RICS PRACTICE INFORMATION

# The future of BIM: digital transformation in the UK construction and infrastructure sector

UK

1st edition, July 2020

# The future of BIM: digital transformation in the UK construction and infrastructure sector

RICS practice information, UK

1st edition, July 2020

**Copyright acknowledgements**

Figures 3, 4 and 9b are reproduced with permission from BSI, CDBB and UK BIM Alliance. Permission to reproduce extracts from British Standards is granted by BSI. British Standards can be obtained in PDF or hard copy formats from the BSI online shop: **https://shop.bsigroup.com** or by contacting BSI Customer Services for hardcopies only:
Tel: +44 (0)20 8996 9001, email: **cservices@bsigroup.com**

Figure 9a is reproduced with permission from Mark Bew.

Figure 11 is reproduced with permission from Chapman Taylor Architects.

Figure 13 showing **the solar energy potential of Helsinki Olympic Stadium** by **Helsinki 3D+** is licensed under **CC 4.0 International.**

Contains public sector information licensed under the Open Government Licence v3.0: **www.nationalarchives.gov.uk/doc/open-government-licence/version/3/**

**Published by the Royal Institution of Chartered Surveyors (RICS)**

RICS, Parliament Square, London SW1P 3AD

**www.rics.org**

This document was originally published in July 2020 as an RICS insight paper and was reissued in April 2023 as RICS practice information.

ISBN 978 1 78321 395 5

Typeset using Typefi.

# Acknowledgements


## Authors

Thomas Dowd MRICS (Liverpool John Moores University)

Dianne Marsh MRICS (Liverpool John Moores University)

## Professional group leads

Alan Muse FRICS

Anil Sawhney FRICS

## Freelance editor

Jess Rogers

# Contents

**Acknowledgements** ........ **iii**

**RICS standards framework** ........ **1**

Document definitions ........ 2

**Glossary** ........ **3**

**Foreword** ........ **5**

**1 Introduction** ........ **6**

1.1 Purpose ........ 6

**2 The background to BIM** ........ **8**

2.1 BIM within the built environment ........ 8

2.2 The 'I' in BIM ........ 9

2.3 Dimensions of BIM ........ 10

2.4 BIM collaboration ........ 10

2.5 Current level of adoption ........ 13

**3 The evolution of BIM** ........ **14**

3.1 Overview ........ 14

3.2 The Bew-Richards maturity model (2008) ........ 16

3.3 Digital Built Britain (2015) ........ 16

3.4 Industry 4.0/construction 4.0 (2017) ........ 20

3.5 Design, build, operate and integrate (2018) ........ 20

3.6 BIM according to BS EN ISO 19650 (2019): implementation of information management ........ 20

3.7 BIM evolution: summary ........ 23

**4 Information management, BIM and industry 4.0 technologies** ........ **25**

4.1 Overview ........ 25

4.2 Opportunities ........ 25

4.3 Summary ........ 34

**5 Future action and challenges** ........ **36**

5.1 Overview ........ 36

5.2 Plan of action ........ 36

5.3 Future challenges ........ 37

**6 Summary and conclusions** ........ **40**

7 References ........................................................................................ 43
Appendix A: Digital technologies/value for RICS groups .............................. 48

# RICS standards framework

RICS' standards setting is governed and overseen by the Standards and Regulation Board (SRB). The SRB's aims are to operate in the public interest, and to develop the technical and ethical competence of the profession and its ability to deliver ethical practice to high standards globally.

The RICS Rules of Conduct set high-level professional requirements for the global chartered surveying profession. These are supported by more detailed standards and information relating to professional conduct and technical competency.

The SRB focuses on the conduct and competence of RICS members, to set standards that are proportionate, in the public interest and based on risk. Its approach is to foster a supportive atmosphere that encourages a strong, diverse, inclusive, effective and sustainable surveying profession.

As well as developing its own standards, RICS works collaboratively with other bodies at a national and international level to develop documents relevant to professional practice, such as cross-sector guidance, codes and standards. The application of these collaborative documents by RICS members will be defined either within the document itself or in associated RICS-published documents.

## Document definitions

| Document type | Definition |
|---|---|
| **RICS professional standards** | **Set requirements or expectations for RICS members and regulated firms about how they provide services or the outcomes of their actions.**<br><br>RICS professional standards are principles-based and focused on outcomes and good practice. Any requirements included set a baseline expectation for competent delivery or ethical behaviour.<br><br>They include practices and behaviours intended to protect clients and other stakeholders, as well as ensuring their reasonable expectations of ethics, integrity, technical competence and diligence are met. Members must comply with an RICS professional standard. They may include:<br><br>• mandatory requirements, which use the word 'must' and must be complied with, and/or<br>• recommended best practice, which uses the word 'should'. It is recognised that there may be acceptable alternatives to best practice that achieve the same or a better outcome.<br><br>In regulatory or disciplinary proceedings, RICS will take into account relevant professional standards when deciding whether an RICS member or regulated firm acted appropriately and with reasonable competence. It is also likely that during any legal proceedings a judge, adjudicator or equivalent will take RICS professional standards into account. |
| RICS practice information | **Information to support the practice, knowledge and performance of RICS members and regulated firms, and the demand for professional services.**<br><br>Practice information includes definitions, processes, toolkits, checklists, insights, research and technical information or advice. It also includes documents that aim to provide common benchmarks or approaches across a sector to help build efficient and consistent practice.<br><br>This information is not mandatory and does not set requirements for RICS members or make explicit recommendations. |

# Glossary

| Term | Definition |
| --- | --- |
| **3D printing** | Creation of a physical 3D object from a 3D design created by layering materials to provide its form. |
| **Artificial intelligence (AI)** | Digital technologies that enable machines to replicate or even exceed human intelligence in specific tasks. |
| **Big data** | A collection of large amounts of unrelated data that, once analysed, can create value. |
| **Blockchain** | Akin to a physical ledger: the pages are the blocks that are linked together by the chains creating a secure, undisputable record of digital transactions.[1] |
| **Building information modelling (BIM)** | BIM is fluid and dynamic in definition: it is driven by the creation and management of information during a project's life cycle, supported by technology and a collaborative process. |
| **Common data environment (CDE)** | A single source of information used to collect, manage and exchange project documents, consisting of various forms of information (such as models, drawings, schedules, etc.). Facilitating collaboration between project team members helps to avoid duplication and mistakes.[2] Depending on the project's requirements, a range of technologies may be required to facilitate collaboration and act as a CDE; if so, how they interface with other needs to be considered.[3] |
| **Construction 4.0** | The term used to define the impact of the fourth industrial revolution on the built environment. |
| **Data analytics** | The analysis of big data using software and/or algorithms to create value. |
| **Digital Built Britain** | The digitalisation of the UK's built environment. |

| Term | Definition |
|---|---|
| **Digital twins** | A 3D digital model connected in real time to a real physical asset, replacing 'as built' drawings with 'as is'.[4] |
| **Fourth industrial revolution** | A digital revolution defined by emerging technologies. It emerged from the third industrial revolution (electronics and information technology). The first revolution was water and steam power, and the second was electric power. |
| **Industry 4.0** | The term used to define the impact of the fourth industrial revolution on the manufacturing industry. |
| **Internet of Things (IoT)** | The connection of any physical objects, via the internet, to enable the sharing and analysis of data, allowing them to be automated or controlled remotely.[5] |
| **Optioneering** | The methodical analysis of alternative solutions in terms of products, technologies and designs adopted to inform smarter decision-making processes in the built environment. |
| **Smart building** | A smart building records real-time information (data) of its components and occupants via the Internet of Things; this can then be analysed to ensure optimal performance and enhance usage for the occupants.[6] |
| **Smart city** | An extension of smart buildings, connecting a city's buildings and infrastructure to enhance their performance and use for citizens. |

# Foreword

The landscape of BIM has changed significantly over the last 5 years, with the break-up of the UK BIM Task Group, and the shift to international standards. This has caused some confusion and doubt as to the commitment of public sector clients, and the way to proceed.

The launch of the UK BIM Framework in the autumn of 2019 marked a significant step forward in providing clarity on the way forward. It came with a commitment from British Standards Institution (BSI), Centre of Digital Built Britain (CDBB) and the UK BIM Alliance to work together in supporting the industry in its implementation of BIM as the fundamental step to the wider digital transformation of the built environment in the UK.

This publication provides useful insight into the progression of the BIM movement in the UK, charting the continued development and transition of standards to ISO, and the original work of the UK BIM Task Group extending out to the wider built environment industry, exemplified by the significant collaborative effort in developing the UK Guidance for the BS EN ISO 19650 series and the UK BIM Framework as a whole.

There remains much to be done. With the collaborative leadership and support of the professional bodies, such as RICS, and with the combined efforts of BSI, CDBB and the UK BIM Alliance around the UK BIM Framework, the UK is now in a great position to consolidate its position as one of the global leaders in the field of digital transformation.

**Dr Anne C. Kemp OBE FRICS**

**Atkins Global**

# 1 Introduction

The influence that technology has had on the surveying profession has been the subject of much debate. Recently, this debate has centred on building information modelling (BIM) and the potential benefits it can bring to a project and asset life cycle. Traditionally, surveyors have employed technology to design and manage the construction process but, now, asset surveyors are increasingly realising BIM's potential to create efficiencies throughout the project life cycle. BIM not only allows the sector to offer innovative solutions to small- and large-scale problems, but also supports stakeholders in creating an efficient method of working that is capable of creating and adding value.

BIM has evolved into a much bigger paradigm, and what this means for chartered surveyors is constantly shifting. The industry is now on the verge of the fourth industrial revolution: digitalisation is having a profound impact on the work itself and the way the industry works together.[7] As clients increasingly look to technology for solutions that create efficiencies, the profession needs to gain a better-informed understanding of:

- what BIM has to offer in terms of technology and
- how the narrative surrounding BIM is changing.

Surveyors need to be more proficient in the use of these technologies so that data, artificial intelligence (AI) and the Internet of Things (IoT) are at the core of service provision.

However, BIM is not only about technology but also about processes, protocol and standards. The publication of the BS EN ISO 19650 series has introduced a collaborative framework for managing information through BIM throughout the whole life cycle of an asset, irrespective of its type or size. BS EN ISO 19650 identifies BIM as methodologies that offer a solution to store and exchange information (BIM technology), and as a method to manage information through these internationally agreed standards. BIM maturity is described in terms of stages and information management, not around BIM levels 1, 2 or 3.

Therefore, it is essential that surveyors understand the current BIM framework within which they operate and the technologies that can not only support them in their role but also provide the client and end user with the information they need in order to efficiently manage the asset.

## 1.1 Purpose

It is essential to understand that there is no one definition of BIM: it means different things to surveyors in different roles and to the various organisations that they serve.[8] Additionally, as more technologies become available, this understanding of what BIM can offer will change. Consequently, with the introduction of BS EN ISO 19650, and as technology develops, the industry's perception of BIM will become blurred, and the stages/levels of BIM will become less obvious. Surveyors first need to develop an understanding of what BIM has developed into, and then need to consider why they should adopt it.

This practice information aims to provide some answers about the evolving 'what' and 'why' of BIM and its potential. This potential has previously centred around technology and the sharing of information (as defined by levels 1, 2 and 3) but, now, the shift is towards information 'management' as opposed to 'modelling', and towards linking other industry 4.0 technologies. This practice information outlines:

- the background to BIM
- the need to innovate
- why the development of the definition of BIM needs to be explored and
- the need to examine the digital technologies available.

This practice information aims to assist chartered surveyors in making better-informed strategic decisions around BIM implementation that will support market leadership and authority in their field.

This practice information is organised into six chapters. Chapter 2 introduces the background to BIM within the built environment. Chapter 3 considers the evolving definitions of BIM. Chapter 4 looks specifically at the potential technologies available to the chartered surveyor. Chapter 5 examines the future action required if surveyors are to move forward with BIM and discusses the challenges that they may face. Chapter 6 provides a summary. Case studies are provided throughout to further support the application of BIM and its benefits to the profession.

# 2 The background to BIM

## 2.1 BIM within the built environment

Construction is a major player in the global economy: it represents 13% of gross domestic product (GDP) and employs 7% of the global working-age population.[9] In contrast, UK construction represents a much lower proportion of GDP (at approximately 6% (£113bn)) and employs 2.4m people[10] across a wide range of products, services (including chartered surveyors) and technologies. Nevertheless, it contributes significantly to the UK economy and, as such, is often the focus of scrutiny. Productivity and predictability are major concerns in the construction and property sector; the need for significant change to industry practices in order to overcome these issues has been the subject of numerous reports, as shown in Figure 1.

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/Figure
1.jpg.

Figure 1: Major construction reports

Many of these reports concentrated on identifying problems and setting targets and placed less emphasis on solutions. The Government Construction Strategy 2011 (GCS 2011) specifically identified technology as a solution to public sector asset procurement and management. It identified BIM and digital technologies as being key to transforming work practices, which was necessary to improve productivity. By adopting new ways of working, GCS 2011 believed a target of 20% efficiencies in public-sector construction spends would be possible, although in reality only 7% were realised, as reported in GCS 2016–20. The Construction 2025 strategy together with GCS 2016–20 continued with the technological themes of its counterpart but now offered a long-term view of industry and government working together to achieve targets, as shown in Figure 2. The aim now is to become global leaders in construction through the digitalisation of the industry, with BIM at its core.

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/Figure
2.jpg.

Figure 2: Construction 2025 targets (adapted from Construction 2025, licensed under the Open Government Licence v3.0)

More recently, the Industrial Strategy: Construction Sector Deal promoted collaboration between government, industry and research institutes to support the transformation of the sector through technological innovation and the creation of a highly skilled workforce.[11] In this document, the UK government pledged funding to research institutes such as the Centre for Digital Built Britain to support innovation in areas centred on digital design, new technologies and offsite manufacturing. Unfortunately, the construction sector is notoriously slow to innovate, being one of the least-digitised industries in the world.[12] However, there has never been a better time than now for chartered surveyors to boost their productivity through AI and data analytics technologies, to name but a few, in order to support businesses in creating efficiencies and to stimulate economic growth.

## 2.2 The 'I' in BIM

BIM uses advanced computer systems to build 3D models that can store information about an asset in terms of its design, condition and operation.[13] BIM is often perceived as not being relevant to all built-environment professionals – they see 'building' as being distinct to only one aspect of the profession. But information (the 'I') is relevant to all. Information is a valuable resource, the value of which cannot be underestimated during the life cycle of a built asset. With the availability of international standards, the focus is shifting from technology around BIM to a clear and precise focus on information and its management and security.

Chartered surveyors are the producers and custodians of this information over the life cycle of a built asset. As further advances in AI and advanced data analytics continue, the potential in terms of faster, better-informed decisions is huge.

The management of this information is key to improving productivity, not only within organisations but also across the sector as a whole. It offers clients faster, more accurate decisions based on real-time data. It is therefore a professional responsibility to digitise data in order to inform and transform business effectiveness and contribute to the well-being of society as a whole.[14]

## 2.3 Dimensions of BIM

BIM is multi-dimensional and allows extra dimensions of data to be linked to a model. As more information is made available in addition to a design, it can be added (e.g. cost and schedule), thereby providing a fuller understanding of the project/asset. As new information is added to the model, the role of international standards, such as the International Construction Measurement Standards (ICMS), become increasingly important. These standards allow sharing of information in a standardised fashion.

Decisions about the type of information stored (and why) are often based on the technology available and how the business values the information, which often relates to the type of decisions the business makes. The common dimensions of BIM that have been developed are:

- design (3D)
- time (4D)
- cost (5D)
- sustainability (6D)
- facilities management (7D) and
- health and safety (8D).

The dimensions apply to surveyors in all roles and can support decision-making in real estate (3D, 5D, 6D, 7D), quantity surveying (5D, 6D) and project management (3D, 4D, 5D). BS EN ISO 19650 now recommends that the information provided is constrained to that required to make decisions, and that the client only receives information that will be of value to them. It is essential to reflect that these extra dimensions should only be added if this information is requested by the client or end user or is likely to add value to the process.

## 2.4 BIM collaboration

BIM supports the sharing and integration of information and collaboration. BS 1192:2007 was the foundation document to support collaboration which led to the development of the suite of PAS 1192-2:2013 documents. There is now a move from the PAS 1192 series of standards to international standards following the publication of the first two parts of a new international BIM standard, BS EN ISO 19650 (see Figure 3).

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/Figure
3.jpg.

Figure 3: BIM international standards (from PD 196500:2019 Transition Guidance to BS EN ISO 19650, reproduced with permission from BSI)

In this publication, the principles of BIM level 2 remain the same and are loosely replaced by information management maturity stage 2. BS EN ISO 19650 provides a collaborative framework for managing information through BIM throughout the whole life cycle of an asset, irrespective of its type or size.

The associated *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* offers an insight into the current perception of BIM, where maturity is around information management and stages, not levels, as was previously the case. It places emphasis on the client providing clear, value-driven definitions of their information requirements based on the quality and quantity of information required and the efficient, timely transfer of this information between the various parties at each stage in the project life cycle. It identifies BIM methodologies for information management and digital technologies that support the exchange of data which help parties to make better-informed decisions based on improved predictability through improved risk management. The common data environment (CDE) workflows are pivotal to the efficient exchange of information and are not just the technology used to support it, as was previously the case (i.e. a model). *Information Management According to BS EN ISO 19650 – Guidance Part 2: Processes for Project Delivery* offers further guidance, including CDE workflows and the activities associated with ISO 19650-2 clause 5.

The processes detailed in BS EN ISO 19650-1 and 2 are similar to those identified in BS 1192:2007 and the PAS 1192-2:2013 suite of documents that it replaces. There is some variance in terminology between the two sets of standards that needs to be considered from a legal and contract perspective, as identified in Table 1.

| Old term (PAS 1192 documents) | New term (BS EN ISO 19650 documents) |
|---|---|
| Contract | Appointment |
| Employer | Appointing party<br>Lead appointing party (tier 1)<br>Appointed party (tier 2) |
| Employer's information requirements (EIRs) | Exchange information requirements (NB also known by the acronym EIRs) |
| Level of model definition<br>Level of detail (LOD)<br>Level of information (LOI) | Level of information need |
| Responsibility matrix | Responsibility matrix<br>Assignment matrix |
| Suitability | Status |
| Supplier | Lead appointment party (tier 1)<br>Appointed party (tier 2 and below) |

Table 1: Comparison of terms (based on Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts (2nd edition)

At the time of writing, all other standards in the BIM level 2 suite remain, in order to help define processes and procedures around the digital exchange of data sets through the life cycle of a project. However, these too are likely to change from 2020 onwards, with PAS 1192-3:2014 scheduled to be replaced with BS EN ISO 19650-3 and PAS 1192-5:2015 with BS EN ISO 19650-5. In addition, at the time of writing, the BS 8451 series *Library Objects for Architecture, Engineering and Construction* were being developed in the form of ISO 22014 and 22057.

To support the industry during this switch from the current known suite of documents, a transition guidance document has been prepared to help the existing users of BS 1192 and PAS 1192-2 understand the changes made between the UK's standards and the ISO documents that replace them.

These ISO documents recognise the potential value of information; they place less emphasis on the model and more emphasis on information management. 'Information protocol' is one of the most important documents in the ISO process, linking information management of asset delivery to that of its operation and maintenance. Early involvement of the facilities manager (FM) is encouraged, with the design being linked to its operation and the life cycle of the asset, thereby supporting long-term, joined-up thinking and associated ownership of the built environment.

As the industry moves forward with BIM, boundaries are becoming more blurred and the levels that were being worked towards are disappearing. BIM level 2 and level 3 (that some perhaps thought they were familiar with) will become the baseline in terms of information management.

## 2.5 Current level of adoption

If BIM can support decision-making, how seriously is the industry taking it? The NBS 2019 survey based on approximately 1,000 responses from industry professionals reported growth in BIM awareness and adoption, from 10% in 2011 to around 70% in 2019. However, this represents a 1% drop in adoption from 2018, with clients' unawareness of the benefits of BIM being blamed for this drop. On a positive note, 60% of BIM-engaged respondents reported a 60% increase in efficiencies. While BIM is becoming an industry norm, its momentum is slowing and, rather worryingly, 22% of those who have yet to adopt BIM confirmed that they are unlikely to do so. The direction in which the industry was moving with BIM also caused uncertainty: 54% of those surveyed believed the industry was taking too long to define BIM level 3.[15] In light of *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), this should no longer be a consideration as it is the stage you are at with BIM that is now perceived to be more relevant.

How many surveyors fall into this category? How many surveyors are unaware of the benefits of BIM? How many surveyors understand what the BIM of the future is?

# 3 The evolution of BIM

## 3.1 Overview

BIM is, and has been, on an evolutionary journey, from the 2008 Bew-Richards maturity model through to 2019 and BIM in accordance with BS EN ISO 19650 (which, at the time of writing, had a number of standards/parts pending publication). This section reflects on the evolution of BIM in order to enable comparisons to be made regarding the understanding of BIM and the current matured version, where levels become stages and the BIM level 3 definition becomes obsolete. The 'single collaborative model', where all stakeholders work on one model, is no longer the utopia it was thought to be, and the BIM level 2 federated model system, where design, construction and maintenance teams use their own software and 'plug into' a federated model as and when required, is now recommended. There is also a proliferation of digital technologies, industry acronyms and terminologies that may lead to some confusion, which also need to be considered.

The timeline in Figure 4 tracks the UK BIM journey, from the GCS 2011, which introduced BIM into the construction industry mainstream, to the UK government's BIM level 2 mandate of 'making BIM level 2 business as usual' via BS EN ISO 19650 and beyond.

The timeline can be summarised as follows:

- **2008**: the Bew-Richards maturity model defines BIM as levels 0, 1, 2 and 3
- **2015**: the Digital Built Britain level 3 strategy replaces BIM level 3 with the term 'Digital Built Britain'
- **2017**: industry 4.0/construction 4.0: signifying the impact of the fourth industrial revolution on the built environment
- **2018**: the Centre for Digital Built Britain introduces the term 'design, build, operate and integrate'
- **2019**: the publication of BS EN ISO 19650 – BIM in accordance with the information-management processes and internationalisation of the UK's BIM level 2.

Each of these milestones is expanded on in sections 3.2–3.6.

Missing image:
//192.168.100.221/Typefi_Cloud/
RICS/RICS Master Guidance/
RICS_A4_standards/2023-05-02
13.51.22/links/Figure 4.jpg.

Figure 4: BIM timeline (from 'Building Information Modelling – UK Transition to ISO Standards' presentation slides, reproduced with permission from BSI)

## 3.2 The Bew-Richards maturity model (2008)

The 2008 Bew-Richards BIM maturity model defined four levels of BIM (0–3), from the paper-based silo approach to the collaborative, fully integrated and interoperable model-based approach.[16]

- **Level 0**: project information is predominantly paper based.
- **Level 1**: a mixture of paper-based (2D) and/or a 3D environment, including some form of CDE to support the sharing of project information across the project team.
- **Level 2**: discipline-centric proprietary BIM, or 'pBIM'. Each discipline produces its own project information within a 3D environment. Intelligence is then added to the models by attaching data/information; for example, specifications or dimensions for each object/component. Standards are set for producing, exchanging and archiving information in a CDE. Each model interfaces with each other via middleware software, thereby enabling integration to aid coordination.
- **Level 3**: fully integrated 'iBIM'. A single collaborative model is accessible to all team members, enabling multiple users to work on the model concurrently. Any amendments to a particular discipline's information updates another's in real time.17

## 3.3 Digital Built Britain (2015)

The Centre for Digital Built Britain (CDBB) replaced the UK government-funded 'BIM Task Group'. It focuses on the next part of the BIM journey, bringing 'together industry, academia, and policymakers in order to consider the wider effects of the digital agenda on society and the economy'.[18] The CDBB's vision for the next level of BIM was more far-reaching than the potential limiting nature of previous definitions as it proposed to replace the BIM level 3 term (and associated definitions) with 'Digital Built Britain' (DBB), believing that this terminology better reflects the aspirations of a fully digitalised built environment by integrating and taking advantage of the opportunities represented by new technologies and the innovations of the future,[19] such as AI, the IoT and data analytics, to name but a few. In doing so, the CDBB therefore radically expanded its scope of work (see Figure 5) compared to the remit of the BIM Task Group, which primarily focused on the UK adoption of BIM alone.

Missing image:
//192.168.100.221/Typefi_Cloud/
RICS/RICS Master Guidance/
RICS_A4_standards/2023-05-02
13.51.22/links/Figure 5.jpg.

Figure 5: Digital Built Britain operational model (from Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan, licensed under the Open Government Licence v3.0)

Data is central to the DBB vision, as shown in Figure 6. Emphasis is now on the flow of data and its potential to support collaboration. The data flows bottom–up from small individual projects that inform portfolios, which in turn inform regions.

Missing image:
//192.168.100.221/Typefi_Cloud/
RICS/RICS Master Guidance/
RICS_A4_standards/2023-05-02
13.51.22/links/Figure_6.jpg.

Figure 6: Data flow and decision-making

This bottom–up information and collaboration flow is represented across the delivery (design and construction), operational and performance phases of an asset, portfolio, etc., with the aim of allowing for more informed 'smart decisions' based on total expenditure cost (TOTEX) rather than capital (CAPEX) and operational (OPEX) expenditure being treated independently.

This approach will require a rethink of industry processes for designing, procuring, constructing and operating assets. Making data easily accessible across these three phases via open data portals such as data.gov enables an ecosystem/marketplace of collaborating data analytical innovators to:

- challenge the established roles of consultants, contractors, suppliers, etc.
- provide new procurement and/or business models
- measure actual performance compared to designed performance levels via embedded sensors and the IoT
- incorporate AI, machine learning, 3D printing and digital twins and
- adopt blockchain/smart contracts, reducing inefficiency by removing intermediaries.

In 2015, DBB articulated the next part of the BIM journey, building on level 2 as a stepped progression to facilitate far-reaching transitions across the sector. Figure 7 shows in detail BIM level 3 as defined by CDBB.

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/Figure
7.jpg.

Figure 7: DBB BIM level 3 phases (based on Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan, licensed under the Open Government Licence v3.0)

Steps 3A and 3B predominantly encompassed the Bew-Richards BIM level 3 definition discussed in section 3.2, moving from individual federated models to a single shared model to aid collaboration, requiring new/updated protocols and standards (PAS documents) and building on the new procurement routes (cost led, integrated project insurance, two-stage open book).

The significant variation is found at level 3C, which seeks to take advantage of data analytics to secure cross-sector innovations. This challenges the existing way of doing things, and brings changes to current processes and roles. Where stage 2 or level 2 is deterministic based on set criteria, the vision for level 3 at that time became more probabilistic, which will continually incorporate future advances and innovations into the decision-making processes in the design, construction, operation and management of assets,[20] such as those digital advances discussed in section 4 and shown in Figure 8.

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/
Figure_8.jpg.

Figure 8: Transition from BIM level 2 to DBB phase 3C

In this 2015 publication the term 'BIM level 4' was touched upon. It built on the progress made by the previous levels with a focus on social outcomes and well-being[21] by defining issues using collated built-environment data in order to maximise the well-being of citizens and social outcomes of communities. Using the problem as a starting point enabled industry innovators to propose a solution based on the available data and technologies; for example, through their 'Turning Data into Knowledge' initiative, Transport for London released open and free data on their services to the marketplace. This enabled innovators to develop real-time 'apps', which saved time for passengers and created more certainty on timetabling, which in turn increased the well-being of passengers by reducing the stress of their daily commute and allowing them more free time.[22]

## 3.4 Industry 4.0/construction 4.0 (2017)

Another common term used in relation to BIM is 'industry 4.0', which signifies the impact of the predicted fourth industrial revolution on the manufacturing sector. Following on from the first, second and third, the fourth revolution 'is characterised by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres'.[23]

The term has been modified by the built environment sector into 'construction 4.0' to signify the impact of the fourth revolution's digitalisation of the built environment, encompassing BIM in the same way Digital Built Britain and 'design, build, operate and integrate' had previously (for more information, see Construction 4.0: An Innovation Platform for the Built Environment). The extent of this digitalisation is as yet unclear, although currently it includes the automation of industrial production strategies; for example, offsite manufacturing, prefabrication and 3D printing. In addition, AI, robots, drones and machine learning are proffered as technologies that can be adopted for more mundane and dangerous tasks, thereby allowing humans to concentrate on adding value to high-level tasks that require analysis and subjective thinking.[24] These are further discussed in section 4.

## 3.5 Design, build, operate and integrate (2018)

The CDBB Year One Report announced a change in language from BIM levels 2, 3 and 4 to 'design, build, operate and integrate'. The new term emphasised the integration of the delivery and operational models to collate data in order to help improve the performance of assets in real time. The report also introduced the concept of 'digital twins' and aspirations of a 'national digital twin', digital representations of assets and smart cities that can be used to run virtual 'optioneering' simulations to improve design, construction, operation and performance of not only assets but also cities and regions, thus radically expanding the scope of the potentially limiting old BIM level definitions.

## 3.6 BIM according to BS EN ISO 19650 (2019): implementation of information management

BS EN ISO 19650 represents a significant shift away from focusing on BIM levels and their associated definitions towards a framework for information management where information is standardised to allow it to be 'exchanged, integrated and interrogated for different purposes across a range of […] cutting-edge technologies'.[25] The move to BS EN ISO 19650 is, in part, to internationally standardise the principles and terminology used rather being UK-centred, as in previous PAS documents. It also requires clients to clarify the information they need and what the information is to be used for up front, rather than being generic by stating they want to achieve a specific BIM level definition. Therefore, the measurement of BIM maturity by levels has been replaced with information management maturity 'stages'. The stages are a more fluid/flexible definition; for example, stage 2 overlaps with the previous levels 1 and 2, and stage 3 overlaps with levels 2 and 3, as shown in Figure 9b.

A single collaborative model where, initially, all designers work on and develop one model, (previously defined as BIM level 3) is no longer referred to in the ISO documents. Instead, there is the federated information model where various stakeholders across the life cycle of an asset continue to produce their own models, either graphical (predominately design based) or non-graphical (programmes, reports, etc.), to exchange and collaborate via middleware software during the design, construction, maintenance and operation phases of an asset,[26] thereby encouraging the innovation and use of digital technologies.

Figure 9a and 9b: ISO UK BIM maturity wedge and ISO information management maturity diagram (sources: Figure 9a reproduced with permission from Mark Bew; Figure 9b is from PD 19650-0:2019 Transition Guidance to BS EN ISO 19650 and is reproduced with permission from BSI)

Figure 9b introduces the 'layers' from BS EN 19650.

- **Standards layer:** this establishes the processes and polices in which information contained in the information layer (be it models, federated models, programmes, certificates, schedules, databases, drawings, documentation, etc.) are collated, managed and exchanged in a secure environment across the whole life cycle of an asset, reaping the full benefits of collaboration.[27] BS EN ISO 19650 part 1 and part 2 primarily form the standards for stage 2, with future standards pending.
- **Technology layer:** this includes digital innovations; for example, a CDE, which should ensure that information is stored and is easily accessible as and when required for all stakeholders across the life cycle of an asset. The ISO part 1 guide emphasises that a CDE is not necessarily a single solution: it may be a range of technologies that store and manage information in a number of 'information containers' that are able to interface with each other, even if interoperability issues are envisaged. Therefore, CDE is an information management technology, whether singular or multiple systems.[28]
- **Information layer:** this also includes data that, by adopting digital technologies (as discussed in section 4) can be captured, interrogated and analysed to inform decisions that feed into the business layer.
- **Business layer:** this represents the benefits derived from the integration of the previous layers (standards, technology and information) across the life cycle of an asset. These benefits include capitalising on innovative ways of working to reduce waste and/or reworking across the design, construction, operations and maintenance of an asset. Another benefit is improved performance of a physical asset through the use of data-based intelligent models, which enables simulations and 'optionneering' of an asset system, informed by real-time information garnered from sensors and/or devices connected to the IoT. The layers' lofty aspirations are to aid the development of digital twins and smart cities,[29] but this may be daunting for many; therefore, another way of embracing BS EN ISO 1950 and its associated layers is to use them as a basis to improve current working practices at whatever degree is deemed relevant.

## 3.7 BIM evolution: summary

As stated in the UK government's 2017 Industrial Strategy: Building a Britain Fit for the Future, 'it is not enough just to look at the economy we have. We must make preparations for the economy we need to become' (p. 23).

Numerous terminologies have been applied to BIM; in essence they all relate to the same vision of the digitalisation of the built environment via the fourth revolution, which includes collaborative ways of working facilitated by early contractor involvement and underpinned by digital technologies and data collection to aid more efficient methods of designing, creating and maintaining assets.[30] Digital technology will combine with various innovations, the IoT, advanced data analytics, data-driven manufacturing and the digital economy to enable the built environment to be:

- planned more effectively
- built at a lower cost and
- operated and maintained more efficiently.[31]

The industry is in a state of flux: terminologies, acronyms, digital innovation definitions and their usage, standards and incorporation into the built environment are in their infancy, with pockets of excellence forging ahead while others struggle to keep pace with the change. Therefore, BIM and the digitalisation of the built environment need to be an evolutionary rather than a revolutionary process in order to enable everyone in the sector to deliver the transformational opportunities that the digital transformation represents.

Surveyors need to stop searching for a definition of BIM level 3 as it does not exist and need to look now towards stage 2. They need to approach every project with a blank page and implement bespoke requirements from the myriad of technologies in line with the information management framework of BS EN ISO 19650. The client, too, needs to learn that it is no longer good enough to ask for 'BIM' as it is not a single concept or entity. BIM implementation is a fundamental first step to the digital transformation of the built environment, but it is just that: a first step.[32]

# 4 Information management, BIM and industry 4.0 technologies

## 4.1 Overview

In order to move forward with BIM, the focus needs to be on information management and not on technology. Surveyors must not be overly concerned if the information they have requested or provided is stored in one or more models, or indeed any model at all, as emphasis must be on following the BS EN ISO 19650 framework. This may necessitate some changes in the way the industry works, the processes that are followed and, potentially, the technologies that are adopted. Technologies should be selected that enable the capture, storage and exchange of data in a format that is capable of supporting efficiencies. To do this it is first necessary to understand the technology available to the surveying profession, the value it can add to the services provided and the challenges that may be faced in implementation. If BIM can deliver sustainable, long-term improvements in asset performance, the profession needs to be fully aware of the opportunities that BIM can offer to its businesses and then develop new business models that are capable of transforming data into knowledge.[33]

New business models need to be founded on collaboration and new technologies that take the profession from its comfort zone of silo working to an open and honest collaborative environment that shares best practice. This is a fundamental shift in processes and cannot be achieved overnight. It needs to be incremental, and individuals as well as businesses need to be on board. Individuals need to be aware of the potential that technologies can bring to their role and, instead of being intimidated by change, need to embrace the opportunities that they bring.

## 4.2 Opportunities

Despite the plethora of terminologies used to describe BIM, they all revolve around information, data and technology. However, technology no longer dictates the present state of BIM: it is the process of information management that identifies the stage of BIM, and technology is a method used to create efficiencies. How technology is selected is informed by how it can add value to services and help create, capture and exchange the information that is used. With this worldview, a set of appropriate technologies from the industry 4.0 framework can be assembled to assist in achieving the goals set by the sector, as shown in Figure 10.

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/
Figure_10.jpg.

Figure 10: BIM terminologies and technologies

### 4.2.1 Design for manufacture and assembly

Design for manufacture and assembly (DfMA) is a design philosophy that applies to offsite construction. It aims to use information management to improve health and safety, productivity, sustainability and the cost of construction. The difference between this and traditional offsite manufacture is that DfMA takes a holistic approach and can adopt BIM 3D models to facilitate the sharing and transfer of information to create efficiencies and support whole-life costs.

#### 4.2.1(a) Offsite construction

St James Edinburgh chose to follow a DfMA approach for its development. The main contractor Laing O'Rourke drove the offsite manufacturing process from a single dataset informed by their in-house DfMA-based supply chain, working in a CDE with the design team. The tight site location required careful planning and information management; offsite construction and BIM technologies helped improve efficiency and kept the project programme on track. The project details are:

- 1.7m square feet project
- new-build retail, leisure, entertainment and residential and
- 850,000 square feet of retail space, a 214-bedroom luxury W Hotel, 30 restaurants, a multiscreen cinema, 150 apartments and 1,600 covered car parking spaces.

#### 4.2.1(b) 3D volumetric construction

Volumetric construction is a modern method of construction that produces large, room-size structures in factory conditions which are then transported to and assembled on site. The Holiday Inn Express modular hotel project in Trafford City, Manchester, was built saving six months on the traditional construction approach (see Figure 11). This resulted in a six-month saving on interest loans and generated income six months earlier.

## 4.2.2 3D printing

3D printing is a technological process that creates a 3D object; it involves adding material together in layers causing it to solidify to produce a single component or complete entity. 3D Printing Concreative is a 3D-printing company that produces 3D concrete components. It has developed large-scale printing technology capable of producing a single element of 6 × 4.5 m in one action, employing the world's largest 3D concrete printer with a six-axis arm. The world's first 3D office was placed on the premises of the Emirates Towers in Dubai. It was printed and installed in just over 17 days and employed only 18 people. This 250m$^2$ building cost £95,000 (excluding interior and exterior fit out).

Like many technologies, 3D printing is not new, but it is only now that businesses are aware of its full potential. In addition to producing 'the end product', 3D printing has the potential to create models quickly and provide clients with a visual representation of a project. It can also provide faster, cheaper and more sustainable solutions. Despite its potential, many professionals are concerned that increased automation can be detrimental to their business, but the positives need to be looked at in terms of visualisation for real estate.

Missing image:
//192.168.100.221/Typefi_Cloud/RICS/RICS Master Guidance/RICS_A4_standards/2023-05-02 13.51.22/links/Figure 11.jpg.

Figure 11: The Holiday Inn Express modular hotel, Manchester (© Chapman Taylor Architects)

## 4.2.3 AI/automated design/machine learning

BIM is an enabler for AI in the built environment. AI can become part of the core business strategy with its ability to think, learn and become 'smart', since it can make decisions that previously were made by surveyors in design and construction, real estate and facility management. Developments in AI, machine learning and the IoT – the so-called 'fourth industrial revolution' – can be seen throughout the real estate sector.[34]

In real estate surveying there is the potential for 88% of core tasks to be automated in some way.[35] For example, AI could be used to value a building, since data currently drives decisions in real estate and there is now the potential for a machine to manage valuation data. In addition, AI could process the visual factors of a house using an AI-enabled camera or drone to perform exterior checks and measurements.

The greatest impact of AI, however, is in facility management.[36] Buildings are becoming smarter thanks to sensors, connected assets and AI developments. A facility manager (FM) can collect valuable data on assets, energy and people that can be used to predict performance and maintenance and, ultimately, improve the future performance of buildings, sustainability and space utilisation.

The Deloitte headquarters (HQ), the Edge in Amsterdam, is one of the most sustainable and smartest buildings in the world. Gigabytes of data on how the building and its employees interact are collected and stored on a central dashboard. The FM can track everything, including the number of people in the building, allowing sections to be closed when employees are below a specific number, thereby cutting the costs of heating, cooling, lighting and cleaning.

AI and machine learning are also emerging in pockets of excellence in cost estimating and programme forecasting/delay analysis. Technological advances in data analytics have enabled algorithms to be developed to allow machine learning to have predictive capability. For example, historical project programme data is collected and fed into the system, enabling the algorithm to learn from past projects, even to the extent of planned programmes versus actual, to give confidence in proposed programmes and/or highlight areas of high risk. This means informed decisions can be made in potential avoidance or mitigation measures.[37]

A cost-estimating machine learning prototype has been developed that operates in a similar fashion. However, to reap the full benefits, the built environment needs to collect more detailed data and share it, which for commercial, competitive reasons could be a barrier, especially to small- and medium-sized enterprises, even if the data collected is guaranteed to be anonymised. The data will also need to be in the same standardised classification structures; for example, cost estimates using RICS' *New rules of measurement 1*, *New rules of measurement 2* and then aligning to *BCIS standard form of cost analysis*. Therefore, AI and machine learning do have the potential to significantly enhance the built environment's predictive capabilities.[38] For more information, see RICS' Artificial intelligence: What it means for the built environment.

## 4.2.4 Internet of Things/sensors

The Internet of Things (IoT) is the connection of any physical objects that have smart, digital capabilities; for example, sensors linked to the internet that enable the collection of data that can be shared with various other physical objects, allowing them to be either controlled remotely and/or automated.[39] It is predicted that, by 2020, there will be approximately 50bn objects plugged into the IoT,[40] creating real opportunities to innovate. Embedded sensors and other devices can be used to monitor the condition of infrastructure, supporting better-informed planned maintenance interventions which, in turn, informs and improves asset briefing. Via the IoT, preventative maintenance could be implemented: the sensors could record when a part is nearing the end of its life cycle and could autonomously order its replacement to be delivered before it fails.

In the Deloitte HQ, work sensors are embedded into the building fabric that direct individuals, via their mobile device, to a free car or working space. The working space temperatures, humidity, lighting, $CO^2$, UV light and noise levels[41] are all autonomously set to the requirements of the individual and activated by their card entry system or to the usage of a room based on past data. This has the potential to improve space utilisation.

In Kansas City in the USA, approximately 300 sensors have been fitted to the underside of manhole covers that continuously monitor sewage flowing through 2,800 miles of pipes. These sensors, via the IoT, autonomously reconfigure valves and gates according to the specific requirements, thus preventing potential floods/overflows and 'optimising existing infrastructure rather than building costly' new ones.[42]

The potential opportunities are enormous and, for the surveying profession, can help support government-driven sustainability targets, from asset and building performance management to providing feedback loops for future projects based on real-time operational data. Reliable real-time information leads to better service provision and, ultimately, improves business credentials.[43]

### 4.2.5 Open and big data

Data supports knowledge-based decisions. In the surveying profession, data plays a significant part in the decisions that are made in relation to the planning, creation and use of assets. Businesses offering surveying services need to understand what data they hold, what data they need and the importance this data has to their service provision.[44] A robust data strategy needs to be adopted based on value. The value of the data itself (data is considered the new oil) and the added value in terms of the creation of efficiencies and improved decision-making need to drive this strategy. This means challenging existing roles in order to make wider use of service performance data by being able to measure and compare the planned 'in service' performance of assets to that of 'as briefed' and 'as delivered'.

The increasing accessibility of data, its variety and the range of tools available for its interrogation across the whole of the built environment (buildings/infrastructure, capital/operational/whole life cycle) ensure that data is increasingly playing a significant part in surveying profession roles.

Notwithstanding that there are still challenges in data collection and use, there is a reluctance to make data open, sharing it for the 'greater good'. This could be due to a variety of reasons, including commercial, ethical and legal sensitivities (e.g. *General Data Protection Regulation* and intellectual property rights). Once collected there are further challenges, such as understanding:

- the various ways in which data can be used
- who has the skills to carry out data management/data analytical roles
- what is available and what is valuable
- which data can be cross-examined

- who would benefit from its use and
- how it might be future-proofed.

It is key that these challenges are addressed as they may impact the quality, consistency, provenance, security and robustness of the data and its eventual analysis, which could hinder its usefulness in finding added value opportunities in the future.

Governments have a role to play in mitigating these challenges: they need to be aware of the benefits, especially those derived from data sharing, and can be a driving force to its implementation by describing what data they require in contract specifications and then quantifying the benefits to encourage private-sector uptake. Professional bodies should also develop and/or encourage the adoption of international standards; for example, RICS is promoting ICMS for the quantification and benchmarking of asset cost data. The continued use and uptake of BIM and advances in digital technologies (AI, digital twins, etc.) will not only aid the availability and collection of data but will also aid its interrogation (data analytics) to find new uses for data in a form that is of value to various stakeholders in the built environment.[45]

#### 4.2.5(a) Dependency-driven analytics/big data analysis

Large companies operate increasingly complex infrastructures to collect, store and analyse vast amounts of data. For those businesses willing to tap into data analytics, there are significant opportunities to improve the bottom line and reduce supplier/project outcome risks. Examples of these, such as AI/machine learning and smart cities, are discussed in sections 4.2.3 and 4.2.6, respectively. Today's supply chains are more multi-tiered, geographically far-reaching and complex than ever. This can have significant implications for supply chain transparency and the ability to identify opportunities, mitigate risks and ensure that a supply chain is operating efficiently and cost-effectively. In buildings, data might be generated by a very wide variety of sources, including:

- design and construction (e.g. BIM)
- post-occupancy evaluation, enabling as designed, as operated and as maintained to be analysed
- utilities, building services, meters, building management systems, etc.
- infrastructure and transport systems
- enterprise systems (e.g. purchasing systems, performance reporting, work scheduling, etc.)
- maintenance and replacement systems, enabling a shift from preventative maintenance to prescriptive maintenance
- operational cost monitoring and
- information and communication technology (ICT) systems and equipment.

Data from these sources can be used to understand behaviour, assess performance, improve market competitiveness, allocate resources and so on. The emergence of the IoT, improved data standards, big data analytical technologies and visualisation techniques are increasingly enabling these problems to be overcome, allowing decision-makers to understand and interrogate complex data from a variety of sources.[46]

### 4.2.6 Smart cities, smart buildings and data

'Smart' in this context essentially means the connectivity of a building (or asset components) and its occupants, the infrastructure of a city with its services and the daily lives of its residents and occupants through the IoT. It also means harnessing innovations via data analytics and even automated machine learning data analytics from the data collected from this connectivity. A feature of a smart building is the recording of real-time information to enable instant optimal performance, whether that be buildings services (heating/lighting, etc.) or usage (utilisation of space). These two elements can then support the health and well-being of occupants and mitigate their impact on the environment.[47]

Smart cities and smart buildings use ICT and the IoT to manage resources and assets more effectively, the aim being that the sharing of data, data analytics, AI, machine learning and 3D printing can create a smart environment (see Figure 12), and that national/digital twins can further enhance their performance using lessons learned to enrich the social well-being of their citizens and occupants. For more information, see RICS' Blockchain: an emerging opportunity for surveyors?

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/
Figure-12.jpg.

Figure 12: What is a smart city?

### 4.2.7 Distributed ledger technology

Distributed ledger technology is probably better known as 'blockchain', which is synonymous with Bitcoin, a cryptocurrency that has had some impact on the financial sector. But what is blockchain? Essentially it is a record or simple database (ledger) of transactions, payments and/or agreements where their associated details are recorded by either sharing or disseminating according to pre-agreed privileges across a number of participants (distributed) using the internet as a conduit (technology). The information is recorded and stored chronologically and predominantly decentralised, and therefore is not controlled by a single party (e.g. a bank or government).

Once published, it cannot be altered without the consent of the collective parties.[48] Therefore, a secure, transparent, auditable, simultaneously updated one version of the true record of transactions is created, which has the potential to increase productivity, and therefore reduce cost, through greater efficiencies by cutting out the intermediaries.

Although blockchain is very much in its embryonic stages in the built environment, it can offer infinite possibilities to surveyors.[49] Using blockchain could be considered if the following are key criteria for project transactions:

- trust
- security in terms of hacking of data and risk of changing records
- there are multiple users involved in the decision-making process and
- transparency for all in the transactions is required.

The built environment may incorporate blockchain in stages, building on its advancements, first for the transactional process including automation, then fidelity, governance and data management.[50]

Smart contracts are an application of blockchain, whereby a computer program uses a set of ‘if/then’ rules to automate the process of transactions. The ‘if/then’ rules are predetermined obligations, milestones associated with the numerous transactions associated with any built environment contract. An obvious example would be payments: if the predetermined amount of work has been completed to the predetermined specification, then the validators within the blockchain will sign the payment off and payment could automatically be processed.[51] However, one current drawback is that there is no room for ambiguity or subjectivity in the ‘if/then’ rules and decision-making process. There will also be upfront resources required to set the ‘if/then’ protocols, which may incur upfront legal costs to generate the value-for-money savings in the total expenditure costs.[52]

The inherent secure and immutable nature of blockchain could aid the liabilities and copyright issues associated with federated models, with any changes or contributions being recorded and saved within a ‘block’ for ease of reference at a later date and their fee payments included in the ‘if/then’ protocol. A BIM model via blockchain could be used to record the origin, provenance and authenticity of an asset’s materials, from extraction to manufacture/production to construction and incorporation into the asset as a whole.[53]

Blockchain has the potential to transform the real-estate market by enabling property transactions to become simpler, quicker, cheaper and more secure. Combined with tokenisation (the digitisation of an asset), blockchain could offer real estate surveyors with a new way to conduct business and invest in property.[54] Tokenisation has enabled currencies such as Bitcoin to emerge, where currency is not represented by traditional physical notes, but is digital only (cryptocurrency). In a real-estate scenario, an asset could be converted into a digital token; investors could purchase a percentage of the asset in the form of tokens via cryptocurrency, which would increase or decrease in value accordingly. The blockchain guarantees the ownership is immutable and cuts out third parties. However, this is currently only theoretical due to the legal implications and regulatory policies playing catch-up to these potentially transformative capabilities.

### 4.2.8 Digital twins

A digital twin is a realistic 3D digital model of a real physical thing.[55] The digital twin is connected to the real asset, providing real-time performance feedback to facilitate smarter, informed decision-making to ensure the asset is running to its full potential, not only in terms of cost but also carbon and the social well-being of its occupants/users. As stated in the CDBB's Demonstrating the Potential of Digital Twins, 'by providing real-time data about its condition and how it is being used, digital twins will have an important role to play in planning and managing our key assets'. A digital twin can also be used to run simulations and 'optioneering' exercises within the digital environment to ensure the best solutions are implemented within the physical domain.[56] A digital twin could also be an extension of the BIM model that was used for the design and construction phase, plugging into other systems to create a real-time dynamic/telemetry interface.[57]

The vision for a national digital twin is not for one UK-wide asset/infrastructure twin but for individual twins that are connected, creating an 'ecosystem of connected digital twins'.[58] These can be created by different companies in different sectors; for example, building portfolios, utility infrastructures (water, transport, energy and telecom networks) and many more.[59]

The city of Helsinki, in its bid to become a carbon-neutral city by 2035, placed building energy data into a semantic 3D model (see Figure 13). The aim is to provide real-time reliable data that could inform planners and decision-makers to assess the potential and available resources for energy efficiency improvements while at the same time allowing property owners and managers to assess the property's energy consumption.[60]

Missing image:
//192.168.100.221/
Typefi_Cloud/
RICS/RICS Master
Guidance/RICS_A4_
standards/2023-05-02
13.51.22/links/Figure
13.jpg.

Figure 13: The solar potential of Helsinki Olympic stadium (image of the solar energy potential of Helsinki Olympic Stadium by Helsinki 3D+ is licensed under CC 4.0 International)

### 4.2.9 Virtual reality/augmented reality

Virtual reality (VR) technology is on the increase and adds further to the potential benefits of BIM. As VR equipment becomes more affordable, the potential for use by the profession increases. It allows clients and users to be engaged with throughout the life cycle of the asset. Virtual models can be created of complete developments, allowing clients and other stakeholders to take virtual tours around projects before they are constructed. This will enable clients to better visualise the space, since the immersive environment will allow them to interact with it and check its fitness. For example, 'Goldman Sachs estimates that by 2025 the VR market in real estate could be worth £1.99bn and disrupt the way properties are let and sold'.[61] VR can help with the visualisation of whole cities pre-construction and can inform the decision-making process. Wyndham city in Australia is using mixed holographic reality to present a 3D image of its future city so that citizens can comment on the future before it becomes a reality.

This virtual world can also be merged with the physical or actual world in either augmented (AR) or mixed reality (MR) formats. This is of great benefit to FM surveyors as it supports them in their role when carrying out maintenance by providing real-time information.

### 4.2.10 Drones

The impact of drones on the built environment cannot be underestimated and, with predictions of 76,000 drones being in use by 2030, this impact is likely to continue to be substantial.[62] Currently, drones are used in land surveying, creating efficiency savings in terms of labour and time. But the advantage they bring in terms of employees' health and safety is of value when it is too dangerous for humans to gather data. They can capture images for site inspections and topographical surveys and, in conjunction with smart apps, can analyse data in real time to offer solutions and support faster, more accurate decisions. Surveying drones boast quick data-collection times, excellent positional accuracy and safe operator experience.

### 4.2.11 5G

One of the latest innovations in mobile communication is 5G. Its combination of high speeds, massive bandwidth and low latency supports larger, faster transfers of data and will better support the integration of telecommunication technologies, including mobile, fixed, optical and satellite. It is set to greatly support improvements in AR, VR and robotics as it enables multiple users to interact with each other in real time. It will support the technology to quickly capture, organise and analyse large volumes of video information, providing a visual snapshot of a project in almost real time. The high bandwidths of 5G offer greater capability to support videos in the CDE of the BIM model, providing current visual information to the project team.

## 4.3 Summary

We are now entering what some believe to be the fourth industrial revolution, the computerisation of manufacturing, providing contemporary automation, data exchange and advanced manufacturing technologies. New technologies are developing at exponential speed and the opportunities they offer the surveying profession are immense. Now is the time for surveyors to respond and take up the challenge of change, and to adopt technologies that can add value to their services and confidently move them forward into the next era. Appendix A shows the potential for technology in specific RICS professional areas.

# 5 Future action and challenges

## 5.1 Overview

Having considered the various perceptions of BIM and beyond, and the digital transformation it brings, surveyors now need to consider its potential for their business. Will they engage with these continuous and emerging technologies and grasp the new opportunities that they present? Or will they look on while others move forward and add value to their business? Depending on the size of an organisation, some will have a higher capacity to innovate than others. However, regardless of size, everyone needs to reflect and question why they do things the way they do. Is it just because they have always been done that way, or do they do them that way because they add value to their service provision?

## 5.2 Plan of action

This practice information has established that BIM level 3 terminology is no longer fit for purpose and that we need to judge ourselves and our projects against the stages as laid down in BS EN ISO 19650.

In order to move forward in your BIM journey, you may need to.

1. **Identify where you are in the 'BIM' maturity:** undertake a business audit of the current BIM position to identify the current capacity and capability of your organisation in terms of existing protocols, procedures and technologies.
2. **Identify the technologies that can add value to your role:** transformation of an industry begins when new technologies connect with new business models to enable new ways of doing things, leading to new and better products and services.[63]
3. **Define where you want to be in terms of BIM:** ensure that individuals within an organisation have the same perception of BIM as that of the business. A unified vision of BIM is essential, especially as there are currently several versions of the truth. Look at how you manage your information and see how this compares with BIM stages 1 to 3. If you think you are working at BIM level 2, see how that compares with stage 2. What changes do you need to make to achieve your vision?
4. **Develop a clear value proposition and a business case for the adoption of new technologies:** review the benefit to the business and the associated costs of implementation.
5. **Establish a new business model based on realistic targets and capability:** consider the current operations of the business and question if they are all needed. Then look to the business capability and assess what (if any) changes need to be made in terms of procedures, policies and technology.

6 **Understand and work with the challenges:** develop strategies to overcome the challenges, which will reinforce adoption. It is essential to have a clear understanding of contractual and legal implications, insurance-related issues, training and education requirements, commercial issues and copyright and intellectual property right issues.

7 **Review and revise organisational characteristics:** promote a culture that looks to positively encourage innovation and technology.

8 **Adopt a change-management programme:** people are key to resisting change and their influence cannot be underestimated in relation to the benefits of BIM technology, knowledge management, decision-making, processes and leadership. Identify the changes required to implement BIM and make individuals aware of these changes. Provide them with the knowledge they need to make effective changes to their way of working.

9 **Nurture organisational learning:** develop a supportive BIM-learning environment with appropriate systems in place to capture, record and manage BIM knowledge.

10 **Monitor adoption and review:** as new technologies improve and increase, monitor the added value the organisation has achieved with its current technologies and adapt your business model if you choose to implement the most recent.

## 5.3 Future challenges

There is potential for disruption in moving from BIM 'levels' to 'stages' (and then across stages). Therefore, it is imperative that the challenges are identified so that processes and strategies can be considered that either mitigate or overcome their impact.

Challenges worth considering include the following.

- The appointment process for the various project participants will need to ensure that BIM and the required competencies are incorporated into the selection criteria.
- Those trying to map where they are on their BIM journey may find stage 3 challenging in terms of its probabilistic nature, and establishing what they need to do to achieve it, as well as the different terminologies used (as discussed earlier). These issues can be found at varying degrees in an organisation and/or on a project at the organisational level, from the client, consultants, designers, contractors, subcontractors and suppliers, which compounds the challenges of implementation.[64]
- The industry is recognised as being slow to incorporate change; therefore, its culture is a significant obstacle in adoption.
- Organisations are operating on low profit margins, which inherently makes introducing change a risk and therefore an obstacle to progression. Tangible benefits need to be articulated to the industry, and a clearer understanding of the efficiency and financial gains on offer is needed.[65]

- Is there a significant client demand to drive through the changes in processes and workflows required?[66]
- Training is needed to improve understanding and capabilities. This is a commitment to expenditure, time and resources, all of which are in short supply in the industry. Training and education need to be across all phases and roles within an asset's life cycle: not only discipline-specific model software, but also around new ways of working and collaborating to procure, design, construct and manage assets across their whole life cycle. The training has to be continuous, life-long learning, in addition to continuous professional development, to ensure that skills keep pace with the industry's digital transformation.[67]
- New skill sets will be required, such as data analytics. This will require universities, further education colleges and professional bodies to review their courses and competencies to ensure the capabilities are there to implement the digitalisation of the industry.[68]
- There is a substantial technology, information and ideas gap hindering the smart delivery, operation and performance of assets, portfolios and smart cities. Bridging this gap requires collaboration across all disciplines. Universities, researchers, engineers, architects, computer scientists, mathematicians, economists, psychologists, gamers and anthropologists, among others,[69] need to realise the aspirations for the built environment and social well-being of UK citizens, outlined as real benefits of the digitalisation vision of the built environment.
- Changes to ways of working, new business and procurement models all have collaboration, openness and trust at their centre across the supply chain, from those engaged with delivery to those responsible for the operation, maintenance and performance of the asset 'creating for the first time an integrated model of asset creation and operation'.[70] For example, the design process needs to adapt to shifting demands, including more upfront work; this requires input from a number of different parties not normally involved in the concept stages, which brings associated procurement issues.[71]
- More emphasis on sustainability analysis, engineering and 'optioneering', in parallel with capital and operational expenditure considerations,[72] needs to be supported by the updated/new standards envisaged to be ISO-related documents.
- The increase in data collection and open publishing has created national security and personal privacy issues. The UK government is introducing a new Centre for Data Ethics and Innovation to review the existing governance by engaging with the industry to explore and advise on how to ensure ethical, safe and innovative uses of data.[73] In addition, there will be interoperability issues associated with the open and big data platforms, and complexities in accessing and allowing access to the data, such as privacy, confidentiality and regulation preventing public data from being accessed by private companies.[74]
- There will be legal implications associated with copyright, intellectual property, ownership rights and insurance liabilities associated with the single model design development

attributes and the new business models and procedures at the differing stages of an asset's life cycle, which will need to be agreed.[75]

- There will also be challenges associated with new technologies:
  - selecting the appropriate hardware and software for BIM implementation, allowing for compatibility and interoperability with the rest of the industry
  - AI current capacity to machine learn is rudimental
  - drone application is limited by load capacity, airspace regulations, nuisance and privacy issues (for more information, see RICS' *Drones: applications and compliance for surveyors*)
  - office site prefabrication is still restricted by transportation of large structures; demand is low partly due to perceptions of a temporary nature and the high set-up costs of facilities
  - 3D printing requires significant investment and
  - the logistical challenges of storage space associated with the models and information exchanges.[76]
- The costs associated with implementation, training (not only in terms of the courses and experts to carry out the training but also the reduction in workforce productivity during the period of training), the investment into new technologies and hard and software. The inability of the majority of the industry to be able to make investment planning decisions for the long term while they have short-term cash flow pressures.[77]
- Like data, knowledge is an asset and it is essential for any business to plan, manage, operate, monitor and control the knowledge it uses to inform decisions. Knowledge is often lost from organisations as, when staff leave, knowledge usually leaves with them. If knowledge is an asset, then the organisation is missing something capable of offering value. Surveying businesses must become learning organisations capable of capturing, transferring and reviewing lessons learned when adopting BIM-enabled technologies or processes. These lessons could then be shared across the surveying sector as best practice. The publication of ISO 30401:2018 *Knowledge Management Systems — Requirements* provides guidance for implementing an effective management system for knowledge management in organisations.

Finally, we should no longer be concerned about the transition from BIM maturity or level: the key is to be prepared for the information the client requires and to provide it in an appropriate format that will facilitate efficiencies and effective decision-making by the application of appropriate technologies.

# 6 Summary and conclusions

BIM development was initially around design, construction and the 3D model with 4D and 5D potential. This model-centric workflow was informed and supported by national standards, protocols and procedures. More recently, these standards have been internationalised to satisfy the needs of the global market. Emphasis has now moved away from technologies and towards information management, and is more concerned with the appropriate quality and quantity of information in a format that is capable of being worked on collaboratively in order to make correct decisions first time. However, the potential that technology brings cannot be overlooked (especially regarding data management and analysis, the IoT, AI and digital twins), as there is now a greater requirement to consider global workflow patterns and collaboration.

To capitalise on the continued digitalisation of the built environment there are educational challenges that need to be addressed by universities, further education colleges, professional bodies, organisations and individuals. New ways need to be found for providing people with the necessary skills to embrace the digital economy; this may mean changes to educational courses and professional body qualifications for those entering the industry. Additional ongoing support will be needed for those who are already part of it, cultivating a culture of life-long learning to keep apace with the digital innovations and their impact. The new models of education should not only continue with but also place greater emphasis on collaboration, not just across traditional built disciplines but also disciplines from other sectors, harnessing and integrating their knowledge and skill sets into the built environment professional services.

The built environment sector is currently in a state of flux, with governments and industry leaders trying to transition people, processes and technology into the ever-expanding and innovative digital age. This digital transformation brings with it promises of efficiencies in productivity and reductions in waste, with the ultimate potential to produce cost and programme savings and better outcomes at a project, city and society level.

As with any transitional period, a plethora of ideas brings with it change that needs to take shape and crystallise into the new way of doing things. BIM is part of this change and has in fact set in motion the current changes that the sector is witnessing. It has brought about new ways of working, but the perception of BIM has changed over the years. It is important to understand what this change is and where it is coming from to separate the hype from reality in order to discover the opportunity and challenges this new era can bring.

Acting with integrity, maintaining high standards of service, promoting trust, treating others with respect and being accountable for your actions are RICS' values which frame the professional and ethical standards of its members.[78] Such ethical standards need to be maintained and adhered to when incorporating digital innovations into the built environment. Pertinent to these ethical dilemmas is AI and its machine-learning algorithm capabilities, which are enabling the replication of, and potential to even exceed, human intelligence. The built environment is at the nascent stage of AI adoption and is therefore in a good position to counter ethical considerations (such as inequalities due to unintentional (or otherwise) bias within the algorithm decision-making programming) by ensuring transparency.

The right to privacy versus collecting data about individuals (sensors, facial recognition, surveillance, etc.) need to be considered, including how to ensure security and anonymisation of the shared, open access data troves that inform machine learning. The volume of data collection in the future will be unprecedented and the potential benefits that can be derived are powerful, but with this comes responsibility. It is critical these ethical issues are considered if we are to achieve societal and industry-wide acceptance of the integration of these technologies, and if we are to avoid/mitigate any would-be 'techlash' – the backlash against unchecked technology advances, as seen in high-profile ethical breaches in other sectors.

Relying on regulatory intervention, in the UK the Centre for Data Ethics and Innovation will predominantly trial these innovations. We should learn from previous industrial revolutions: short-term advancement, such as exploiting carbon fuel for greater industrialisation, should not be prioritised over long-term considerations, such as climate instability. The fourth industrial revolution's data and AI could be the new oil and carbon fuel. Therefore, 'digital ethics' should be embraced within the transformation of the built environment to avoid unintended consequences as a result of their deployment.[79]

This practice information has aimed to take readers through the evolution of BIM, from the 2008 definition of BIM in terms of levels, to the current BS EN ISO 19650 best-practice information management documents that replace levels with stages. BS EN ISO 19650 does not explicitly refer to BIM level 2, since BIM level 2 is deemed 'business as usual', and it does not refer to BIM level 3. It offers a framework in which to integrate information management and the digital innovations of today and of the future into the design, construction, maintenance and operation of a built environment asset.

Clearly and rightfully, the focus has shifted from BIM as a technology, instead bringing information management to the fore. In addition, and closely aligned to the process, is digitalisation: an overview has been provided of some of the innovations that potentially can be adopted by the surveyor. Appendix A is an initial attempt, based on a review of the literature and industry reports, to assess the potential value of these technologies to some of the RICS surveying groups in terms of low, medium or high impacts on the role. Once again, this perspective on value is evolving as technologies evolve; therefore, further analysis of how these technologies can be implemented by each surveying group is still required. The overall aim of Appendix A is to provide readers with 'food for thought' as to what, where and how they may implement these technologies into their role and/or innovate further to add value to their role.

The transition period is far from complete and the industry varies from pockets of excellence, to those looking for the next step in their BIM journey, to those attempting to transition to

BIM level 2 (as per the 2008 definition), to those who are not engaging at all and are carrying on with their own version of business as usual. Therefore, this document is a snapshot in time. The landscape has changed significantly over the past 10 years; who can predict with any certainty the next 10? 'BIM' as a term (overtaken by 'digital twins') and the search for its definition and a step-by-step guide to implementation will probably never be defined.

Each project is no longer looked at in isolation; instead, it is considered how these projects come together to create a Digital Built Britain. Surveyors need to ensure that their vision is consistent with that of the organisation and the bigger ecosystem they serve. This needs to be the starting point for implementation: surveyors have to be clear about the what, why and how of BIM and the digital innovations, as this will inform their definition, which in turn creates their vision. This has to be the foundation upon which transformation begins.

Therefore, to summarise, this practice information has attempted to:

- recap the background to BIM
- track the evolution of BIM from 2008 to 2019, collating all the terms and concluding that there are no levels, only stages
- confirm the current state of play in the built environment's transition to digitalisation
- review prominent digital initiatives available to the surveyor and
- as the definition of BIM changes, describe the broader landscape of digital technologies that will play a crucial role in the transformation of the built-environment sector.

# 7 References

1 ARUP, *Blockchain Technology*, 2017. Available at: www.arup.com/perspectives/publications/research/section/blockchain-technology (accessed 12 December 2019).

2 RICS, *Building Information Modelling for Project Managers*, 2017. Available at: https://www.rics.org/uk/news-insight/research/insights/bim-for-project-managers/ (accessed 12 December 2019).

3 UK BIM Alliance/CDBB/BSI, *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), July 2019.

4 ARUP, *Blockchain Technology*, 2017.

5 RICS, *The Impact of Emerging Technologies on the Surveying Profession*, 2017. Available at: https://www.rics.org/uk/news-insight/research/insights/the-impact-of-emerging-technologies-on-the-surveying-profession/ (accessed 12 December 2019).

6 Institution of Civil Engineers, *Blockchain Technology in the Construction Industry*, 2018.

7 Marsh, D., *BIM and the UK QS Organisation: A Framework for Value Creation*, PhD thesis, Liverpool John Moores University, 2017.

8 RICS, *The Impact of Emerging Technologies on the Surveying Profession*, 2017.

9 RICS, *A Circular Built Environment: From Principles to Practices*, 2019. Available at: www.rics.org/uk/wbef/natural-environment/a-circular-built-environment-from-principles-to-practices/ (accessed 12 December 2019).

10 Jackson, G., et al, *The UK economy at a glance*, article in *The Financial Times*. Available at: https://ig.ft.com/sites/numbers/economies/uk/ (accessed 12 December 2019).

11 HM Government, *Industrial Strategy: Construction Sector Deal*, 2018. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/731871/construction-sector-deal-print-single.pdf (accessed 12 December 2019).

12 Boland, H., *UK missing out on £100bn boost as big businesses fail to innovate,* article in *The Telegraph*, 25 June 2019. Available at: www.telegraph.co.uk/technology/2019/06/25/uk-missing-100bn-boost-big-businesses-fail-innovate/ (accessed 12 December 2019).

13 HM Government, *Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan*, 2015. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/410096/bis-15-155-digital-built-britain-level-3-strategy.pdf (accessed 12 December 2019).

14 RICS, *The Impact of Emerging Technologies on the Surveying Profession*, 2017.

15 NBS, *National BIM Report*, 2019. Available at: www.thenbs.com/knowledge/national-bim-report-2019 (accessed 12 December 2019).

16 RICS, *International BIM implementation guide*. Available at: https://www.rics.org/uk/upholding-professional-standards/sector-standards/construction/international-bim-implementation-guide/ (accessed 12 December 2019).

17 Centre for Digital Built Britain, *About the Centre for Digital Built Britain*. Available at: www.cdbb.cam.ac.uk/AboutDBB (accessed 12 December 2019).

18 Centre for Digital Built Britain, *What is a Digital Built Britain?* Available at: www.cdbb.cam.ac.uk/AboutDBB/whatisdbB (accessed 20 February 2020).

19 HM Government, *Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan*, 2015.

20 HM Government, *Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan*, 2015.

21 HM Government, *Industrial Strategy: Building a Britain Fit for the Future*, 2017. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf (accessed 12 December 2019).

22 HM Government, *Industrial Strategy: Building a Britain Fit for the Future*, 2017.

23 Schwab, K., *The Fourth Industrial Revolution: What it Means, How to Respond*, 2016. available at: www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ (accessed 20 February 2020).

24 Centre for Digital Built Britain, *Year One Report: Towards a Digital Built Britain*, 2018. Available at: www.cdbb.cam.ac.uk/system/files/documents/CDBBYearOneReport2018.pdf (accessed 12 December 2019).

25 UK BIM Alliance/CDBB/BSI, *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), July 2019, p. 12. Available at: www.ukbimalliance.org/wp-content/uploads/2019/04/Information-Management-according-to-BS-EN-ISO-19650_-Guidance-Part-1_Concepts_2ndEdition.pdf (accessed 12 December 2019).

26 BSI, *PD 19650-0:2019: Transition Guidance to BS EN ISO 19650*, 2019.

27 UK BIM Alliance/CDBB/BSI, *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), July 2019.

28 UK BIM Alliance/CDBB/BSI, *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), July 2019.

29 UK BIM Alliance/CDBB/BSI, *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), July 2019.

30 Infrastructure and Projects Authority, *Government Construction Strategy 2016–20*, 2016. Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/510354/Government_Construction_Strategy_2016-20.pdf (accessed 12 December 2019).

31 Neely, A., 2019, *Can AR and VR Allow Us to Build Beautiful?*, 2019. Available at: www.cdbb.cam.ac.uk/system/files/documents/CDBBCH_009_Neely.pdf (accessed 12 December 2019).

32 UK BIM Alliance/CDBB/BSI, *Information Management According to BS EN ISO 19650 – Guidance Part 1: Concepts* (2nd edition), July 2019.

33 HM Government, *Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan*, 2015.

34 RICS, *Future of the Profession: Consultation Response Report*, 2019. Available at: www.rics.org/globalassets/rics-website/media/news/future-of-the-profession-post-consultation-report.pdf (accessed 12 December 2019).

35 RICS, *Future of the Profession: Consultation Response Report*, 2019.

36 BIFM, *Embracing Technology to Move FM Forward*, 2018.

37 Amratia, D., *nPlan*, article in *Civil Engineering Surveyor Journal*, September 2019.

38 Harvey-Rice, T., and Day, E., *Aecom building*, article in *Building Magazine*, 27 September 2019.

39 RICS, *The Impact of Emerging Technologies on the Surveying Profession*, 2017.

40 Macauley, J., et al, *The Internet of Things in Logistics*, 2015, quoted in RICS, *The Impact of Emerging Technologies on the Surveying Profession*, 2017.

41 Centre for Digital Built Britain, *The Edge Amsterdam – Showcasing an Exemplary IoT Building*, 2018. Available at: www.cdbb.cam.ac.uk/news/2018CaseTheEdge (accessed 12 December 2019).

42 RICS, *The shape of things to come*, article in *Modus*, September 2018. p. 27.

43 Philp, D., quoted in *Building blocks*, article in *Modus*, March 2019.

44 RICS, *How to Become a Data-Led Business*, 2018.

45 RICS, *Sharing Construction Cost Data – Benefits, Challenges and Opportunities*. Available at: www.rics.org/north-america/news-insight/research/insights/sharing-construction-cost-data--benefits-challenges-and-opportunities/ (accessed 6 February 2020).

46 Designing Buildings Wiki, *Big Data for Buildings*. Available at: www.designingbuildings.co.uk/wiki/Big_data_for_buildings (accessed 12 December 2019).

47 Wanless, J., et al, *Smart buildings – the case for smart enablement*, article on Building.co.uk, 2019. Available at: www.building.co.uk/data/smart-buildings-the-case-for-smart-enablement/5099714.article (accessed 12 December 2019).

48 Institution of Civil Engineers, *Blockchain Technology in the Construction Industry*, 2018.

49 Arup, *Blockchain and the Built Environment*, 2019.

50 Shojaei, A., *Exploring Applications of Blockchain Technology in the Construction Industry*, ISEC, 2019.

51 Arup, *Blockchain and the Built Environment*, 2019.

52 Arup, *Blockchain and the Built Environment*, 2019.

53 Arup, *Blockchain and the Built Environment*, 2019.

54 RICS, *Blockchain and Tokenisation in the Property Sector*, 2019. Available at: www.rics.org/uk/news-insight/future-of-surveying/surveying-technology/blockchain-and-tokenisation-in-the-property-sector/ (accessed 12 December 2019).

55 Centre for Digital Built Britain, *The Gemini Principles*, 2018. Available at: www.cdbb.cam.ac.uk/system/files/documents/TheGeminiPrinciples.pdf (accessed 12 December 2019).

56 Centre for Digital Built Britain, *The Gemini Principles*, 2018.

57 Philp, D., in *Building blocks*, article in *Modus*, March 2019.

58 Centre for Digital Built Britain, *The Gemini Principles*, 2018, p. 13.

59 Rogers, D., *Twin tracks: The drive to create a smart digital model of the UK,* article in *Construction Research and Innovation*, 10:2, 49–52, DOI: 10.1080/20450249.2019.1621591, 2019.

60 Lemola, J., *Helsinki Compiles Building Energy Data into Semantic 3D City Model*. Available at: www.stadinilmasto.fi/en/2018/07/16/helsinki-compiles-building-energy-data-into-semantic-3d-city-model/ (accessed 12 December 2019).

61 RICS, *What Can Virtual Reality Do For You?*, 2018.

62 UCEM, *Principal Thoughts: The Use of Drones in Construction*, 2018. Available at: www.ucem.ac.uk/news-events/blog/principal-thoughts-the-use-of-drones-in-construction/ (accessed 12 December 2019).

63 Parida, V., Sjödin, S. and Reim, W. (2019) *Reviewing literature on digitalization, business model innovation, and sustainable industry: past achievements and future promises*, article in *Sustainability*, 11:2, 391, 2019.

64 RICS, *International BIM implementation guide*..

65 Khosrowshahi, F., and Arayici, Y., *Road map for the implementation of BIM in the UK construction industry*, article in *Engineering, Construction and Architectural*

*Management*, 19:6, 610–635, 2012. Available at: https://pdfs.semanticscholar.org/bb59/a2cdceefad41fb4742595154a2ac0bf070d0.pdf (accessed 12 December 2019).

66 Khosrowshahi, F., and Arayici, Y., *Road map for the implementation of BIM in the UK construction industry*, article in *Engineering, Construction and Architectural Management*, 19:6, 610–635, 2012.

67 RICS, *International BIM implementation guide*.

68 HM Government, *Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan*, 2015.

69 Centre for Digital Built Britain, *Year One Report: Towards a Digital Built Britain*, 2018.

70 HM Government, *Digital Built Britain: Level 3 Building Information Modelling – Strategic Plan*, 2015, p. 11.

71 RICS, *International BIM implementation guide*.

72 RICS, *International BIM implementation guide*.

73 HM Government, *Industrial Strategy: Building a Britain Fit for the Future*, 2017.

74 RICS, *Smart Cities, Big Data and the Built Environment: What's Required?*, 2017. Available at: www.rics.org/contentassets/cb3fd55b63df4d1fa6b9d8e921a8ddfd/rics_smart_cities_big_data_2017_research_110917_rt.pdf (accessed 12 December 2019).

75 RICS, *International BIM implementation guide*.

76 FIEC, *Challenges and Opportunities*. Available at: http://www.fiec.eu/en/themes-72/construction-40/challenges-and-opportunities.aspx (accessed 12 December 2019).

77 Shimonti, P., *What's limiting BIM adoption in construction?*, article on Geospatial World, 2018. Available at: www.geospatialworld.net/blogs/whats-limiting-bim-adoption-in-construction/ (accessed 12 December 2019).

78 RICS, *Ethics*. Available at: www.rics.org/uk/upholding-professional-standards/standards-of-conduct/ethics/ (accessed 6 February 2020).

79 Radclyffe, C., and Nodell, R. *Ethical by Design*. Available at: www.ssonetwork.com/events-rpaandaisummit/downloads/ethical-by-design-a-whitepaper-on-the-case-for-and-management-of-digital-ethics-in-the-enterprise (accessed 6 February 2020).

# Appendix A: Digital technologies/ value for RICS groups

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Building Control | | | | M | M | H | H | | | H | H | | | M | | H |
| Building Surveying | M | M | H | H | H | H | H | M | L | H | H | H | M | H | M | H |
| | M | M | M | H | H | H | H | H | H | H | | H | H | H | M | M |
| Dispute | | | | M | M | M | H | | | H | H | | | | | |
| Facilities | M | M | M | H | H | H | H | H | H | H | | H | H | M | | H |
| | M | M | H | H | H | H | H | M | M | H | H | H | H | | | |
| | M | H | M | H | H | M | M | M | M | H | | M | M | | | |
| | | | | M | M | M | H | M | M | H | H | H | H | M | M | |
| Minerals and Waste | M | H | H | H | M | H | H | M | M | H | H | H | M | | | |
| Planning and | M | M | | H | H | H | H | | | H | M | H | H | H | | |
| Personal Property / Arts and Antiques | | | | | | | | | | H | | | | H | | |
| Project | M | M | M | | M | M | M | M | M | H | | M | M | M | H | M |
| Quantity Surveying and | M | M | | | | M | M | M | H | M | M | | | H | M | H |
| | | | | H | H | H | H | H | H | H | M | H | M | | M | |
| Rural | | | | H | H | M | M | | H | | M | M | M | | H | |
| Valuation | | | M | M | H | H | M | M | H | H | H | M | M | | | M |

H = high; M = medium; L = low.

## Delivering confidence

We are RICS. Everything we do is designed to effect positive change in the built and natural environments. Through our respected global standards, leading professional progression and our trusted data and insight, we promote and enforce the highest professional standards in the development and management of land, real estate, construction and infrastructure. Our work with others provides a foundation for confident markets, pioneers better places to live and work and is a force for positive social impact.


Americas, Europe, Middle East & Africa
**aemea@rics.org**

Asia Pacific
**apac@rics.org**

United Kingdom & Ireland
**contactrics@rics.org**