Capabilities needed in Information management for a Digital Built Britain

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Abstract

Network FOuNTAIN is the Network For ONTologies And Information maNagement in Digital Built Britain, a project funded by the Centre for Digital Built Britain. The vision of the Network is for all stakeholders in Digital Built Britain (DBB) to be able to meet their information needs. With the establishment of concepts such as Building Information Modelling and Common Data Environments, built environment design, construction and operation are becoming increasingly information-intensive. The Network undertook five workshop activities between July and December 2018. This paper summarises the proceedings of these workshops, and in particular establishes future capabilities needed to realise the vision of DBB. The first workshop sought to establish the scope of "Information Management". It was concluded that the capability to gauge Information Management Maturity was needed. The second and third workshops focused on ontologies and reviewed the variety of standards currently available. It was concluded that the capability was needed to establish the appropriate scope of standardisation, and to design or extend existing ontologies in general. The capability was also needed to develop current classification systems, schema and frameworks, Uniclass 2015 in particular, to maximise the potential to share data. The fourth workshop explored system requirements; it identified three modes of consuming information and the corresponding software requirements for each mode. The three modes identified are: *Search & Retrieval*, *Browsing & Expiration* and *Information Delivery*. The fifth and final workshop focused on business models and concluded that the capability was needed to identify and derive business value from Information Management. The paper closes with a research agenda required to deliver those capabilities. Fundamental research is needed to formulate a process of establishing the appropriate scope of standardisation for Information Management at *project*, *organisation* and *industry* levels. This research needs to unfold in the context of emerging related international standards.

Keywords: Information Management, Ontologies, Capabilities

1. Introduction

Information is a crucial component of any perspective of Digital Built Britain (CDBB 2018a). Information can flow from the users and other stakeholders of the built environment, including those associated with services that depend on the built environment, back to the professionals who plan, design, build and operate built assets. The effective generation and exchange of information during this whole life cycle of built assets enable an improved delivery of the built environment. For example, users of the built environment and of services (and the providers of those services) can use information generated by built environment professionals for more effective operation of the built environment and provision of services. The Hackitt report (2018), presented to Government in the wake of the Grenfell Tower fire that killed 72 people, calls for a "golden thread" of good quality information to enable building owners to better manage their buildings safely. The information flows within the design and construction teams of constructed facilities are particularly important in the effective provision of the built environment.

The complex nature of projects coupled with the diversity of the delivery team gives rise to the need for standards and ontologies as part of an Information Management strategy. Information Management has been proposed as an important component of roadmap to DBB (Enzer et al. 2019). As a predecessor to that roadmap, and posed more broadly than merely constructed infrastructure, better data has been proposed as the enabler for citizens to make better decisions (NIC 2017).

This paper describes the work of the Network For ONTologies And Information maNagement (Network FOuNTAIN) to determine the *capabilities in Information Management* needed in a Digital Built Britain (DBB). The Network was supported by the Centre for Digital Built Britain and comprises researchers and industry practitioners. The vision of the Network is for all stakeholders in DBB to be able to meet their information needs, with access to the information they need about the built environment as they work to deliver and operates buildings and infrastructure. With the establishment of concepts such as Building Information Modelling (BIM) and Common Data Environments (CDE), built environment design, construction and operation are becoming increasingly information-intensive.

The Network undertook five workshop activities between July and December 2018. The purpose of those workshops was to:

(0) Scope out the issue of Information Management in DBB;

(1) Explore ontologies to extract information from data;

(2) Catalogue the types of information to be managed in DBB;

(3) Specify software requirements for tools to manage this information; and

(4) Investigate an approach to formulate a process model for delivering value from Information Management.

This paper presents the outcome of those activities listed above and attempts to extract the capabilities required by stakeholders to deliver a Digital Built Britain. The full report from the Network has been published (Demian et. al 2019).

2. Methodology

The work of the Network was undertaken by convening workshops, as listed above. The workshops broadly included introductory presentations followed by unstructured discussion sessions. The workshops were audio-recorded to ease notetaking, and the recordings were destroyed immediately after a report was circulated and approved by attendees following each workshop. The ordering of the workshops was intended to follow a logical sequence: Workshop 0 scoping the topic, Workshop 1 focusing on the creation of information through ontologies, Workshop 2 cataloguing the types of information to be managed, working 3 investigating the software functionality needed, and Workshop 4 exploring the process of deriving business value. The only exception to the standard workshop method was for Workshop 2, as described in section 5.1.

3. Scope of Information Management

The first workshop, Workshop 0, focused on the scope of Information Management, and attempted to establish a theoretical lens through which the subsequent work of the Network could be managed. It was led by Mr Matthew West and was attended by nine individuals: four academics and five industry practitioners. From the workshops discussion, it was noted that the value of information comes from its use in supporting decisions. *Information Management* is about ensuring the right information is delivered at the right time to the right people. *Quality* means meeting requirements agreed between information users and suppliers.

3.1 Information Management Landscape (IML)

The Information Management Landscape (IML) found in a White Paper by West and Cook (2018) was discussed at the workshop and informed subsequent activities. That publication uses examples to illustrate the capability required for data integration and identifies the elements of the IML required to deliver that capability, as shown in Figure 1.

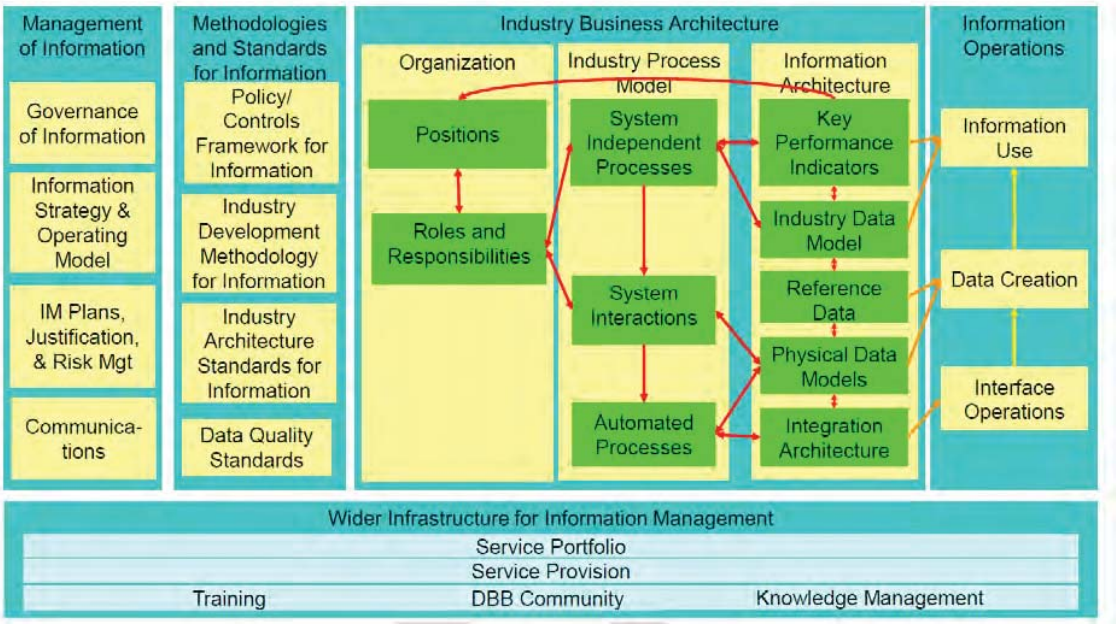

Figure 1: The Information Management Landscape, (reproduced from West and Cook 2018)

The IML proved to be a useful guide for planning and managing the subsequent activities of the Network. Workshop 1 on Ontologies and Workshop 2 on Cataloguing Information both addressed the "Industry Architecture Standards for Information" element. Workshop 3 on System Requirements addressed the "Information Use" element. Workshop 4 on Business Models addressed the entire "Industry Process Model" block.

ISO19650 Part 1 (ISO 2018a) provides an alternative representation of the Information Management domain specifically for the built environment. It refers to the purpose of information, and defines trigger events and key decision points where an information requirement might arise.

3.2 Information Management Maturity

IM Maturity can be broken down into five stages: *Initial*, *Recognising*, *Specifying*, *Managing* and

Optimising (West 2011). Workshop attendees discussed the maturity of the industry as a whole, and of particular groups or organisations. At the publication of the Latham Report in 1994, the industry was considered to be still at the *Initial* stage. The Avanti project around 2006 (Constructing Excellence 2006) perhaps signalled *Recognising* maturity. The release of COBie and the emergence of the concept of Open BIM signal important milestones in UK industry Information Management maturity, but formal classifications are difficult.

No clear consensus was reached regarding IM maturity of companies. Attendees agreed that the client is the most important "organisation" to drive maturity, pushing the IM agenda or pulling the information it needs. Generally, it was felt that many organisations are at *Specifying* level.

ISO19650 Part 1 (ISO 2018a) gives an alternative classification of IM maturity, (again specifically for the built environment, or the adoption of BIM) broken down into three Stages, which supersedes the BIM Levels of the classic Bew-Richards "wedge" (CIOB 2018).

Capability 0: Capability to gauge Information Management maturity, as part of existing standards or new standards.

3.3 Current Information Management Research

As an indicative "snapshot" of current IM research, attendees of Workshop 0 were asked to map their research activities against the elements of the IML. The nested nature of the IML elements prevented meaningful identification of research gaps. It appeared that the "Industry Data Model" element is receiving much research interest, with other items being the focus of some research activity. The work of Network FOuNTAIN, and particularly of Workshop 2, add to this. As a snapshot of the research gaps in the work of attendees' organisations in August 2018, the following elements had no research activities mapped to them:

- Management of Information
- IM Plans, Justification, & Risk Management
- Communications
- Policy, Controls Framework for Information
- Industry Development Methodology for Information
- Industry Architecture Standards for Information
- Industry Business Architecture
- Positions
- Information Architecture
- Key Performance Indicators
- Physical Data Models
- Integration Architecture

4. Ontologies

Workshop 1 was led by Professor Stuart Barr of Newcastle University and Dr Tom Beach from Cardiff University. It was attended by seven academics and nine industry practitioners, including two industrial advisors or consultants to the UK Government. An "Ontology Tutorial" was presented, followed by a session where several attendees presented case studies of how ontologies were used in their professional practice. The workshop closed with a discussion of the current industrial and academic use of ontologies, gaps in the state-of-the-art and opportunities for future development.

4.1 Fundamentals of Ontologies

Ontologies are a formal, standard representation of objects, their attributes and relationships between them. This representation is often used for reasoning. *Schemas* are similar to ontologies, but are often created for the purpose of designing database systems, and so their emphasis is on storing and

querying datasets, rather than reasoning. *Standardisation* is an inherent characteristic of ontologies.

The main theme that emerged from that part of the workshop is *the tension between standardisation and flexibility*. A balanced approach is to standardise common aspects and allow users to extend bespoke aspects. Too little standardisation means high flexibility for all stakeholders but can result in poor interoperability between stakeholders (no common language). Too much standardisation results in inflexibility and risks stakeholders not using the ontology. The balance can be expressed in terms of "standardising the right things", rather than too much or too little standardisation. This is set out in Capability 1a below. It is noteworthy that Uniclass 2015 was identified as having a significant following and value to the practitioner community. Like several of the standards cited at that workshop, Uniclass 2015 can be argued to be a classification system rather than an ontology in the strictest sense. In some applications, the ISO15926 series of standards has been found to offer more flexibility than Uniclass 2015 in terms of object attributes (BIM4Water 2017). Uniclass 2015 has been restructured and redeveloped to provide a comprehensive system suitable for use by the entire construction industry and for all stages in a project life cycle (NBS 2018a). Despite aspects of extensibility, the fact that objects could only be classified in a single way in Uniclass was considered a weakness. It is important that any approach to ontology development give due consideration to valued current tools, for example Uniclass 2015, exploring ways to integrate available insights and best use current investments and skills.

Capability 1a: Capability to establish the appropriate scope, priorities and pace of standardisation, at *industry*, *project* and *organisation* levels.

4.2 Ontological Issues Faced by the Industry

In addition to the issue of standardisation vs. flexibility outlined above, the following issues emerged from the discussion:

- "Principles" need to be established at the outset, before designing or adopting an ontology. What are the needs and purposes of information creators, managers, users?
- Clarity is needed regarding the nature of existing standards. Are they ontologies (ifcOWL), schemas (IFC, CityGML), or classification systems (Uniclass 2015, COBie) and therefore what might be their role in the future?
- What are the strengths and weaknesses of candidate ontologies? [This issue was addressed in the subsequent Workshop 2.]
- What is the appropriate scope of an ontology: buildings, cities, infrastructure, linear infrastructure? Is it required or reasonable for a single ontology to cover all? [This issue overlaps with the issue of standardisation vs. flexibility and is addressed in Capability 1a.]

The discussion from that part of Workshop 1 can be distilled in Capability 1b:

Capability 1b: Capability to underpin data exchange and integration by developing an appropriate approach to develop new, to extend and adapt existing ontologies, and to create the means to integrate current schema and classifications. (A prescriptive process model is needed.)

5. Ontologies for Cataloguing Information

The original aim of Workshop 2 was to create a list (or catalogue) of all the various types of information that require managing in DBB. However, following a number of informative discussions at the earlier workshops, it became apparent that such listing might already exist in existing ontologies or standards. Instead, a panel of expert practitioners was surveyed to review current ontologies and standards, to investigate how they categorise information. The Delphi method was used through an online platform. Like Workshop 1 before it, the focus of Workshop 2 corresponds to the "Industry Architecture Standards for Information" element of the IML, and perhaps touches on the "Information Operations" element.

5.1 Method

An initial desktop literature review was conducted to identify current ontologies or standards for Information Management in the built environment, a catalogue of information types, and a list of project processes within the current standards. The Delphi method was then applied in an attempt to achieve a reliable consensus from the panel of experts over two initial rounds of enquiry. Practitioners from the Network were invited to form the panel of experts. A third round was included to capture additional comments from the experts, as well as substantiate experts' key credentials. A summary of the results from the previous round was used to inform consensus building in the subsequent round. Participants were encouraged to review the anonymous opinions of all experts, before being provided with an opportunity to revise their previous response, thus supporting a more consensus-based conclusion.

The questionnaire contained four key sections:

- Section 1: enquired about the *suitability*, *completeness*, and *adaptability* of current ontologies or standards, i.e. IFC, Uniclass 2015, COBie, CI/SfB and CityGML. Questions were assessed using a Likert Scale from 1 to 5.
- Section 2: interrogated participants about the possibility of combining ontologies to obtain a more comprehensive information catalogue.
- Section 3: asked the experts to define what are the most important types of information. Open-ended questions were then used to explore future trends in types of information.
- Section 4: enquired about the *suitability*, *completeness*, and *adaptability* of current process models, namely, Construction Industry Council (CIC) Scope of Services, RIBA Plan of Work 2013, PAS1192:2 and the Government Soft Landings (GSL), again using a 1-5 Likert Scale.

5.2 Findings

Experts could not reach full consensus on one particular ontology or standard generally being the most suitable. However, Uniclass2015 did stand out as having a significant following. Similarly, for the project processes, none attained the scores required for consensus to be decisively considered the most *suitable*, *complete*, and *adaptable*. However, the project processes of PAS1192:2 generally emerged as the most suitable and adaptable.

Table 1: The Most Important Information Types for a Digital Built Britain (in ranked order)

Importance of Information Types	Rank	Second Round Results		
		Mean	Median	STDEV
Asset information	1	4.5	4.5	0.50
Record information (certificate, forms, manual, plan, register, report)	2	4.00	4.00	0.71
Data set (GIS dataset, information exchange file, room data sheet)	3	4.00	4.00	1.00
Graphical (drawing, 2D models, 3D models, photograph)	4	3.63	4.00	1.11
Design information (calculation, schedule, specification)	5	3.50	3.50	0.87
Contractual (client requirement, contract, instruction)	6	3.38	3.00	0.70
Financial (bills of quantity, cost plan, invoice)	7	3.00	3.00	0.71
Planning control (consent)	8	2.88	3.00	1.05
Project planning (method statement, policy, procedure, programme)	9	2.63	2.50	0.99
Communication (brochure)	10	2.63	2.50	1.32
Communication (request for information, technical query)	11	2.50	2.50	1.12
Communication (correspondence, file note, memo)	12	2.13	2.50	0.93
Record information (snagging list, survey, transmittal)	13	2.63	2.00	0.86

The experts' opinions were also collected on what are the most important information types to be

managed. The Government Soft Landings (Cabinet Office, 2013) information categories were initially used. The GSL categories all refer to "Government department assets". Despite this, experts from the first round felt that "Asset information" should be added as a separate category, which was subsequently scored highly by the experts. The initial results are presented in Table 1. "Asset information" was ranked top, with "Record information" and "Data set" ranked second and third respectively. Thorough analysis of these data will be reported in future publications.

As for Workshop 1, the initial findings from Workshop 2 point to Uniclass 2015 as having significant (but not consensus) support, providing coverage of many of the needs of a candidate standard framework to share data. Capability 2 can preliminarily be set out as follows:

> Capability 2: Capability to develop current classification systems, schema and frameworks, Uniclass 2015 in particular, to maximise the potential to share data, best using current skills and investments.

6. System Requirements

The purpose of Workshop 3 was to explore the requirements in BIM and CDE platforms, focusing on the *consumption* (as opposed to the *production*) of information. This focus corresponds to the "Information Use" element of the IML. The Workshop was led by Peter Demian, and was attended by four academics, six construction delivery practitioners and one construction IT practitioner.

Three modes of interaction were presented: (1) Search & Retrieval; (2) Browsing & Exploration; and (3) Information Delivery. The choice between the three modes depends on the task at hand, the type of content (information) being managed and (most importantly) the user's awareness of his or her information need. If the user knows exactly what information is needed, he or she will be able to articulate a query, search and retrieve the required information. If the user is unsure exactly what information is needed, but has some notion of an information need, browsing and exploration might be more appropriate. If the user has no idea what information is needed, or is even unaware that there is a need for information or that useful content might be available, the system unilaterally delivering information to the user might be the most effective mode of interaction.

6.1 Search & Retrieval

Search & Retrieval is appropriate when the user is aware of the information need with some precision, and the nature and sheer scale of the information make it difficult to visualise the whole repository and explore it systematically. The example of the 3DIR project was presented at Workshop 3 (Demian et al. 2016). The task of formulating queries in Search & Retrieval received particular attention in the workshop discussion. Queries in a natural language would be extremely useful, as would query templates or a visual query language (akin to visual computer programming).

6.2 Browsing & Exploration

Browsing & Exploration is useful when the awareness of the information need is not precise enough to enable formulation of an explicit query. It might also be more effective when interacting with a moderately sized (rather than large) repository of information. Even though no explicit query is formulated, some data from the user's current task can be extracted and used as an *implicit query*, to highlight potentially relevant items in the repository. The "Shneiderman mantra" of "overview first, zoom and filter, and then details on demand" was cited (Shneiderman 1996). The CoMem project was presented as an example of this mode of interaction (Fruchter and Demian 2002).

From the discussion, Uniclass 2015 again emerged, this time as the most likely representation of practitioners' search models to structure Browsing & Exploration. The relative simplicity and hierarchical nature of Uniclass 2015 were both seen as beneficial characteristics. Its limitations include its inflexibility and its poor coverage of infrastructure information.

6.3 Information Delivery

If a user has no idea what information is needed, or is unaware that useful content might be available, the system can unilaterally deliver information which might be deemed relevant based on an implicit query from the user's current work. In DBB, particular protocols require that information is delivered to particular stakeholders at particular times (for example, CDE Sub Group 2018), and this is a possible application of this mode. It was agreed that Information Delivery, sometimes considered disruptive, *did* have a place in CDE ad BIM platforms.

6.4 Software Requirements and Capabilities

The aim of Workshop 3 was to establish the software requirements for Information Management functionality in BIM and CDE platforms. The following functionality can be distilled from the discussion:

- Querying repositories using a visual syntax or the natural language used by stakeholders
- Browsing & Exploration of information repositories based on Uniclass 2015
- Information Delivery based on industry or project protocols

These functions can be framed as the following capability required by UK software developers:

> Capability 3: The capability to develop fit-for-purpose software which enables stakeholders
> -to query information repositories visually or using natural language,
> -to explore information repositories based on current models (such as Uniclass-2015),
> -to interrogate information repositories automatically using ontology-based tools, and
> -to set information delivery schedules based on industry and project protocols.

The three modes of information consumption and the corresponding capabilities should enable the effective *finding* and *understanding* of information. These complement the Plain Language Question (PLQ) approach (NBS 2018b), whereby a client or employer poses questions at various decision points or construction stages. The NBS BIM Toolkit (NBS 2018c) includes a function for drafting PLQs and allocating them to project stages and appointments. The BIM Task Group gives a set of PLQs categorised across the project stages (BIM Task Group 2018). PLQs can be used as the mechanism to query or browse repositories, or drive the creation and delivery of information.

7. Business Models

Mohamad Kassem from Northumbria University led a discussion of business process models and made a case for a value-driven ontology for business models under DBB, sttended by five industry practitioners and five academics. This focus aligns with the "Industry Process Model" block of the Information Management Landscape (Figure 1).

There was consensus that a systematic approach is needed for identifying and delivering business value (in broader terms, including social, economic and environmental value) from Information Management. The use cases explored by the attendees (the use of digital data to improve service delivery in healthcare infrastructure, and the use of digital data to improve the use orperformance of equipment on site) highlighted the challenges of understanding how value can be created from managing digital data. There is a need for a systematic method to explore the value chain involved in creating and exchanging digital data to unlock business value. The merits of ontologies, business models, and process models in this context were discussed. It was concluded that a process model is needed for identifying and delivering business value through Information Management in DBB.

Capability 4: The capability systematically to identify and derive business value (including political, technological, social, economic and environmental value) from Information Management. Specifically, a value-driven process model is required.

8. Concluding Remarks

Over its five workshop activities, Network FOuNTAIN established six capabilities that will be important in Digital Built Britain in the coming years. These can be summarised as:

- Capability 0: Capability to gauge Information Management maturity.
- Capability 1a: Capability to establish the appropriate scope of standardisation.
- Capability 1b: Capability to design or extend existing ontologies *in general*.
- Capability 2: Capability to develop current classification systems, schema and frameworks, Uniclass 2015 *in particular*.
- Capability 3: Capability to develop Information Management software.
- Capability 4: Capability to identify and derive business value from Information Management.

Capability 0 can potentially enable and Capability 4 can potentially drive the other Capabilities. Capability 0 aligns with aspects of BS19650 (ISO 2018a,b). Capability 4 aligns with the Gemini Principles driving the creation of a National Digital Twin (CDBB 2018b). Capability 1a is the one possibly entailing some more basic research, and is positioned as a longer-term target, although it is of fundamental priority. This paper makes an important contribution to knowledge by identifying the capabilities in Information Management that will be needed by professionals as the industry in the UK and worldwide undergoes is digital transformation. The most important limitation of this work is that it is based on the views of a small (albeit influential) group of professionals and researchers.

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