts across the three levels and build the momentum needed for the step changes that have been envisaged in policy.

5.1.2 Coordinate multi-faceted initiatives to sustain industry transformation momentum

The government can leverage its position as a key stakeholder in the construction industry to play an essential coordinating role. The systemic changes needed as part of industry transformation requires the presence of a 'strong' player who is able to assess the state of the industry following the roll out of a mix of coercive and incentivising measures, and to strategise accordingly. The mandatory use of BIM and OSM for public sector projects provides a basis for sustaining the product platform development as a central innovation with the potential to lead to a breakthrough in reconfiguring the way in which the industry works. Furthermore, a focus on creating an environment that will enable existing construction firms to transition from conventional approaches to BIM and OSM-led project delivery will enable the construction industry to embrace these innovations and will facilitate the entry of new businesses offering support services to traditional firms.

5.1.3 Support upskilling initiatives

Training and upskilling labour remains a critical component of the industry transformation agenda and must be supported at national and regional levels. The CITB and the Supply Chain Sustainability School offer training modules in the areas of BIM and OSM. Whilst main contractor firms can pay for their employees to receive training, SMEs face financial challenges and so need support. Subsidies or grant funding to support SME construction firms working on government projects is a useful way to bridge the resources gap that often limits the ability of such firms – who form over 95% of the industry's productive capacity. Governments in Hong Kong[17] and Singapore, for instance, have successfully implemented such funding and are realising positive outcomes in their construction industries.

5.1.4 Establish a knowledge pool and sharing platform to accelerate industry learning

The government should lead industry stakeholders in the creation of a central digital knowledge sharing platform that is accessible to firms operating in the construction industry. Currently, knowledge gaps exist. Information about best practices, as well as pitfalls for learning in supporting the successful adoption and use of BIM and OSM, is patchy, discrete, and not widely accessible to the wide range of firms operating in the construction industry. Meanwhile, cross-industry learning remains pivotal to realising a transformed industry. The creation of a centralised platform designed to host relevant information for construction firms seeking to make the transition from conventional to BIM and OSM-led project delivery will help bridge the knowledge gaps hindering industry transformation.

5.2. For Executives of firms in the construction industry

5.2.1 Establish and implement transformation plans with clear and achievable targets

Executives of construction firms of all sizes need to develop a digital and manufacturing technology transformation strategy that sets out realistic objectives in plain language. This strategy should be simple, easy to understand and consistent. It should be consistently communicated across all levels and areas of a firm and repeated until a new organisational culture has been embedded.

[17] Oti-Sarpong et al. (2020) A critical examination of BIM policy mandates: implications and responses.

It is very important that senior executives and management support and drive the development of the strategy alongside their employees. In creating and implementing transformation plans, company executives should appoint a person (or team) who will champion the transformation vision and who is (are) committed to overseeing the implementation of the agreed plan. Providing leadership by openly demonstrating commitment to the digital transformation agenda, and demonstrating how the vision can be realised through everyday internal and project-related activities, will foster employee confidence in the vision, the implementation strategy and the expected outcomes of the transformation journey.

Finally, whilst getting the right technology is important, focusing attention solely on technology tends to overlook an important aspect of achieving digital transformation – changing people's perspectives. It is important to develop a leadership plan that focuses on enabling people to fulfil their potential whilst embracing the use of new technologies. Leadership that focuses on changing the minds of people by appealing to their individual, work-related, aspirational goals will enable employees to achieve organisational goals for the use of digital and manufacturing technologies.

5.2.2 Prioritise employee skills training and competency development

Construction companies in the journey from conventional methods of working to the use of BIM and OSM must prioritise employee training and upskilling. Attention needs to be paid to helping employees adapt to new technology-driven processes and software changes. Creating opportunities for employees to take the initiative in learning about the use of BIM and project design, coordination and delivery using OSM is also critical. To this end, companies should support their employees to undertake pertinent training courses provided by relevant institutions, including the CITB, British Standards Institution (BSI), Royal Institution of Chartered Surveyors (RICS) and the Supply Chain Sustainability School.

In addition to training existing staff, future recruitment to increase firm capacity in BIM and OSM should incorporate clear competency profiles into role descriptions. This will ensure that employees understand the skills they are expected to have and the tools they are expected to use as part of their contribution to the firm's transformation journey.

5.2.3 Adopt a 'growing together approach' for equipping suppliers

Large contractors should aim to assist firms in their existing supplier networks to improve or build capabilities in using BIM and OSM for projects. Doing so will save time and resources in establishing new working relationships and in building trust with other firms they may not know well. It is therefore helpful to support trustworthy and high-performing suppliers to develop relevant capabilities for using digital technologies and OSM. This 'growing together'

approach can be achieved by hosting workshops and training sessions with subcontractors to understand their needs and jointly develop plans to help their development. There are mutual benefits to be gained from doing this. A strong supplier network equipped with digital and manufacturing capabilities is crucial in order to demonstrate relevant capacity at the tendering stage of projects, and critical for successful project delivery.

6. Conclusion

This report summarises the key contributions from the research project '*Analysing the social context to transforming construction through digital innovation and offsite construction*'. Taking the ongoing construction industry transformation in the UK as the point of departure, qualitative research designs and methods were employed to analyse the key social, cultural and behavioural factors inhibiting building information modelling (BIM) and offsite manufacturing (OSM) uptake in the UK construction industry. These inhibitors are holding back transformation across the construction supply chain for project delivery, and the research aims, ultimately, to offer solutions to tackle them.

Overall, the research project has deepened and sustained collaboration across industry, public bodies and academia – a key outcome of the CIH deployment phase. Findings from the research show that whilst there are a number of multi-level inhibitors to the greater adoption and use of BIM and OSM in the UK, some construction firms offer exemplary lessons of success that could be emulated across the industry. These construction firms show that barriers can be overcome with committed leadership and clear strategies driven by the desire to achieve collective success with employees and supplier firms. From a policy perspective, lessons from governments in countries that have achieved widespread use of BIM and OSM have been highlighted. These lessons show that it is possible for the UK to capitalise on local resources and leverage existing institutional pressures to transform the construction industry into one that can deliver new energy efficient buildings faster with 33% lower construction and whole lifecycle costs, and 50% reduction in delays and greenhouse gas emissions in the next ten years. Public sector procurement can be harnessed to demand innovative ways of delivering housing, educational, health and social care building projects using BIM and MMC (e.g. OSM) from construction firms.

Overall, the research findings support the development and adoption of the UK BIM Framework and the creation of new frameworks to support success in BIM adoption. This contributes to the creation of information management guidance, frameworks and rules which will underpin the future digital built environment and grow UK skills and knowledge exports for digitalisation and adoption of manufacturing technologies for construction. The insights also inform the creation of a national skills development framework in tertiary institutions and construction firms to facilitate successful uptake of digital and manufacturing technologies across the construction industry, a key impact aim of the CIH.

Based on the findings presented, several recommendations for policymakers and executives of construction firms have been outlined. In essence, the recommendations call for continued

collaboration between the government and industry stakeholders in the areas of leadership for transformation; education, training and upskilling; aligning policy, project pipelines and procurement and mutually beneficial knowledge sharing. Based on the robust nature of the insights gained from this research, an informed implementation of the proposed recommendations by industry stakeholders will lead to significant improvements in terms of how construction firms will adopt and use BIM and OSM for project delivery. This will contribute to the realisation of the step-changes already envisaged in policy documents.
Achieving a transformed construction sector is a grand challenge that will benefit from investment into sustained research programme. The findings from the research serve as the basis for future studies that will offer knowledge to further support government and industry efforts to adopt innovations and improve the way construction works.

Further research is needed to take stock of the policy initiatives designed to drive the widespread take up and use of digital innovations and offsite manufacturing, and to examine the impacts on the existing configuration of the industry, in order to understand the ways in which firms have responded to those initiatives. This is relevant for informing future policy for driving even greater innovation in the construction industry.

Furthermore, the future of the construction industry will continue to be driven by BIM and OSM, and the government is working towards industry-wide use of platforms which integrate digital and manufacturing technologies. Significant attention is being paid to the development of the platform as a technical artefact., but to better inform a smooth transition, there is a need to investigate the far-reaching implications of the use of these platforms for organisations and professional bodies, and of industry practices for delivering built assets.

7. References

Cabinet Office (2011). *Government construction strategy*. London: Cabinet Office.

CIH (2021) *Platform Design Programme: Defining the Need.* UK: Construction Innovation Hub.

CIOB (2016). *Productivity in Construction: Creating a Framework for the Industry to thrive.* UK: The Chartered Institute of Building.

Creswell, J. W. (2002). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Upper Saddle River, NJ: Pearson Education.

Egan, J. (1998) *Rethinking Construction*. Report of the Construction Task Force. London: Department of Trade and Industry.

Ehwi, R.J., Oti-Sarpong, K., Shojaei, R. & Burgess, G. (2022). Offsite Manufacturing Research: A Systematic Review of Methodologies Used. *Construction Management and Economics*. 40:1, 1-24, DOI: 10.1080/01446193.2021.2007537

Farmer, M (2016) *Modernise or Die: Time to Decide the Industry's Future, The Farmer* Review *of the UK Construction Labour Model*., London: Construction Leadership Council.

HM Government (2013). *Industrial Strategy – government and industry in practice. Construction 2025*. London: HM Government.

HM Government (2018). *Industrial Strategy – Construction Sector Deal*. London: HM Government.

HM Government (2020) *The Construction Playbook – Government Guidance on sourcing and contracting public works projects and programmes.* London: HM Government, Cabinet Office.

HM Treasury (2017) *Autumn Budget 2017.* London: HM Treasury.

HM Treasury (2020) *National Infrastructure Strategy – Fairer, faster, greener*. London: HM Treasury

IPA (2016) *Government Construction Strategy 2016-20*, London: Infrastructure and Projects Authority.

IPA (2019) *Proposal for a New Approach to Building: Call for Evidence*, London: Infrastructure and Projects Authority.

Latham, M. (1994). *Constructing the Team*. Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry. London: HMSO

Oesterreich, T. D & Teuteberg, F. (2019). Behind the scenes: Understanding the socio-technical barriers to BIM adoption through the theoretical lens of information systems research. *Technological Forecasting and Social Change*, vol 146, p. 413-431.

Oti-Sarpong, K and Burgess, G (2020) *Offsite Manufacturing and Construction Industry Transformation: A Multi-Level Sociotechnical Transitions Perspective* In: Scott, L and Neilson, C J (Eds) Proceedings of the 36th Annual ARCOM Conference, 7-8 September 2020, UK, Association of Researchers in Construction Management, 475-484.

Papadonikolaki, E., Krystallis, I., & Morgan, B. (2022). Digital Technologies in Built Environment Projects: Review and Future Directions. *Project Management Journal*. https://doi.org/10.1177/87569728211070225

Saldaña, J. (2016). *The coding manual for qualitative researchers*. London: Sage Publications Ltd.

Cambridge Centre for Housing & Planning Research

8. Acknowledgements

Funder Acknowledgement

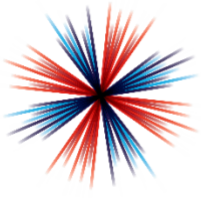
This research forms part of the Centre for Digital Built Britain's (CDBB) work at the University of Cambridge. It was enabled by the Construction Innovation Hub, of which CDBB is a core partner, and funded by UK Research and Innovation (UKRI) through the Industrial Strategy Challenge Fund (ISCF).

Industry partners and collaborators

The authors gratefully acknowledge the contributions from interviewees and the construction firms that participated in and supported this research. Without their generous support, this research project would not have been possible.

UNIVERSITY OF CAMBRIDGE

Cambridge Centre for Housing & Planning Research



INDUSTRIAL STRATEGY

UK Research and Innovation