Projects as vehicles for widespread adoption of digital manufacturing technologies in the AEC sector.

Kwadwo Oti-Sarpong[a], Konrad Graser[b]

[a] ko363@cam.ac.uk; University of Cambridge, United Kingdom

[b] graser@ibi.baug.ethz.ch; ETH Zürich, Switzerland

Global attention to transforming the AEC sector

The architecture, engineering, and construction (AEC) sector in many advanced countries (e.g., UK, Switzerland, Sweden and Singapore) is undergoing significant technological transformation[1]. The ongoing changes are underpinned by a drive to increase the use of 'digital manufacturing' – i.e., digital technologies[2] (e.g., building information modelling (BIM)) and manufacturing-led approaches[3] (e.g., offsite manufacturing (OSM), industrialised/modular construction) – for cost effective and timely provision of socio-economic infrastructure in a sustainable manner.

Championing the transformation drive are mostly governments through the implementation of a mix of policy-backed coercive and voluntary measures to drive, an increased use of BIM and OSM[4] by clients and supplier firms in the AEC sector in delivering building projects (e.g., for housing, education, health). The efforts are yet to deliver the wished-for transformation based on widespread use of digital manufacturing technologies in the AEC sector as envisaged in policies.

Projects: Vehicles for achieving the desired transformation

A major criticism of the ongoing largescale transformation agenda is the lack of real project examples providing evidence of success and lessons for future attempts[5]. This criticism, perhaps, reflects a missed opportunity to utilise projects as effective vehicles to achieve the visions of a transformed sector.

Projects are the heartbeat of the AEC sector – bringing together various actors from different professional backgrounds, adopting, and adapting to multiple technologies, techniques, and innovative processes to deliver a socio-economic built asset[6]. By nature, projects are well-suited for demonstrating the utility of various technological innovations for delivering built assets to desired targets and showcasing how multi-actor involvements and inter-organisational interactions play out. Indeed. the critical role of projects in triggering sector-wide changes has been identified[7] as an effective way of showing the viability of proposed innovations and rallying the support of key stakeholders. Exemplary construction projects therefore offer an opportunity to demonstrate how the implementation of multiple innovations work together in a multi-disciplinary inter-organisational setting. They can contribute immensely to the success of the ongoing transformation agenda in various countries.

In this post, we spotlight a world-leading project example that demonstrates how the use of digital manufacturing technologies work together and highlight lessons for the future. We

particularly discuss the need to capitalise on the project-centric nature of the AEC sector to begin making significant strides of transformation.

The DFAB House project in Switzerland

The DFAB House is a demonstrator building by the Swiss National Centre of Competence in Research (NCCR) Digital Fabrication. The building demonstrates six Digital Fabrication (DFAB) technologies, including Mesh Mould, a robotically welded rebar mesh combining the functions of stay-in-place formwork and reinforcement; In situ Fabricator, the world's first on-site application of an autonomous, mobile construction robot; Smart Dynamic Casting, an automated system for concrete slip forming using a reusable, actuated formwork; Smart Slab, a pre-cast concrete ceiling slab fabricated with 3D printed formwork; Spatial Timber Assemblies, a robotic prefabrication process for timber modules, and Lightweight Translucent Façade, a non-planar membrane facade with aerogel insulating filling[8].

The DFAB House is a ground-breaking project in two ways: first by using six fundamentally new DFAB technologies to construct all its major building parts; second, as the world's first residential building constructed by multiple DFAB technologies to be permitted and occupied. Besides pushing forward DFAB technology itself, the project brought us many insights on the process of managing and organizing DFAB projects, which we had the chance to make available to a wider audience through two publications[9, 10] summarized in the following paragraphs.

The DFAB house project addressed two overarching questions. First, how to design and build a real-world, habitable building using multiple DFAB processes? Answering this question involved facing practical realities: First, how can digital fabrication be scaled up from the lab to a real-world application? How to integrate and interface several new construction methods? How to best combine research and industry resources and expertise? Second, what are the lessons to be learned from this kind of project? For example, how do new technologies stand up to realistic constraints? How to deal with risk and uncertainties, budget, and schedule challenges? What new forms of collaboration can be identified from such a diverse multi-disciplinary project?

We found that five strategies were particularly important in implementing the DFAB House project: the co-development of processes and production systems through close interdisciplinary collaborations; an integrated, bottom-up approach to project management and organization; the merging of the diverse social and cultural perspectives of the different disciplines and professions involved; a strategy to generate and capture knowledge in transdisciplinary teams; and leveraging the project impact by proving feasibility, investing in innovation-readiness, and increasing visibility.

The DFAB House showed that a building-scale demonstrator project, rather than merely putting to use prior knowledge, can be an effective format for exploring the feasibility of multidisciplinary innovations in AEC. The project informed the development of its DFAB technologies in two ways: 1) on the level of applicability at full construction scale, testing each technology against external constraints critical for its successful implementation, and 2) on the socio-technical level, by engaging a similarly diverse group of stakeholders in its development as will be found in future applications of DFAB on real life projects.

By providing a unique environment where technology researchers, industry practitioners and decision-makers were able to interact, the project brought together a diverse set of stakeholders and perspectives usually not found in either academia or practice alone. The successful outcome from the building project helped increase acceptance of DFAB in the industry. Its success has also generated industry-wide interest in the DFAB House approach and paved the way for several ongoing research-industry partnerships aimed at developing market-ready DFAB solutions.

Lessons from the DFAB House project global attempts at industry transformation

The DFAB House project offers a timely example of how industry-government-university collaboration can exemplify how grand scale transformation could be achievable. As an institutional project that has already set in motion much needed partnerships and drawn attention from the public, the DFAB House illustrates a model[11] for transdisciplinary co-development involving technical, process and organisational changes in the AEC sector. In addition to demonstrating that a repertoire of technologies and manufacturing approaches can indeed work well together and showing practical viability of high-end technological innovations, the project offers a pattern for multi-stakeholder involvement towards achieving such outcomes.

The success of the DFAB House project should encourage investors, governments, construction firms, and the public to start making or increase investments into the use of digital and manufacturing technologies. For firms operating in the AEC, the outcome of this project shows how, with the right strategic alliances, the successful implementation of modern digital and manufacturing technologies can be achieved. It should also give researchers hope that their technological innovations can be adapted to the creation of a built environment that is responsive to societal needs.

In conclusion, projects, by nature, are well-suited as vehicles to drive innovation in the AEC sector. This is because they unite multiple stakeholders (e.g., investors, designers, technologists, researchers, regulators) behind the common goal to deliver an output that is often complex. The DFAB House project shines light on issues arising from this, and points to the critical role projects can play in the ongoing and future transformation of the AEC sector around the world. We therefore submit that it is worthwhile to increase attention to deliberate policy-backed projects that will serve the purpose of promoting the viability of multiple digital, manufacturing, automated and robotic technologies.

Authors

Kwadwo Oti-Sarpong, Ph.D.
Research Associate

Cambridge Centre for Housing & Planning Research (CCHPR)
Centre for Digital Built Britain (CDBB)
University of Cambridge, United Kingdom.

Konrad Graser
Doctoral Candidate

Chair of Innovative and Industrial Construction; Department of Civil, Geomatic and Environmental Engineering
ETH Zürich, Switzerland.

References

1. Oti-Sarpong, K., Parn, E., Burgess, G., & Zaki, M. Transforming the construction sector: An institutional complexity perspective. *Construction Innovation: information, process, management* https://doi.org/10.1108/CI-04-2021-0071

2. WEF (2018). *Shaping the Future of Construction: An Action Plan to Accelerate Building Information Modelling (BIM) Adoption*. Switzerland.

3. Boston Consulting Group (BCG) (2019) *The Offsite Revolution in Construction*, USA: Boston Consulting Group.

4. Ernstsen, S. N. et al. (2021) 'How Innovation Champions Frame the Future: Three Visions for Digital Transformation of Construction', *Journal of Construction Engineering and Management*. American Society of Civil Engineers (ASCE), 147(1), p. 05020022. doi: 10.1061/(asce)co.1943-7862.0001928.

5. House of Lords (2018) *Off-Site Manufacture for Construction: Building for Change - Oral and Written Evidence Presented to the UK House of Lords*, London: Crown.

6. Papadonikolaki, E., Krystallis, I., & Morgan, B. (2022). Digital Technologies in Built Environment Projects: Review and Future Directions. *Project Management Journal*.

7. Winch, G. M. & Maytorena-Sanchez, E. (2020) 'Institutional projects and contradictory logics: Responding to complexity in institutional field change', *International Journal of Project Management*, 38(6), pp. 368–378. doi: 10.1016/j.ijproman.2020.08.004.

8. https://dfabhouse.ch/dfab-house

9. Graser, K., Baur, M., Apolinarska, A., Dörfler, K., Hack, N., Jipa, A., Lloret-Fritschi, E., Sandy, T., Sanz Pont, D., Hall, D. & Kohler, M. (2020). DFAB HOUSE – A Comprehensive Demonstrator of Digital Fabrication in Architecture. *FABRICATE 2020*, UCL Press, London.

10. Graser, K., Kahlert, A. & Hall, D. (2021). DFAB HOUSE: implications of a building-scale demonstrator for adoption of digital fabrication in AEC. *Construction Management and Economics* 39:10, pp. 853-873, DOI: 10.1080/01446193.2021.1988667

11. Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy*, 29(2), 109-123.

Kwadwo Oti-Sarpong's 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 CIH is funded by UK Research and Innovation through the Industrial Strategy Fund.