From Digital Design to Data-Assets: Competing Visions, Policy Projects, and Emerging Arrangements of Value Creation in the Digital Transformation of Construction

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Kathrin Braun, Cordula Kropp & Yana Boeva *

Abstract: *»Von der digitalen Planung zu Daten-Assets: Konkurrierende Visionen, Politikprojekte und neue Arrangements der Wertschöpfung in der digitalen Transformation des Bauwesens«.* The construction sector faces multiple challenges such as poor productivity, performance, and competitiveness and has a huge share in global waste production, CO_2 emissions, and resource depletion. In this situation, a broad range of public and private stakeholders place their hopes on the digitalisation of construction, in particular, building information modelling (BIM). The article seeks to destabilise the notion of "the" digitalisation in a synchronic and a diachronic perspective. First, we map out the landscape of digital visions regarding the future of construction by examining pertinent academic, public, and professional discourses in recent years. We identify a vision of industrialised construction, a vision of data-based integration, a vision of singularised architecture, a vision of digital sustainability, and an emerging vision of the "twin green and digital transition." In a diachronic perspective, we zoom in to UK "BIM-and-beyond" policy from 2011 to 2021 and show how BIM has evolved from a digital design tool into a critical component for building a national system of data-assets for data-based value creation. In both perspectives, we see a recurring storyline according to which the sector will solve all its problems if it only undertakes the digital transformation.

Keywords: Digital transformation, architecture, construction, datafication, building information modelling, sociotechnical imaginaries.

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1. Introduction

The digital transformation has gained momentum in architecture and construction in recent years, promoted not least by governments and alliances of private sector, academic, and state actors. A broad array of public and private stakeholders, including policy-makers (European Commission 2021), are promoting digitalisation as key to solving the sectors many challenges such as poor competitiveness, efficiency and productivity, time and budget overruns, poor performance, failures and disasters, shortage of labour, or shortage of finite resources. At the same time, there is a strong political-economic drive to generate wealth out of building data by committing the construction sector to generate appropriate data sets.

In parallel, ongoing discourses about the future of planning and construction also reflect a growing awareness about the grand challenges facing humanity, namely the lack of adequate and affordable housing for large parts of the global population, combined with environmental degradation, resource depletion, climate change, and the role construction plays in relation to these challenges. Having a huge share in global waste production, greenhouse gas emissions (GHE), and energy and resource consumption, the building sector is the "elephant in the greenhouse," as Hans Joachim Schellnhuber (2021) put it. To meet the Paris Agreement target of limiting global warming to 1.5°C, the entire global building and supply chain must decarbonise by 2050 (International Panel on Climate Change [IPCC] 2018). Approaching zero GHE in 2050, according to the IPCC, is still possible, but only if policies get implemented that effectively combine energy efficiency and ambitious sufficiency and renewable energy measures. However, sufficiency, defined as reducing a building's demand for energy, materials, land, and water over its lifecycle without the need for further technology that would, again, need to be produced, powered, and maintained, has been grossly neglected in the past. The decade 2020–2030, the IPCC states, is critical for implementing the necessary policy-shift to set the right incentives and appropriate governance structure to capture the mitigation potential of the construction sector: "For buildings, there is only one round left between now and 2050, so we either get this right or it's wrong forever," says Yamina Saheb, one of the lead authors of the report (Hahn 2022).

In this situation, great hopes are placed on digital technologies that are expected to offer new solutions to the multiple crises facing the sector as well as the planet and open up new pathways to a better, more efficient, more productive, and at the same time more sustainable and livable future for planning and construction. The concept of the "twin transition" or "twin green and digital transition" coined by the European Commission captures this idea of solving the sectors economic and environmental problems through aligning the two transitions.

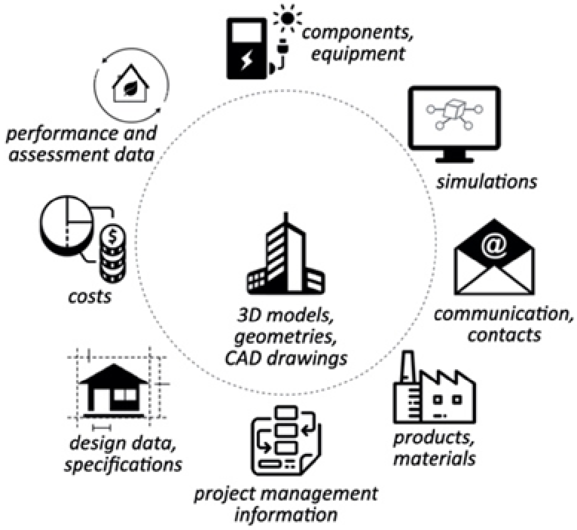
There is a consensus, the EU Commission proclaims, about the "priorities for the European economic growth model, including the green and digital transitions [...] These priorities jointly contribute to the objective of competitive sustainability" (European Commission 2022, 1). The digital transformation, in this view, enables planning and construction to be part of the solution, instead of being part of the problem. In construction, the transition would encompass digital visualisation technologies, monitoring and tracking technologies for lifecycle assessment, sensors, automated prefabrication, and others, but a key role is assigned to building information modelling (BIM, see section 2). Contrary to the dominant discourse, however, there is no such thing as "the" digitalisation. Digitalisation can mean different things to different actors in different contexts and the resulting visions have practical implications for what course of action is being promoted under the heading of "digitalisation." Talk of "the" digitalisation suggests a coherent, progressive, unilinear development without alternatives and thereby obscures the multiplicity of possible futures and the driving forces behind them. In this article, we want to destabilise this notion of "the" digital transformation from two perspectives: In a synchronic perspective, we map out the landscape of sociotechnical visions regarding the future of planning and construction that have been circulating in public and professional discourses over the past years, competing for attention and support. In a diachronic perspective, we take a case study approach, zooming into the past ten years of what we call BIM-and-beyond policy in the UK, setting in with the first major policy document addressing BIM, the Government Construction Strategy in 2011. Whereas in a synchronic perspective, we see a spectrum of concurring visions against a still somewhat open horizon of possible futures, in the diachronic, case-study perspective, we see some of these visions tending to dominate or superimpose others: The case study shows a trend of BIM evolving from a digital tool for the design and delivery of individual construction projects into a generator of data-assets. In this process, it successively becomes a key component for a larger political project of building a comprehensive national information management system that would simultaneously optimise the efficiency of public policies and services and act as an apparatus for data-based value creation across public and private sectors. Conversely, we find that the actual policies are gravitating towards technoeconomic values of increased productivity, economic growth, cost control, and risk reduction. While environmental sustainability also becomes more prominent over time, it is never given priority over technoeconomic goals; a digitalisation geared at making construction sustainable within the planetary boundaries will only be supported if it does not get in the way of economic growth and competitiveness.

What is BIM and why is it considered key to the digital transformation of construction?

2. Informing Building Design and its Promises

BIM is by no means a bounded object with clear definitions and a stable meaning. It can be considered a digital tool, a new approach, and/or an infrastructure for building design, project management, and managing building data over a building's entire life cycle. With BIM, two-dimensional, draft-based planning is being replaced by a three-dimensional digital model into which, theoretically, all relevant building data are entered and made available for all involved parties in real time. Different from the still influential computer-aided design approach with its generation of two-dimensional perspective drawings, the BIM approach aims to create "information-rich construction elements as building blocks" (Beetz et al. 2020, 513) that ideally allow for a continuous digital reuse during the whole lifecycle of a building. Besides enriching a building model with semantics, BIM serves as a platform for "data-sharing and communication across the organizational boundaries and in the intended collaboration encoded into the software" (Neff, Fiore-Silfvast, and Dossick 2010, 558). By focusing on the coordination of the contributing organisations and actors including architects, structural engineers, and different construction subcontractors (i.e., electricity, heating, ventilation, etc.) within a combined model, it promises to reduce "redundancies in the design and construction process by centralizing data" (Cardoso Llach 2019, 454). Therefore, BIM connects modelling software with other digital applications to develop a highly detailed building model; a database including information about geometry, components, costs, materials, simulations, and other features; and an interface for collaboration among various project partners or with other parties such as public authorities (see Fig. 1). It allows users to process large amounts of data from construction costing via energy efficiency to data about the collaboration process as such or even individual user performance of participants (Zhang and Ashuri 2018). The prospect of a central model coordinating and representing all building data and information and detecting clash collisions of building elements in the design before construction is what others have labelled as the constituent of a "BIM utopia" (Miettinen and Paavola 2014).

Figure 1 The Concept of Building Information Modelling (BIM)



BIM can be seen as a sociotechnical arrangement that critically enables and drives the datafication of planning and construction. Over the past years, it has increasingly been hailed as a key component for building new integrated data-infrastructures to deliver better, faster, and more resource-efficient solutions across the building sector and beyond. The EU, for instance, promises that BIM adoption will greatly increase construction performance in terms of

> [g]reater productivity of the sector – delivering more built assets for the same or less expenditure; improved output quality of public built assets; adapting to a sustainable built environment – one that supports the challenges of climate change and the need for a circular economy; increased transparancy of construction performance; new opportunities for sector growth, through exports and additional service offerings; a stronger and digitally-skilled sector attracting talent and investment. (EU BIM Task Group 2017, 16)

Thus, BIM is constructed as a key requirement and a driver for accelerating the digital transformation of construction, which, in turn, is supposed to provide solutions to a set of grand challenges facing humanity. The idea that digital technologies will act as a kind of universal technological fix for a host of complex social, economic, and environmental problems is a pervasive, albeit not uncontested feature within the discourses on digital architecture and construction as we will show in the following.

3. Sociotechnical Visions and Policy Pathways

We build on the work on sociotechnical imaginaries (SI) to help illuminate the landscape of diverging possible digitalisations in architecture and construction. Sociotechnical imaginaries, as defined by Sheila Jasanoff, are

> collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology. (Jasanoff 2015, 4)

SIs both indicate and enact ways in which science and technology can contribute to desirable forms of social coexistence; they may, for instance, guide and shape research and development processes, funding schemes, political agenda setting, or regulation and implementation of technoscientific projects (Borup et al. 2006; Konrad and Böhle 2019). Thus, SIs are essentially performative; they structure the field of possible action concerning sociotechnical projects such as the digital transformation, acting as "infrastructures of imagining and planning futures" (Sismondo 2020, 505).

Originally, the concept was coined by Sheila Jasanoff and Sang-Hyun Kim (2009) to indicate rather coherent, historically persistent, and nation-specific imaginaries that inform grand national projects such as nuclear power programmes. More recently, Jasanoff (2015; Jasanoff and Kim 2015) and others have broadened the concept to include the imaginatory repertoires of further types of collective actors, such as corporations, social movements, or research communities on further scales of social life below or beyond the state.[1] This work has pluralised the concept, highlighting the competition, interrelations, and power asymmetries between sociotechnical imaginaries (Beck et al. 2021; Mager and Katzenbach 2021; Mutter and Rohracher 2022). Astrid Mager and Christian Katzenbach (2021) further argue that in the realm of digital technologies, SIs have become increasingly commodified and dominated by technology companies. There is a certain consensus in the literature that not any idea qualifies as sociotechnical imaginary but the concept should be reserved to notions, ideas, images, and visions that are collectively held and embedded in collective value systems, publicly performed, and to some degree institutionalised. Still, stability can be contested and reversed. We consider sociodigital visions to form a constitutive element both of existent SIs and of the processes of selectively promoting and stabilising certain SIs. Conceptually, sociodigital visions may not (yet) have attained the institutional stability of SIs, but like these are collectively held, based on implicitly or explicitly shared values and

[1] For an overview over the concept of imaginaries in relation to science and technology, see McNeil et al. 2017.

assumptions, circulating and enacted in certain publics, and contested and performative.

To identify the main sociodigital visions circulating in the field of planning and construction in recent years, we draw on the research tradition of interpretive policy analysis (IPA), starting from the understanding that there is no unmediated access to social reality, including policy programmes as well as larger sociotechnical projects and arrangements. Instead, our understanding of and interaction with the world is inevitably mediated by interpretive schemes and ordering devices captured by concepts such as frames, narratives, discourses, or story lines that enable us to make sense of what is going on.[2] No matter their other differences, these concepts share some important characteristics: they seek to capture the inextricable connection of analytic and normative views and statements, of theoretical and practical stances towards the world, of sense-making and action. Furthermore, they serve to examine the mobilisation of actors and the dominance of certain ways of meaning-making and acting over others. Sociotechnical visions and imaginaries, we hold, can be added to the list of such ordering devices. However, there are different ways of conceptualisation. As Maarten Hajer and David Laws (2006) note, they can be positioned on a continuum between an individualistic, actor-centred pole, taking the views, aims, and intentions of identifiable actors as their starting-point, and a relational pole, exposing certain social and cultural schemes that shape, albeit not determine, the room for sense-making and action in a specific context. For sociotechnical visions and imaginaries, this means that on the one pole they may be understood as rhetorical devices used by identifiable actors since they suit their aims and intentions, and on the other as collective patterns of valuation and interaction that precede actors' behaviour and intentions and are not necessarily fully transparent to them. Closer to the actor-centred side of the continuum, for instance, Simon Egbert (2018) shows how political decision-makers in Germany employ certain discursive strategies to legitimise the use of algorithm-based predictive policing since it suits their interests to present an – allegedly – more effective technical solution to specific social problems. Referring to building construction, Sidsel Nymark Ernstsen and co-authors (2021) identified three emergent visions for implementing digital technologies in construction: efficient construction, user-data driven built environment, and value-driven computational design. Interestingly, the first two resemble visions we also found, yet we also identified sustainable construction and singularised architecture as visions in their own right (see section 4). While Ernstsen et al.'s study, being based on interviews with construction practitioners from UK companies, takes an actor-centred approach and offers insights into the

2 For an overview, see Hajer and Laws 2006; Fischer et al. 2016.

views of the particular social group of innovation champions in UK construction industry, our research was directed at the question of which sociodigital visions are circulating in a broader discursive space across academic, practitioners', and policy publics in order to see whether and how these visions may shape further practices and pathways.

To this end, we examined a range of pertinent documents such as policy papers, reports, surveys, expert analyses, guidelines, blog entries, position papers, or trade magazines[3] produced by relevant actors such as professional associations, interest groups, consulting firms, and industry and government actors. While, the focus was on Germany and the UK, we also included documents by trans- or international actors such as the World Economic Forum (WEF), the EU, or transnational consultancies or business networks that figure prominently in these discourses. Germany and the UK are both interesting cases within Europe; in Germany, there is still some reluctance towards digital architecture and construction while the UK praises itself to be a world-leader in that regard. The aim of this article, however, is not to explain national differences but to point out a spectrum of different possible digitalisation pathways in architecture and construction in order to open up room for reflection and debate about different possible digitalisations and possible tensions between these.

The documents have a representative as well as a performative character; they reflect the factual analyses, problem constructions, views and goals of their authors but they also, more or less explicitly, seek to interfere into the processes they address and to actively shape the development of digital planning and construction. In this sense, they result from recent discourses and take part in them; they seek to structure the field of possible action through informing and guiding actors' decisions, choices, and ultimately actions. Hence, these documents not only *say* but also *do* something, such as address and define some problems and ignore others, define standards, delineate what does and what does not count as BIM, and so on, thereby modifying the reality they are addressing.[4] The focus was on the construction of problems and challenges that are taken to constitute the need for digitalisation; on associated promises and expectations, reservations, and concerns; implicit or explicit values, goals, and ideas of a desirable digital future; and the ensuing demands for action. In addition to document analysis, we draw on 26 in-depth interviews we conducted with experts, practitioners, researchers, and stakeholders in architecture and construction between 2019 and 2021, mainly in Germany. The interviews provide background knowledge about the uptake of digital arrangements

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[3] We analysed more than 116 documents, 49 of which specifically refer to the UK.

[4] For explaining the concept of performative documents, see also Asdal (2015). The understanding of discourse as being performative and linked to practice is a common feature in interpretive policy analysis, however; for a systematic account see Wagenaar (2011).

(particularly BIM), experiences and practical issues, common ways of usage, and general assessments.

4. A Landscape of Competing Visions – A Synchronic Perspective on BIM

We identified four major sociodigital visions regarding the future of construction: a vision of increased efficiency and productivity through industrialised construction, a vision of optimised management and control through data-based integration, a vision of singularised architecture, and a vision of digital sustainability (Braun and Kropp 2021). More recently, we can perhaps see a fifth one emerging with the notion of the "twin transition," fusing the fourth to the first and second one.

4.1 From Projects to Products: Automated Construction

One of the most powerful visions circulating in official documents is that of a "digital revolution" in the construction sector that will hugely increase its efficiency, productivity, and potential for cost savings and fuel economic growth and competitiveness in global markets, in short, lead to "delivering more built assets for the same or less expenditure" (EU BIM Task Group 2017, 16). Great expectations in that respect are placed on adopting approaches of automated or semi-automated industrialised mass production that have long been employed in the automotive or aircraft industries. A key element here is modular construction, meaning that standardised building components or entire buildings are mass-produced through fully or partially automated prefabrication processes in off-site factories and then transported to the construction site and assembled. While offsite prefabrication as such is not new in architecture, the recent resurgence of modular construction is fueled by the deployment of digital planning technologies such as BIM and computer-aided manufacturing technologies such as computer numerically controlled (CNC) machinery and robotics, and other technologies such as sensors or virtual reality (American Institute of Architects [AIA], n.d.).

Proponents of the modular approach hold that it makes construction less dependent on the vagaries and vicissitudes of the individual construction site, allowing for production under controlled factory conditions. Within this framework, buildings are no longer one-off projects but replicable, standardised mass products (McKinsey & Company 2019), albeit variable within certain limits. "We stack them like Legos on the building site, and then you have a completed building," says the chief operating officer of a modular construction firm (Evers 2021). Automated construction is seen to "help the industry fill the continually widening skills gap by needing less skilled workers" (Microsoft and the Royal Institute of British Architects [RIBA] 2018 2018). It is mostly propagated by consulting firms such as McKinsey (McKinsey Global Institute 2017; McKinsey & Company 2019), but also by other influential stakeholders such as the Royal Institute of British Architects (Microsoft and RIBA 2018), the World Economic Forum (World Economic Forum 2016, 2017, 2018), government sponsored expert reports (Farmer 2016), and not least big tech firms such as Alphabet, Apple, Meta, and Autodesk, who have invested heavily in modular construction firms (Evers 2021). "[L]ack of affordable housing is a challenge worldwide", proclaims Andrew Anagnost, CEO of construction software company Autodesk, announcing their investment in modular construction company Factory_OS, "we need to build more housing quickly and within the fundamental limitations of the planet. [...] Autodesk is doing just that" (Evers 2021). Factory_OS, in turn, employs Autodesk's BIM software, which, they say, is critical for coordinating on- and off-site-production.

However, the "productification" of buildings also meets with reservations. For many architects as well as clients, modular construction is associated with "low quality, boxy looking modular buildings or homes that lack character or architectural appeal" (Mills 2019) and only reinforces the "*Verschuhschachtelung*" ("shoeboxing") of the built environment, as an attendee at the German Conference of Architects 2019 said to us.

4.2 From Fragmentation to Integration: Data-Based Optimisation

The second influential vision we identified is one of optimised, integrated data-based planning and management processes. Within this vision, a key role is assumed by BIM. It enables the quick iteration of renderings, the speedy implementation of modifications to the planning process, and, in theory, the integrated tracking of planning information throughout the entire life cycle of a building. Its proponents see it as a key requirement to overcome the fragmented nature of construction processes and install a more integrated mode of planning that will reduce various kinds of risks and improve transparency, collaboration, control, and building performance.

The diffusion of BIM is strongly driven by governments that have set up policy frameworks for encouraging, supporting, and partly mandating the implementation of BIM (Hore, McAuley, and West 2017; Lee and Borrmann 2020). They see BIM as a means to optimize control and reduce risks, construction failures, and ensuing litigation. In Germany, the use of BIM has been a legal requirement for infrastructure projects since 2020, an extension to publicly financed high-rise buildings is planned. The government expects that the general shift to BIM will provide better coordination and optimised management of building operations through team-oriented, cooperative problem-solving and a reduction of "planning risks, technical risks, planning approval risks, interface risks, etc." (Federal Ministry of Transport and Digital Infrastructure [BMVI] 2015, 7) and improve cost certainty, adherence to deadlines, and quality.

This vision does not seem to convince everyone either. Surveys among the industry in Germany and the UK show that while BIM adoption is increasing, there is also enduring reluctance, in particular among small and medium sized enterprises (SME), with the expected costs of investment being among the main barriers (Bundesinstitut für Bau- Stadt- und Raumforschung 2019; Dainty et al. 2017; Microsoft and RIBA 2018; NBS 2020; Pricewaterhouse-Coopers 2019; Reiß and Hommrich 2018). There is a concern that the diffusion of BIM may actually increase the stratification of the market with small-sized architectural studios losing out to big construction companies with in-house architects, their own BIM experts, and the means to shoulder huge amounts of upfront investments.

4.3 From Conventional to Complex: Singularised Architecture and Construction

A further vision is circulating mainly in architecture and design discourses and promoted by architects who explore the potential of digital technologies to expand the design space. Digital technologies have sparked the imagination and opened up new possibilities for creating complex, unconventional, non-standard projects that could not have been built without the use of computer-based technologies. Concepts such as parametric design, generative design, or computational design thinking (Menges and Ahlquist 2011; Vrachliotis 2012, 233) indicate some of these new approaches.

This vision is partly opposed to that of automated, industrialised construction presented above as it envisages a future where digital technologies are employed to create complex, unique, spectacular, aesthetically attractive buildings as one-off projects. Thus, it is in a sense a vision of reversing the trend from projects to products. Drawing on the concept of singularisation by Andreas Reckwitz (2020), we can understand it as a vision of computer-based singularisation in construction. Singularisation, for Reckwitz, describes a sociocultural shift from a logic of the general to a logic of the particular in the context of what he terms the rise of cognitive-cultural capitalism (Reckwitz 2019). While industrialised construction targets a demand for buildings as functional and affordable mass products, singularised architecture responds to a demand for individuality, authenticity, and particularity.

We can distinguish two strands of singularisation: one associated with notions of "iconic architecture" in an upscale market segment and one on the basis of modular construction in a lower market segment. The rise of iconic architecture, according to Leslie Sklair (2006, 2017), co-emerged with the era of globalised capitalism and the development of computer-supported technologies in architecture in the 1990s. The digital turn provided architects with instruments that allow, for instance, to create non-Euclidean buildings that would not have been possible before (Carpo 2013; Imperiale 2000). A series of iconic projects by "starchitects" like Norman Foster, Frank Gehry, or Zaha Hadid Architects were realised using digital design technologies. Such buildings of the late 20th and early 21st centuries represent the power and wealth of banks, insurance companies, large corporations, and other prosperous clients and serve as consumer magnets for an entire region, like the Guggenheim Museum in Bilbao, which became paradigmatic for this effect. This vision of an iconic, digitally-enabled, singularised architecture is mainly supported by "starchitects" who perform it and well-off clients who commission it.

The use of digital technologies, however, also allows for introducing elements of singularisation into the lower segments of the building market; the principle of digitally-enabled mass customisation, that has long been employed in the automotive and textile industries, can also be applied in off-site prefabrication of building components or even wholesale buildings (Kolarevic 2009). WikiHouse, for instance, offers a digital building system for the do-it-yourself production of a tiny house based on one's own ideas and needs – albeit within a predetermined set of options.

4.4 From Problem to Solution: Sustainable Construction

Finally, there is the vision of a technologically-enabled sustainable transformation of architecture and construction that will radically reduce GHE, waste production, and use of finite resources. In 2020, building construction and operations accounted for 36% of global energy demand and 37% of energy-related CO_2 emissions (United Nations Environment Programme [UNEP] 2021). A vision that has gained tracture in recent years is that digital technologies and data-based arrangements such as design software, integrated data management, robotic manufacturing, sensors, and artificial intelligence will fundamentally transform building construction in order to meet the Paris Agreement target. The digital documentation of construction materials can, for example, include all useable components of a building and enables the transition into a circular economy. Additive manufacturing and 3D printing of building components can reduce waste and resource consumption while supporting local production and shortening transport routes (Nikmehr et al. 2021; Yevu, Yu, and Darko 2021).

In a scenario by the WEF on the green future of construction,

> 3D-printing robots are used to print building elements out of new materials, minimizing construction waste. Site crews wear augmented-reality glasses to see real-time instructions on the most environmentally efficient way to complete tasks. Virtual reality and mobile-collaboration applications

> minimize travel and the moving of materials and equipment. [...] O&M [operations and maintenance] companies monitor sensors embedded in various asset elements to make sure their environmental impact stays within acceptable limits [...] software systems [...] track live data from the sensors to determine when maintenance or repairs are needed, optimizing the timing of replacements. (World Economic Forum 2018, 17)

The European Commission also views digitalisation as key to a sustainability-oriented transformation. To this end, it has inscribed its concept of the "twin green and digital transition" (European Commission 2022) into a set of funding calls under Horizon 2020, the main EU funding programme for research and innovation, in order to push the transition to sustainability in specific industries, among them construction, with the guiding rationale being that the two transitions will mutually reinforce each other. Notably, however, a recent expert report cautions that this may not automatically be the case, since digital technologies have substantial environmental footprints that go against the green transition and rebound effects may undermine technological achievements (Muench et al. 2022). Sufficiency strategies, as demanded by the IPCC, play only a minor role within the concept of the twin transition.

Our analysis shows the prevailing view that digital technologies have begun to change the world of planning and construction and that these changes will accelerate in coming years. Digital technologies promise to solve a broad range of pressing problems facing the sector as well as our societies and the planet at large. While we found diverging ideas about what the most pressing problems are, what values and objectives should guide the digital transformation and what potentials should accordingly be developed, there was also a recurring storyline according to which architecture and construction face dramatic challenges which, however, can be met if only the sector harnesses the potential of digital technologies. Tensions, potential incompatibilities, or conflicts between different values and objectives are only rarely addressed; a recurrent assumption is that "the" digitalisation will provide a technological fix to various kinds of problems. This assumption also shows in a diachronic perspective when we look at the development of BIM policy in the UK.

5. Translating Visions into Pathways – A Diachronic Perspective on Digital Construction Policy in the UK

On the level of discourse, we found a pervasive promise that digitalisation will reconcile values as diverse as increased productivity, economic growth, decarbonisation, environmental sustainability, standardisation, and singularisation. Yet, when visions, promises and assumptions get translated into policies and concrete sociotechnical arrangements, decisions need to be made, priorities set, funding allocated, norms and standards defined, and infrastructures established. In the process, the horizon of possible futures and untapped potentials will narrow down to certain pathways. In the following, we will zoom in on the evolution of digital construction policy in the UK from 2011 to 2021. The UK prides itself of having taken a world lead in the adoption of digital technologies in planning and construction, with "the most ambitious and advanced centrally driven programme in the world" (HM Government 2015, 7). Whether justified or not, these aspirations make the UK an interesting case to study the co-production of novel sociotechnical means of production, notions of a good life in society, and forms of social organisation and relations of power, interests, and collaboration concerning the (digitised) built environment.

Since the 2010s, the UK government has undertaken concerted efforts to promote and support the digital transformation of the national construction sector. Digitising construction has been the subject of a series of policy programmes and strategies and has motivated the establishment of new bodies and frameworks tasked to implement them. A key role throughout these policies has been assigned to BIM. In this case, we can see how over the past some ten years, both the meaning and functions of BIM and its integration into a growing data-based information management network were constantly expanding. Initially viewed as a tool to create 3D design models and save time and costs in project delivery, BIM is now promoted as a way of managing information throughout the design, construction, maintenance, and operation phases of buildings up to demolition or refurbishment. What is more, it has turned into a generator of data-assets and a building block for smart city and digital twin aspirations.

In the following, we will inspect some major steps of policy development regarding BIM implementation from the perspective of government or government-supported bodies and government-industry alliances, based on an analysis of policy documents and focusing on the problem descriptions, objectives, visions, and overarching narratives structuring respective policies.

5.1 Constructing Sociodigital Leadership

In the UK, the digital transformation of planning and construction has been addressed primarily as a matter of industrial policy, in a succession of general and sector-specific policy strategies. BIM is assigned first and foremost the task of boosting productivity and economic growth and strengthening the UK's position in the world economy. It also figures in building safety and building performance programmes.

The first major step towards BIM implementation was the Government Construction Strategy for 2011 to 2015 (Cabinet Office 2011), issued by the Conservative and Liberal Democrat coalition government in May 2011. Its main strategic goal was to reduce the cost of public sector construction by 10-20% by the end of the electoral term and to stimulate economic growth in construction. Besides, reduction of carbon emissions is mentioned briefly but the report does not quantify or specify this objective. To achieve the 20% goal, the strategy declared that the government would "require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016" (ibid., 14).

Also in 2011, the UK BIM Task Group, a Government-funded group managed through the Cabinet Office, was created to bring together expertise from industry, government, institutes, and academia; lead the government's BIM programme; and drive the adoption of BIM in order to achieve the 2016 objective. The BIM Task Group was eventually superseded by the Cambridge-based Centre for Digital Built Britain (CDBB) founded in 2017. In addition, the Construction Industry Council (CIC), a representative organisation of professionals, research organisations, and business associations in the construction industry, was tasked with establishing a network of regional hubs to disseminate information about BIM and the according requirements across the UK.

Notably, BIM was not really defined by the strategy; the document does not provide a clarification what BIM exactly means and what it encompasses and what not. In the following years, the government used a taxonomy of so-called maturity levels with regard to BIM with the 2011 mandate referring to Level 2 BIM. Essentially, Level 2 BIM denoted a managed 3D environment allowing for collaboration but with data still created in separate discipline models. The taxonomy of BIM maturity levels was eventually abandoned in 2019 and replaced by the "UK BIM Framework" (Construction Innovation Hub 2020).

In 2013, the Construction Strategy was followed by another sector-specific industrial policy programme titled *Construction 2025* (HM Government 2013), set up as a joint industry -government strategy "to put Britain at the forefront of global construction over the coming years" (ibid., 3). The goals were more ambitious than just reducing the costs of public construction. It stipulates that the construction industry and government jointly aspire to achieve by the end of 2025

- a 33% reduction in initial and whole life cost of construction,
- a 50% reduction in the overall time from inception to completion for new build and refurbished assets,
- a 50% reduction in greenhouse gas emissions in the built environment,
- a 50% reduction in the trade gap between total exports and total imports for construction products and materials (ibid., 5).

With this strategy, industry and government committed to the BIM programme, agreeing that

> *only* through the implementation of BIM will we be able to deliver more sustainable buildings, more quickly and more efficiently. BIM is also critical to the successful implementation of a wider offsite manufacturing strategy. (ibid., 9, emphasis added)

Construction 2025 makes extensive mention of sustainability, green buildings, and reduced carbon emissions. The official policy goal for the built environment at the time was to meet a 80% carbon reduction target by 2050 (ibid., 34). This document for the first time introduced the idiom of reducing "cost and carbon," which would recur time and again in subsequent policy documents, indicating the expectation that digital technology will serve to achieve both goals at the same time and in the same move. In *Construction 2025,* however, digitalisation and sustainability goals were largely addressed in separate chapters; construction should improve on both counts, it was stipulated, but it was not discussed whether and how exactly digitalisation should be implemented in a way that GHE and environmental damage are effectively reduced.

A pervasive theme in *Construction 2025* and ensuing programmes is the UK's world leadership in architecture, engineering, and construction (AEC) and how to preserve it. Following Jasanoff (2015), we can see a proper nation-specific sociotechnical imaginary here, presenting Britain both as successor to the British Empire and as the birth nation of modern science and technology, associating the idea of geopolitical greatness with the idea of being quintessentially modern. Yet, the imaginary does not only refer to the past but also to the quest for future market shares and the belief that digital technologies and data systems will provide future solutions to all kinds of problems.

In following years, visions and policies of digital architecture and construction were recurrently interpreted and enacted against the backdrop of this imaginary. The UK, such the claim, has world-class expertise in architectural design, civil engineering, sustainable construction, health and safety in construction, and science and research in general (HM Government 2013, 16). In 2025, according to their vision, it will have maintained and further expanded its leadership role; it will lead the world in low-carbon and green construction exports (ibid., 4, 10) and have a construction industry with a reputation for creating a world-class built environment (ibid., 41). To this end, a concerted commitment to BIM by government and industry was considered mandatory; only that way would construction be able to overcome the multiple problems it was facing – from low levels of innovation, lack of collaboration and sharing of knowledge, lack of training, high degree of fragmentation, to high costs – and secure Britain a prime position in the global construction economy.

5.2 From Digital Design to a Data-Based Economy

The idea of securing world leadership through digital architecture and construction was also proclaimed by the subsequent policy strategy Digital Built Britain (DBB) (HM Government 2015). The general reasoning was that UK companies, planners, and professionals already do have world-class capabilities and already do deliver world-class services and products, but in order to maintain its position, the UK now must adopt world leadership in terms of digitising construction.

One major goal of *Digital Built Britain* was to lead UK construction from implementing Level 2 BIM to Level 3 BIM, resulting from a partnership between the Department of Business, Energy & Industrial Strategy and Innovate UK.[5] The vision was to

> make fully computerized construction the norm and ensure that the benefits of these technologies are felt across the UK and support the export of these technologies and the services based on them. We want to sell our expertise and our cutting edge technologies across the world and seize a share of the $15 trillion global construction market forecast by 2025. (ibid., 5)

The purpose of Level 3 BIM within the DBB strategy was to extend the use of BIM on two dimensions: On the level of individual projects, the use of BIM should be extended on a temporal axis, from the design and delivery phases to procurement, operation, and maintenance. Second, BIM was seen as a core element within a network of technologies and approaches expected to connect over the next decade, such as the internet of things, advanced data analytics, and the digital economy at large. The purpose of BIM Level 3, as the industry foreword states, is to "enable the country to capture not only all of the inherent value in our built assets, but also the data to create a digital and smart city economy" (ibid., 4).

Thus, the policy aimed at embedding BIM in an informational reconfiguration of the entire British economy. Now the stated objective was to create a cross sector approach that would align the construction, the facilities and asset management industries, and developments in the broader economy such as big data, telemetry, and data analytics (ibid., 23). Accordingly, the title "Digital Built Britain" alludes both to digitising building construction and the idea "that Britain is increasingly 'digitally built'" (ibid., 28). The long-term goal is to create an integrated digital economy for infrastructure, buildings, and services (Gov.UK 2017), including health, education, welfare, transportation, finance, and insurance services (HM Government 2015, 36).

[5] Innovate UK is a non-departmental public body operating at arm's length from the government as part of the United Kingdom Research and Innovation organisation. It provides money and support to organisations for business-led innovation. www.ukri.org/councils/innovate-uk/?_ga=2.87079962.325400516.1644501054-1755795382.1629101951 (Accessed November 1, 2022).

Within this overarching strategy, BIM acts as a critical gateway. It is supposed to operate as an approach for optimising planning and construction but also as a means to hold, share, and exploit information in the operational and maintenance phases up to renewal, replacement, and creation of new built assets. The strategy envisions that various markets such as the Smart Cities agenda and the wider market for data analytics and big data will, in the near future, create opportunities for exploiting data resources from built assets (HM Government 2015, 12). A vision of DBB is to channel all these BIM data into government created data stores:

> Under the Digital Built Britain vision, data developed through the delivery, operational and performance phases contained in these data stores will be selectively published through data.gov and other secure gateways as Open data for further market use. (ibid., 14)

In the future, so the strategy expects, even more data about people and social issues would become available and "provide a rich operational analytics market place" (ibid., 16). A key issue for achieving these goals was interoperability and the existence of standards such as BIM standards, standard product libraries, and open data standards.

The DBB strategy also met with criticism as some considered it premature to introduce Level 3 BIM when the issues with Level 2 BIM were not yet solved: "We may have three or four software platforms that are okay for design and construction, but talking about Level 3 BIM when we're struggling with Level 2 seems bizarre," one architect put it (Designing Buildings Wiki 2021). Notably, environmental sustainability plays basically no role in the DBB strategy, being mentioned once or twice only.

5.3 Building Safety and the Golden Thread of Information

Aside from industrial policy, BIM was also promoted as a solution to the problems of building safety. In June 2017, 72 people died when a fire broke out in the 24-storey residential Grenfell Tower in North Kensington in London, many more were injured and hundreds lost their home. While the government argued that the fire was due to a breach in existing fire safety regulations, it was contested whether the supervising authority had not actually approved the use of the insulating material that allowed the fire to spread (Apps, Barnes, and Barratt 2018). Critical inspection showed that the catastrophe had a political history, as fire safety regulation had been continuously diminished since the mid-1980s due to neoliberal politics of deregulation. Additionally, building safety supervision was partly privatised by the Thatcher government in 1985. In 1997, the conservative government additionally opened building safety control to competition, resulting in a fast increase of private supervision firms (205ff.). It was PM David Cameron's declared political maxim to "kill off security culture" and, in 2016, the government announced they would from now on follow a "one in, three out" rule: For each new rule adopted, three existing ones had to go, in order to spare the national economy costs through deregulating construction (Apps, Barnes, and Barratt 2018).

Following the Grenfell fire, the government commissioned an independent review of building regulations and fire safety. The eventual report, *Building a Safer Future* (Dame Hackitt 2018), recommended among other things a building information management system, termed the "golden thread" of building information, as a means to ensure building safety. The "golden thread" should be kept in digital format and contain the information needed to demonstrate compliance with specified building regulations. The government later declared they would "make regulations to put a duty on the people responsible for buildings to put in place and maintain a golden thread that is accurate, accessible and up to date" (Gov.UK 2021). They thus chose a technological solution, largely based on BIM, and placed the responsibility for implementing it on the shoulders of building owners; datafication of building safety should solve the problems created by previous policy failure.

5.4 From Project Modelling to Data Assets

Since the late 2010s, the idea has gained ground that information management was the solution for various problems in the building sector and beyond, that it needs to be as comprehensive as possible, and that BIM data formed an essential resource for such a comprehensive system. More far reaching than the "golden thread" was the National Digital Twin programme (NDTp). It went back to the National Infrastructure Commission's report *Data for the Public Good* (NIC 2017) that highlighted among other things the need for a national programme to make use of data generated in the built environment. The report recommended the development of a national digital twin (NDT) as a national resource for improving the performance, quality of service, and value delivered by assets, processes, and systems in the built environment (CDBB 2018, 8). It was launched in 2018 and is run since by the Centre for Digital Built Britain (CDBB).

A digital twin, for the CDBB, is "a realistic digital representation of assets, processes or systems in the built or natural environment" (CDBB 2018, 11). The concept may refer to entities on various scales such individual buildings, bridges, and energy or wastewater treatment plants to local road networks or whole cities. Importantly, a digital twin differs from a mere digital model in that it comprises an entity in the physical world, its digital representation, and the interactions between them:

> Based on data from the physical asset or system, a digital twin unlocks value principally by supporting improved decision making, which creates the opportunity for positive feedback into the physical twin. (ibid., 10)

With Cristina Alaimo, Jannis Kallinikos, and Aleksi Aaltonen (2020), a digital twin can be understood as an apparatus of data production and value creation, allowing to create value through capturing, aggregating, curating, and recombining data referring to the physical object; the asset is a connection between the physical object and the data object constituted by the clustering and aggregation of data.

The national digital twin is envisaged as an ecosystem of individual digital twins connected through integrated information management (Construction Innovation Hub 2020, 4). The idea is not to create one comprehensive digital twin that would cover the nation's entire built environment, but a system that allows for sharing information between individual digital twins across the building and the infrastructure sectors (CDBB 2018, 12) which would include transport, energy, water, and telecommunications. For this to happen, the policy relies on a national infrastructure for creating, arranging, sharing, and securing data objects. The necessary data, so the idea goes, should be generated through a broad range of decentralised data-collecting apparatuses such as GPS, ticketing, social media, drones, CCTV, BIM, manufacturers' data, and more (ibid., 9). Yet, to create a national federation out of these decentralised data-production points, it takes a whole national data infrastructure. "An NDT," the CDBB explains, "requires information and data to be compatible across the built and natural environment, presented in consistent formats to allow for sharing and integration between different digital twins. It requires curation and mapping of existing and future models and data" (CDBB 2020, 9).

For this to happen a group of experts devised the information management framework (IMF) to set out necessary technical standards, processes, and interoperability frameworks (CDBB 2020). If the NDT is envisaged as a huge national data source, the infrastructure supporting it is envisaged as a "commons" that allows for accessing and sharing data and unlocking the potential value they hold. What is astonishing is the widespread data empiricism, which for a long time has ignored both the heterogeneous conditions under which the data were created and collected through context-specific practices of processing, cleaning and merging, and the subsequent processes of disseminating, decontextualizing, recontextualizing, and reusing data, which have been critically explored under the concept of "data journeys" (Leonelli 2014; Bates, Lin, and Goodale 2016) and may result in growing risks of vulnerability in the future.

Yet, there is a certain awareness that the NDT vision implies security risks as well as difficulties to implement it as a "commons" that can and will be employed for the common good and not only for the interests of particular interest groups. Issues of security and openness are addressed by the so-called Gemini Principles published by the CDBB and compiled by the Digital Framework Task Group. The principles were meant as a compilation of values and principles, stating that the NDT should be committed to the values of openness, security, and quality and all digital twins should have clear purpose, be trustworthy and function effectively (CDBB 2018). Openness of data and information, for the CIH, "means that it is provided or made available in a format that can be accessed and used without recourse to the software that generated it" (Construction Innovation Hub 2020, 7). Openness, in this context, is not so much a legal category but a technical and economic one; if data and information, for technical reasons, can only be accessed by users of a specific software product, provided by a specific software provider, then that provider controls access to that data and information. They may not own the data but they own the entry points to it. Given that a small number of software vendors dominate the market for design and construction software in the UK, this might pose considerable difficulties for keeping the information commons in fact common and equally accessible to all. According to a 2020 NBS survey, three out of the five most used design tools with together 70% of user share were Autodesk products (NBS 2020, 24).

In principle, interoperability and open standards may help alleviate the problem, which is why the Gemini Principles postulate that the NDT "must be based on open standards, industry best practices and open application programming interfaces (API) to allow a vendor-neutral approach, with industry-agreed architecture models" (CDBB 2018, 21). However, research on "data journeys" sensitises to the heterogeneous data practices with many interoperability issues and implications. Moreover, to achieve security, principles of openness, and commonness in practice, pose huge challenges for the design of the NDT policy. Although not prominently highlighted, the documents betray some concern that the wide-spread use of proprietary software solutions and resulting vendor-lock-in effects may pose an impediment to the openness and commons-nature of the national data assets:

> By proposing and standardising open protocols, we will minimise barriers to participation in the Commons arising from vendor lock-in. We must be able to freely distribute new content developed in the Commons, and new actors will be able to contribute data sets and digital twins to the NDT with zero cost of entry. (CDBB 2020, 38)

Vendor lock-in is seen as a problem, but apparently the authors do not think it can be solved, only minimized. Thus, even techno-optimistic reports see the possibility that traditional divisions and fragmentations between crafts, disciplines, or project partners might be replaced by new ones constituted by the business strategies of private IT corporations.

On the way to creating a digital construction economy, the government further published its *Construction Playbook* in 2020, which is supposed to act as a "compact" between government and the construction sector to make sure that public sector works are delivered faster, better, and greener. It outlines the key role the government has assigned the construction sector with regard to ensure the UK's recovery from the COVID-19 pandemic, the goal of achieving net zero carbon emissions by 2050, and, more implicitly, creating an integrated, globally competitive digital economy.

Aside from other measures, the playbook suggested measures to drive what it terms Modern Methods of Construction (MMC), and measures to "standardise designs, components and interfaces as much as is possible" (HM Government 2020, 3). Not only individual construction projects but the whole sector and the overall national economy, as noted by the playbook, were in need of more standardised approaches as regards designs and their management as well as ways of generating and classifying data, data security, and data exchange. Presently, issues of data fragmentation, quality, availability, and accessibility pose major barriers on the way ahead:

> While the volume of data relating to UK construction is rapidly increasing, it is often fragmented or not easily accessible. Improving the consistency and quality of data will be transformational in how we can deliver projects and programmes by improving safety, enabling innovation, reducing costs, and supporting more sustainable outcomes. (ibid., 20)

BIM is seen as a core element for creating an integrated information management for the construction sector, which, in turn, is envisioned to form the runway toward an integrated information management for the overall national economy. With this in mind, the document stipulates:

> Adopting the UK BIM Framework will support the Information Management Framework, a common framework of standards and protocols that will enable secure, resilient data sharing across organisations and sectors. In turn, the Information Management Framework will be a key enabler of the National Digital Twin – an ecosystem of connected digital twins across the built environment. (ibid., 20)

Matters of data and information exchange and the according requirements of standardisation and interoperability continue to be of utmost concern for UK BIM-and-beyond policy, guided by a vision of integrated data management across construction and beyond. BIM, properly understood, is supposed to provide the "golden thread" of data that runs through an asset's lifecycle, from inception to disposal and furthermore connect it to national leadership and welfare. Thus, BIM is no longer understood as a tool for creating 3D designs but a resource for the creation, exchange, use, and reuse of asset data. Lacking or incomplete interoperability is perceived as inability to maintain and access this "golden thread" of information, which ultimately endangers the UK's leadership position in BIM development and implementation (Construction Innovation Hub 2020, 8).

To meet this challenge, the CDBB together with other organisations set up a BIM interoperability programme to improve data exchange and data sharing, the BIM Interoperability Expert Group (BIEG). It consulted 21 stakeholder organisations including clients, industry experts, BIM information management practitioners, academia, standardisation bodies, and technology providers and invited them to give evidence on current issues of interoperability when implementing BIM and deliver recommendations how the situation can be improved (Construction Innovation Hub 2020). The report defines interoperability as “the ability to exchange information between proprietary technologies, so that it can subsequently be made use of in which ever system it is located” (ibid., 5). Thus, interoperability is not synonymous with open data or open-source. Openness in relation to data and information, here, means that data or information is provided “in a format that can be accessed and used without recourse to the software that generated it” (Construction Innovation Hub 2020). Openness is not a precondition for interoperability, but the latter can be achieved through the use of compatible proprietary systems – which, in turn, “might be achieved by using software products from the same vendor” (ibid., 7). The interoperability policy developed does not promote, let alone require, the use of non-proprietary software and does not interfere with the interest of software providers to tie users to their software products and increase their market share (Braun, Kropp, and Boeva, forthcoming). And it is by no means a solution to the risks and issues involved in heterogeneous data practices and the resulting data frictions.

6. Conclusion

We can see that between 2011 and 2021, BIM morphed from a vaguely defined design and deliver device to save “cost and carbon” into an apparatus for data-generating assets. Buildings would operate as a source of data that would flow through an asset’s lifecycle and into a national information management system. Connecting, modulating, analysing, sharing, exchanging, using, and reusing data would allow both public and private actors to optimize decision-making and to unlock the “hidden value” enclosed in the assets in the form of data.

In the British case, the digital transformation of planning and construction is critically driven by the government and alliances between government, industry and academic actors, forming a discourse coalition of powerful actors who, as such, were able to select particular values and objectives, inscribe them into a national technopolitical agenda equipped with institutions and instruments, and thereby translate them into pathways of further sociodigital transformation. In this process, some sociodigital visions turned out more powerful than others. While on the level of political, academic, and professional discourses in British, German, and international publics and fora, a scope of concurring visions could be found regarding the future of construction, this scope was somewhat narrower. The vision of creating a sustainable, decarbonised built environment by means of data and digital technologies figures in many policy documents in the UK case. However, solving the environmental and climate crises is neither the primary motivation nor the top priority of these programmes. The first and foremost priority is to increase productivity and economic growth, improve global competitiveness, and secure the UK a leading position in the emerging economy of data analytics, smart cities, digital twins, and further. Improving sustainability rather figures as a welcome by-product of advancing these technoeconomic ambitions. Visions of a digitally enabled, aesthetically attractive, affordable, complex, singularised architecture do not figure at all into this agenda. Certainly, this does not mean, they do not figure, for instance, into UK architecture, but they do not drive the BIM-and-beyond policy discourses and pathways. The vision of automated, industrialised construction boosting efficiency and productivity certainly is present, but the most influential vision providing direction to these policies is that of creating a comprehensive, integrated, data-based information management system that will serve as a kind of universal infrastructure for a data-driven management of economy and society. Captured in metaphors such as the "golden thread of information" or the "national digital twin," this emergent, as yet imagined, infrastructure is expected to simultaneously improve public services, remedy the consequences of neoliberal deregulation policies such as poor building safety, help to meet decarbonisation targets, secure the UK a competitive advantage in the global digital economy, and bring back its position of world leadership, this time by virtue of its technoscientific and technoeconomic capabilities.

Essentially, it is the vision of a programmable society that looms ahead of these programmes for the digital transformation of planning and construction. In this development, visions of a digital transformation are linked to technological developments to form national strategies in which data are not merely a management resource (Alaimo and Kallinikos 2022), but a central asset and an omnipresent medium for the organisational or even technoeconomic opening of markets by digital platforms leading to novel accumulation chances (Braun, Kropp, and Boeva, forthcoming). Against this background, the datafication of the construction industry should not be misunderstood as a neutral process of integrated management of information, as the documents make it appear, but as a cross-sector manoeuvre of reorganising international competition and digital capitalism. Our analysis provides a glimpse of how, in the space of just ten years, the breadth of four competing visions of the future of digital construction has narrowed and how, in a driving alliance of government and industry, a specific, data-driven trajectory of digital transformation has gotten off the ground step by step.

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