Value to Clients through Data Hand-Over: A Pilot Study

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Executive Summary

This report summarises findings of a pilot study, which uses interviews with leading practitioners (across 6 clients and 6 delivery firms) and a review of industry and policy documents to develop new understanding of the hand-over of data to clients and its use in operations. The research was conducted for the Institution of Civil Engineers (ICE) Information Systems Panel at the University of Reading.

The policy and industry context for this research is fast-moving, there are a number of international initiatives to develop standard formats and processes and embed them in procurement arrangements. To meet sustainability targets and maintain a competitive industry, UK government is looking to developing a structured approach to increasing Building Information Modelling & Management (BIM(M)) take-up over a five year horizon.

Key findings of the research include the focus on using data in operations in parts of industry that have regulatory requirements to ensure safe and ongoing operation. Here, major clients include utility providers; highways; railways; stations; airports; and hospitals. The interviews with leading clients and delivery firms involved in these areas highlighted the focus on accurate data for risk management and compliance, as well as for better decision-making about investment in the physical infrastructure.

Data hand-over from projects into operations is difficult as this is *'not seen as the sexy end of the project.'* Gaining value from data about assets is important to improve decision-making about capital and operational expenditure. Clients emphasize the importance of ensuring data accuracy and completeness and then keeping data up-to-date for ongoing use in operations. However, the main data types used for operations and facilities management differ from those used in projects; and this is causing challenges for hand-over procedures. The report discusses the potential for the integration of operations considerations into the project delivery process.

The report ends with some preliminary conclusions, and next steps for data analysis and publishing from the research. The appendix of this document contains the asset life-cycle diagram that provided a starting point for this work.

1 Introduction

This research focuses on the delivery of value to clients, through data. It provides input into ICE work on a progressive data strategy supporting best practice in the asset life-cycle of major building and infrastructure projects. Recent policy developments have made this work even more timely and topical, and outputs will feed into the work of a UK government and industry working group.

1.1 Objectives

The objectives of this research are to:

1. *evaluate* how data is created, captured and refined;
2. *evaluate* what data is valuable to clients and the asset manager at the end of the project as it extends into operations; and
3. *revisit* the generic infrastructure data asset life-cycle diagram [see Appendix A].

1.2 Research background

The work was commissioned by the Institution of Civil Engineers (ICE) Information Systems (IS) Panel, following a co-production workshop hosted in the Design Innovation Research Centre the University of Reading in early 2010, which investigated the challenges that professionals face in the delivery of major projects. This workshop also led to an ICE briefing paper (Jackson, 2010), which shows the generic infrastructure data asset life-cycle, the associated questions about value management, data capture and refinement, and the concept of progressive information management. The objectives for this study were shaped in this context, drawing on the findings of the 2007, 2008 and 2009 ICE workshops on “Information Management through Life” which identified the issue of progressive life-cycle data value management for infrastructure as an important area for research-based best practice knowledge outputs. To ensure the relevance of the research a steering group was set up, with online meetings in July and October and email correspondence to help shape the interview protocol, identify interviewees, and provide feedback on emergent findings.

2 Methods

2.1 Desk-based study of industry reports

The desk study involved a wide review of the policy and industry reports and grey-literature on the topic. In this we have taken the advice of the steering committee as to the most relevant reports and documents; and also sought to identify international projects that had had particular success in data hand-over to operations as exemplar cases.

At the same time, within the Design Innovation Research Centre, we have been conducting a more focused and systematic review of research evidence, using a methodology that has its origins in medical science and involves a very structured approach to reviewing databases to identify the key research literatures and evidence. Further details of this will be made available to the ICE.

2.2 Interview-based study

Between August and November 2010 we conducted 12 interviews: 6 with major infrastructure clients, to obtain data on the data that is valued at the end of the project process; and 6 with engineers involved in the delivery of leading projects, to understand how data is created, captured and refined. These are summarised in Table 1. Interviewees were chosen as representing leading practice.

Table 1: Interviews conducted

Interview	Type	Company	Interviewee Role
1	Client	University of Reading	Deputy Director of Estates and Facilities Management; and Asset Register Manager
2	Client	BAA	Head of Systems & Standards
3	Client	EDF Energy	Asset Lifecycle Manager
4	Client	Thames Water	Asset Data Manager and GIS Manager
5	Client	Network Rail	Project Information Integration Specialist
6	Client	Nationwide	Projects Implementation Manager
7	Delivery	WSP	Director
8	Delivery	Costain	IT Director
9	Delivery	Kier	Design Manager
10	Delivery	Vinci	IT project manager and ICT R&D Project Manager
11	Delivery	Scott Wilson	Technical Director
12	Delivery	Zaha Hadid	Architect

The interview data are being analysed qualitatively, and preliminary findings are displayed in data tables. These, and the text accompanying them, derive from the narrative emerging from data analysed using the qualitative analysis package NVivo. This was ‘open-coded’ by two researchers and then ‘axial’ codes were developed by combining codes to identify broader themes. Transcription, coding and analysis work is ongoing. However some robust themes are identified across the interviews. Hence, although preliminary and partial, these results can inform work to revisit the data value asset life-cycle with the project steering committee; and to write a briefing paper for the ICE. These results also form the basis for the discussion of findings at the event on ‘Engineering Management in the Digital Economy’ co-organized by ICE and the Advanced Institute of Management Research (AIM) in December 2010.

Outside of the formal interviews, and the discussion with the steering group, we have also had input from managers that own and operate factories (through an EPSRC workshop on virtual manufacturing); talked with managers involved in the delivery of major projects, including CrossRail and HighSpeed 1; and presented the research to the Innovative Construction Research Centre advisory group. The team have attended Building Smart related events in Copenhagen, participated in industry events, by Autodesk and BISRIA/Building Smart on Building Information Modelling. The work has also been discussed at a meeting of the International Advisory Board for the Design Innovation Research Centre (Ray Levitt, André Dorée, Andrew Davies and Kristian Kreiner), at Stanford University, USA.

2.3 Scope of this report

Inside the scope of this ICE best practice project is the data collection (6 interviews with major project clients; 6 interviews with engineers delivering major projects), and preliminary analyses of data from clients on progressive information, and the delivery of this to ICE in a format ready from dissemination to practitioners. Outside the scope of this project is the transcription and detailed analysis of these interviews for research publication (Although this work is underway). Hence this report summarises the preliminary findings at the completion of the ICE funded research. Next steps include the additional work required to build new theoretical understandings and get these published in the academic literatures. As discussed in the final section of this report, this work has involved uncovering the disjointed nature of organizational memory in this context.

3 Desk-Based Study of Industry Reports

In the desk-based study we reviewed industry and policy literatures. These vary in nature, incorporating policy guidance; market reports, industry standards and procedures; strategy documents and popular books. Empirical research is largely excluded, as the team is conducting a separate structured literature review of the evidence base. Instead the focus is on understanding and critiquing the discourses that emerge and data hand-over in industry and policy publications.

There is substantial industry and policy interest in Building Information Modelling (BIM). This review is conducted in the context of a growing UK policy agenda (BIS/Industry Working Group, 2010), with the announcement that government procurement will require the use of Building Information Modelling and Management (BIM(M)). It also draws on evolving policy agendas in the USA and Denmark, two international contexts that were visited during the work; and from observed developments further afield in Australia and Canada. The USA and Denmark, along with Sweden and Norway, have signed a 'Washington Agreement to support open BIM standards. Examples of the many sources of reports are summarised in Table 2 below:

Table 2: Examples of industry and policy information on BIM

Origin	Reports
	Industry *These reports discuss BIM as a necessary part in using data in the building life-cycle. They refer to BIM as being on an evolutionary scale and collaboration is promoted between the construction professions. They also emphasise the potential value of BIM for facilities management (FM) services and in particular the long-term value of BIM in feeding into the green agenda.*
UK	BSI (2010) *Investors Report*, British Standards Institution: from http://shop.bsigroup.com/Browse-by-Sector/Building--Construction/Building-Information-Modelling/.
UK	BSI (2010) *Construction the business case - Building information modelling*, British Standards Institution
USA	Gallaher, M.P., O'Connor, A.C., Dettbarn, J., John L. & Gilday, L.T. (2004) *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*, National Institute of Standards and Technology (NIST).
USA	CRC (2007) *Adopting BIM for facilities management: Solutions for managing the built environment*, CRC.
USA	CRC (2007) *FM as a business enabler: Solutions for managing the built environment*, CRC.
UK	Jackson, P. (2010) *Progressive through Life Data Value Management*. London, Institution of Civil Engineers.
USA	VTT, M.H. (2007) FIATECH Capital Projects Technology Roadmap: Mapped with ECTP Focus Area Processes and ICTs (PICT) and consolidated topics of all 7 Focus Areas.

USA	(2009). Washington, National Institute of Building Science - buildingSMART alliance.
UK	(Draft) *Investing in BIM competence. Building Smart: A guide to collaborative working for project owners and building professionals.*, Building Smart.
UK	Bew, M. & Underwood, J. (2010) Delivering BIM to the UK Market. *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies*. J. Underwood and I. Umit, IGI Global**:** 30-64.
USA	CURT (2004) *Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation*. Cincinnati.
USA	Fallon, K. & Palmer, M. (2007) *General Buildings Information Handover Guide: Principles, Methodology and Case Studies. An Industry Sector Guide of the Information Handover Guide Series* FIATECH.
USA	Jordani, D., A. (2010) *BIM and FM: The Portal to Lifecycle Facility Management*. Washington, National Institute of Building Sciences and buildingSMART alliance.
USA	East, W., E. (2009) *Performance Specification for Building Information Exchange*, National Institute of Building Sciences and buildingSMART alliance.
UK	Nisbet, N. & Dinesen, B. (2010) *Constructing the Business Case: Building Information Modelling*. London, British Standards Institution.
	Industry Standard *These reports outline the open standards that are promoted in the construction industry and how they are being used.*
UK	NBS (2008) *CPIC and Uniclass - Who, what and why?*
UK	Richards, M. (2010) *Building Information Management: A Standard Framework and Guide to BS 1192*, BSI/ CPIC.
	Industry Broader *These reports are on the stages of the delivery of a project and the delivery of BIM in a project, respectively.*
UK	RIBA (2007) *Outline Plan of Work 2007*, Royal Institute of British Architects.
USA	Bentley (2010) *A Bentley Success Story –Burgess and Niple*, Bentley.
	Market Report *The McGraw-Hill reports on surveys in the US that have been conducted on the use of BIM. The surveys report that BIM is primarily used in the early stages of construction but the software most frequently used in operatations is 2D CAD.*
USA	Young Jr., N. W., Jones, S. A., & Bernstein, H. M. (2007). *Interoperability in the Construction Industry*: McGraw Hill Construction.
USA	Jones, S. (2008) Introduction to BIM: Smart Market Report Special Section. *Building Information Modeling (BIM): Transforming Design and Construction to Achieve Greater Industry Productivity*. SmartMarket Report, McGraw Hill Construction.
USA	Young Jr., N. W., Jones, S. A., & Bernstein, H. M. (2008). *Building Information Modelling (BIM): Transforming Design and Construction to Achieve Greater Industry Productivity*: McGraw Hill Construction.
USA	Young Jr., N. W., Jones, S. A., Bernstein, H. M., & Gudgel, J. E. (2009). *The Business Value of BIM: Getting Building Information Modeling to the Bottom Line*: McGraw Hill Construction.
	Policy *These focus on the interoperability between systems in the construction industry into operations. They report good interoperability of system in the construction phases but decreases into operations. The use of IFCs in the Sydney Opera House proved successful in getting the information across for FM use.*
Canada	Ahamed, S., Neelamkavil, J. & Canas, R. (2010) Impact of Building Information Model on Facility Maintenance Management. *National Research Council Canada*: 7.
USA	AIA (2007) *Integrated Project Delivery: A Guide*. California Council, The American Institute of Architects.
Denmark	Bang, H.L. (2010) *Afrapportering fra Udredningsprojektet Byg-og Driftsherrers Digitaliseringsbehov*. Copenhagen, Bygherre Foreningen (Danish Association of Construction Clients).

UK	BIS/Industry Working Group (2010) *Building Information Modelling and Management (BIM(M)): Interim Report*. London, Confidential report to Construction Clients Board.
Denmark	(2005) *Digital Construction*. Copenhagen, National Agency for Enterprise and Construction.
Denmark	Bips (2007) *Digital Construction: 3D Working Methods 2006*. Ballerup, DK, Construction BIPS.
Australia	Drogemuller, R. & Schevers, H. (2006) *Sydney Opera House - FM Exemplar Project: Building Information Modelling for FM at Sydney Opera House*.
International	CIB (2010) Integrated design and delivery solutions, Publication 328
	Popular books *These refer to the potential value of BIM for FM. They outline a number of ways in which BIM would create cost efficiencies in FM services and benefit the long term maintenance of an asset which in turn would have sustainability benefits.*
USA	Hardin, B. (2009) *BIM and Construction Management: Proven Tools, Methods and Workflows* Indianapolis, Wiley Publishing Inc
USA	Eastman, C., Teicholz, P., Sacks, R. & Liston, K. (2008) *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. New Jersey, John Wiley & Sons Ltd.
USA	Smith, D.K. & Tardif, M. (2009) *Building Information Modeling: A Strategic Implementation Guide*, John Wiley & Sons, Inc., Hoboken, New Jersey.
USA	Jernigan, F. (2007) *BIG BIM little bim*, 4Site Publishing.
USA	Krygiel, E. & Nies, B. (2008) *Green BIM: Successful Sustainable Design with Building Information Model*. Indianapolis, US, Wiley Publishing
USA	Kymmell, W. (2008) *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations* New York, McGraw Hill Construction.

The below sections review the discussion of the potential value in operations, the evolution of BIM(M) and related practices, project delivery and data hand-over to facilities and operations in these policy and practice debates.

3.1 Potential value of BIM(M) in operations

The type of information currently delivered to facilities management is paper-based but the use of digital information is growing (Gallaher, O'Connor, Dettbarn, *et al.*, 2004). East (2009) point out that facility managers, tradesmen and the owners are not directly concerned with the geometry of the building but need to know details of what has gone into the building. East (2009) lists a number of types of data that is needed at handover. Information is currently exchanged in a variety of different documents:

- Commissioning Plans
- Daily Reports
- Floor Plans & Drawings
- Insurance
- Manufacturer Product Data
- Photographs
- Quality Control Documentation
- Cost Estimates
- Equipment list
- Fabrication Drawings
- Invoices
- Operations & Maintenance Manuals
- Progress Schedules
- Requests for Information

- Room Data Sheet
- Spare parts Providers
- Tests and Certifications
- Safety inspections
- Specifications
- Warranties

(source: East, 2009: p.18)

While the literature describes BIM as the main information source to be delivered to clients at handover, this remains aspirational. We found no reports that capture examples of the use of BIM created during project delivery in operation, although work did capture its use in facilities management. A range of studies refer to the potential value of BIM in terms of costs and productivity that can be derived from BIM in operations (Becerik-Gerber, 2010; Eastman, Teicholz, Sacks, *et al.*, 2008; Hardin, 2009; Kymmell, 2008). Bew and Underwood (2010) believe that BIM could be used to: *"bridge the information loss associated with handing a project from the design team, to the construction team and the building owner/operator, by allowing each group to add to and reference back to all information they acquire during their period of contribution to the BIM model"* (Bew & Underwood, 2010: p.33). They are among the many writers that note that the design/construct phase is much shorter than operation and even small information gains in facilities management can result in significant improvement, e.g., Jordani (2010). Indeed *"80% of the cost of an asset is spent during the operation of that asset and not in its capital cost at the design and construction phases"* (Bew & Underwood, 2010: p.36).

There have been some efforts to develop BIM directly for facilities management systems and speed up the benefits of BIM for operations and maintenance. For example, through the BIM for Facilities Management Portal which proposes to *"seek input and feedback from owners and FMs, their design and construct partners, and software vendors to develop expectations and business requirements and help to articulate model views"* (Jordani, 2010, p. 16). Increasing the accuracy of data hand-over has implication for the long term usage of data in facilities management strategies. BIM is one way of delivering the accurate information that is vital for decision making (Jordani, 2010). The use of BIM for long term facilities management planning would also feed into delivering assets that can be maintained longer fitting in with the 'green agenda' (BSI, 2010). Nisbet and Dinesen describe how: *"BIM allows a facility to be analysed both for its energy consumption and its other impacts on carbon generation throughout its life cycle. Assessments can also track other environmental impacts, including water consumption and pollution"* (Nisbet & Dinesen, 2010: p.13).

3.2 Evolution of BIM(M) and related practices

Bew and Underwood (2010) have been developing an evolutionary ramp based on an earlier model by Bew and Richards (2008) .

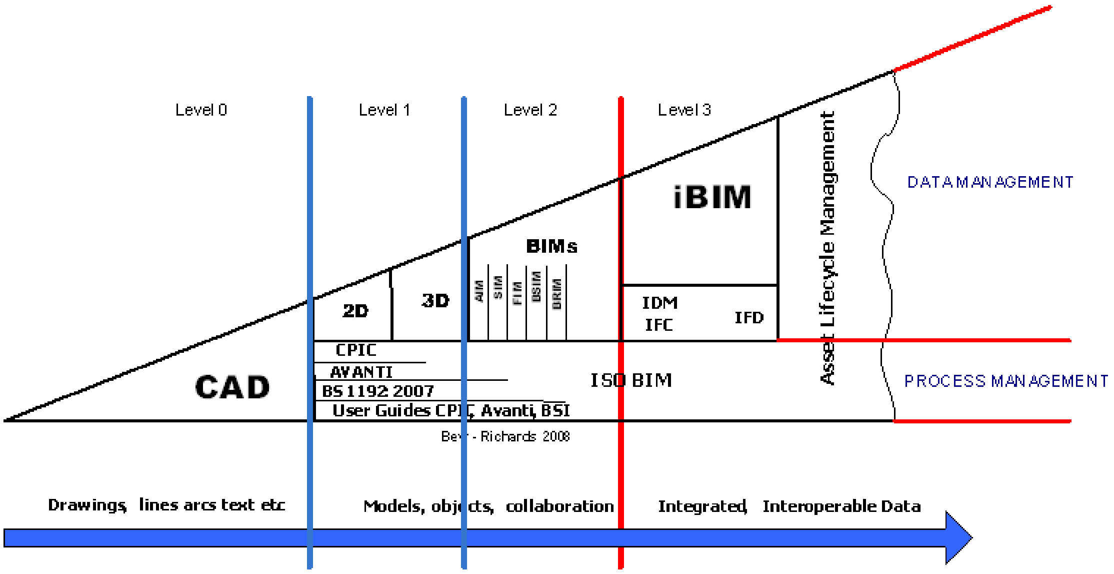

Figure 1: BIM evolutionary ramp – construction perspective (source:Bew & Underwood, 2010: p.35)

The model outlined in Figure 1 illustrates how the data from construction and design could be progressively developed and handed over to operation by incorporating well known standards which will be discussed further below. The model differentiates between data and process which is an important development of any implementation and adoption strategy. This model seeks to highlight the progress use of data in a structured way that incorporates both the project base and then the firm base of the data usage. It starts at level 0 with minimum data such as CAD with paper and moves onto level 1 incorporating 2D and 3D with a number of standards which promote collaboration. In level 2 the technology develops more into a BIM tool as more technology is integrated. Level 3 identified open process and data integration enabled by IFC (Bew & Underwood, 2010). According to the BSI Investors report (2010), the majority of the UK construction are at level 1 processes and 'the best in class' are experiencing significant benefits by moving to level 2'.

There are a number of standards referred to in the diagram above which relate to each other through the process management phases. BS 1192:2007 was *"published to provide a standard and best practice method for the development, organisation and production of information for the construction industry"* (Richards, 2010 p.xv). BS 1192:2007 recommends the use of the Unified Classification for the Construction Industry (Uniclass). This outlines 15 tables which classify different aspects of the construction process. The details of the production information was implemented in the Avanti government funded project (NBS, 2008). Avanti promotes collaborative working between construction project partners through early access to all project information and early involvement of the supply chain (http://www.constructingexcellence.org.uk/ceavanti/default.jsp 30/11/2010). In terms of data management, BS 1192 is also the basis of the delivery of Integrated Building Information Model (IBIM) and associated data (Richards, 2010). The open standards of IFC (Industry Foundation Classes), IDM (Information Delivery Manual) and IFD (International Framework for Dictionaries) are associated with the formats in which information is exchanged and delivered in a project (Bew & Underwood, 2010).

While COBie (Construction Operations Building information exchange) is not referred to in the above diagram, it is seen as being crucial for the delivery of BIM (Jordani, 2010). Indeed one of the working groups in a new initiative by the UK's Business Innovation and Skills (BIS) falls under an "FM integration based on COBie". COBie allows for the exchange of IFC-based facility management data (Jordani, 2010) and captures this information, incrementally, during the design and construction phases (Fallon & Palmer, 2007).

As mentioned already, the UK government department BIS has started a new initiative in the development of standards to deliver BIM(M) in construction projects and facilities management. The primary aim of the working group is to: *"examine the broad construction and post-occupancy benefits of BIM(M) and the development of a structured Government/sector strategy to increase its take-up over a five year horizon"* (BIS/Industry Working Group, 2010 p.30).

3.3 Project delivery and data hand-over

A McGraw-Hill report found that firms and organisations are addressing the need for greater efficiency in the building environment by rethinking traditional ideas of project delivery (Young Jr., Jones, & Bernstein, 2007 p.8). For example, the American Institute of Architects (AIA) outlines an Integrated Project Delivery (IPD) process through 8 sequential project delivery phases that aim to break down traditional silos in construction projects: 1) conceptualization [expanded programming]; 2) criteria design [expanded schematic design]; 3) detailed design [expanded design development]; 4) implementation documents [construction documents]; 5) agency review; 6) buyout; 7) construction; and 8) closeout. IPD primarily considers the early part of a construction project and emphasises the importance of communication in the *"transfer of project data between participants and between technologies"* (AIA, 2007: p.10).

While there are some references to operations in the AIA report, the emphasis is on the three identified stakeholders - designers, constructors and owners. The closeout phase in this report mainly considers whether the project has been delivered on time and on budget. Criteria could be expanded include longer term goals such as energy efficiency, maintenance criteria or productivity and this would require the operations to be active through a full season or other operational cycle (AIA, 2007: p.42). However, the low emphasis of hand-over data at closeout of a project is a bit of an anomaly within the IPD process.

There has been strong emphasis on the use of BIM for project delivery, but this often stops at handover. A more collaborative and informed commissioning process would enable information from design/construct phase to be used downstream by facility managers (Jordani, 2010). The use of Building Information Modelling (BIM) is a way of increasing data accuracy at delivery as well as increasing interoperability (AIA, 2007; Bew & Underwood, 2010; BSI, 2010). Yet East (2009) argues that there is a gap between the requirement for building information deliverables and the technology that is required to deliver such information. Performance specification related to physical components of building is well understood but examples of performance specifications for delivery of electronic information is not found in contracts (East, 2009 p.18).

Interoperability is important in the construction as there are so many different groups working in the same project. Lack of interoperability results in problems such as re-entering data manually from application to application and duplication of business functions (Young Jr., *et al.*, 2007; Young Jr., Jones, & Bernstein, 2008). In Denmark, a 3D working methods is being used to specify a common coherent working method for all the parties to a construction project so that 3D models can be created, exchanged and re-used through the entire project (Bips, 2007 p.1). The 3D working method is based on discipline models and aggregate models. These models are continuously developed during a construction project by various discipline groups. Value is added through increasing precise information that can be used across the board. Thus this 3D working method promotes integrated processes to ensure that a groups contribution in a project can be used through the *"entire process, strengthen collaboration and data sharing, re-use data to a greater extent and thereby ensure better* *consistency and quality of the models that are used"* (Bips, 2007: p.11). The aim is to improve the whole process in the delivery of a completed construction that is of higher quality and lower cost than what was previously attainable.

The need for new methods for interoperable working and the traditional problem of people working in silos are emphasised in the AIA report (2007) and BIPs report (2007). The use of Building Information Modelling (BIM) is seen as a way of increasing interoperability (AIA, 2007). The need to observe standards in the construction industry is emphasised so value can be obtained during the project and during the building cycle (Nisbet & Dinesen, 2010). This value has the largest potential for facilities managers as the professionals who are responsible for the as built asset over a longer cycle than design/construct (Jordani, 2010).

4 Interviews with Suppliers and Major Clients

The interviews with leading clients and delivery firms highlighted the focus on accurate data for risk management and compliance, as well as for better decision-making about investment in the physical infrastructure. The parts of the industry that have regulatory requirements to ensure safe and ongoing operation pay particular attention to obtaining high-quality data about their physical assets. These include utility providers; highways; railways; stations; airports; and hospitals. This section highlights the main findings of the study related to 1) data use, its accuracy, completeness and up-dating as a basis for expenditure decisions; 2) data types, the types of data that are most valuable for operations and facilities management and; 3) integration of the FM discipline from the earliest stages of the project life-cycle through to hand-over procedures and into operations.

4.1 Using data in operations

For major clients the value of data was seen to derive from improved operational expenditure (opex) and capital expenditure (capex) decisions:

> *I think all the utilities would say they see data as a big challenge, to actually improve quality of data, understanding what you need to collect, collecting it, keeping the system clean, clean data, using it wisely, making the best decisions, optimising your opex and capex. If you haven't got good quality data you can't optimise your capex and opex, with the wrong data you're going to be replacing the wrong assets and*

taking the wrong maintenance or not maintaining stuff that needs to be maintained, so it's really critical.

Knowing what is needed to be collected and knowing that the data is accurate means that decisions on capex and opex can be optimised and these decisions can be trusted for being based on the correct data. The main challenges emphasised at the hand-over point of data were first, that of data accuracy and completeness and second, that of keeping data up-to-date for use in operations. For example, one interviewee said:

Big challenges, keeping the data up-to-date and making sure you've got it all. I think those are two different things, making sure you've captured it all, keeping it up to date.

Many projects that we examined use 3D at the design and construction phase. There have been various examples in the literature where 3D was seen as being potentially valuable in operations (Gao, Fischer, Tollefsen, *et al.*, 2005; Hartmann, Gao, & Fischer, 2008). However, cases of 3D use in managing assets have not been found. One issue is that there are different skills involved across the phases of construction. One interviewee tries to explain this by using an example as to why 3D is not used in facilities management practices.

...because it's such a changing environment and, you know, that you've got to be flexible. So I think trying to keep up with, you know, correcting 3D models, if you like, is a challenge beyond – a challenge which we're not resourced to cope with [that] at the moment, I think it's fair to say, but we can keep up with the 2D stuff and, actually, I don't know. I don't know whether we're missing a trick. I would be interested to know if other people find that much more useful

For this client there is uncertainty about whether the use of 2D or 3D is better or not but as the established practice is 2D, their interests are in attributes rather than geometries and the 3D models have not shown themselves to be valuable for them. Another client also questioned the value of 3D in facilities management practices. They felt the use of 2D meets the requirements of facilities management and it is cheaper than 3D. 3D is seen as impressive and seems to appeal to *'the boys who want nice flashy toys'* but the cost benefit analysis is not clear. However, visually there is a perceived tangible benefit. For instance, in 2D, pipes are laid side by side but in 3D, it would be possible to look at pipes exactly as they are in reality (on top of each other), which could help avoid problems when carrying out maintenance work.

However, the challenges here are as much organizational as they are technical, as sometimes data is available but not used due to a certain 'mindset' as expressed by one interviewee. Between firms this lack of data reuse may also be for contractual, insurance and liability related reasons:

> *Often the information isn't reused even though it's available. We probably spend a couple of million pounds on surveys a year for facilities that we actually have information about, even if that information is provided. We haven't lost it, we can access it, we can find it, we can provide it but our suppliers will still commission surveys.*

Finally, an issue that came through is the use and value of data in not only major projects but the smaller ones as well. There is, therefore, the need for approaches that take into account smaller projects, including refit and refurbishment projects, which are often more numerous:

> *We need approaches that are scalable for both the big and the small but at the end of the day all of the asset data needs to be interlinked and kept within that grid and also link into the same maintenance systems, whether it be something we put on a forecourt or a major chilling station.*

The main challenges of hand-over that have been emphasised here are those around accuracy and completeness of data and updating it in use. The ability to use different types of information in operations depends on the tasks, but also the skills of the facilities and/or asset management teams. The next section discusses the different types of data that were discussed in the interviews.

4.2 Data types that are valued

The data that was discussed as most valuable for operations and facilities management has initially been categorised into 5 main groups as depicted in Table 3. This presents a general breakdown of data types, formats, uses and supporting systems or applications. Table 3 sets the stage for a sharper focus in the subsequent sub-sections on how practitioners progressively add value to the data through the project life-cycle so that by the time the data are handed over to operations and facilities management, they are most useful.

Table 3: The main types of data

Data Group	Types	Format	Uses	Systems/ Software
Asset management data	Asset register, instruction manuals, SLAs, etc.	Digital & hard copy – spreadsheets, PDF,	General maintenance, financial accounting,	Asset management systems - Maximo,
Geographical data	GPS & GIS	Digital	Location, replacement, customer service,	Ellipse, ESRI,
Manufacturers' reference data	Feature code libraries, nameplate attributes, specifications,	Digital	Inspection, fault detection, maintenance, replacement,	Sundry databases
Environmental, HSE, warranty and security	Environmental modelling, acoustics, regulatory approvals, residual risks	Digital – reports, statistics, analyses, etc.	Performance modelling, environmental monitoring, health & safety, Repairs, defective product replacement, Security,	Digital & hard copy
Geometric model and drawing data	2D & 3D CAD models, 2D sketches, etc.	Digital – PDF, DWG, DWF, & hard copy - printouts	Reference - checking design intent, updating changes, checking as built v. as designed,	CAD, Documentum, Projectwise,

The last category of geometric models and drawings was not as extensively discussed as the researchers expected, and where it was discussed, it was discussed as a reference set, not as a data-set that would be updated.

> *There's more than one system, we have a database of CAD models which are available obviously for reference during the building's life and whether we change it, things like that but we also use Maximo which is a maintenance management tool.*

In order to produce further accuracy of data that is usable in the life-cycle of a building, one view, put forward by Jordani (2010) is that there is a need for alignment of business perspectives of a design/construct team and an owner/FM for the long term value of the building asset and a translation of data formats and/or representations. *"Simply delivering project BIM(s) to an owner has marginal value. To be effective, the data captured in BIMs must be channelled into a variety of FM software systems"* (Jordani, 2010, p. 13). For this reason, we explore the first four categories from Table 3 further below.

4.2.1 Asset management data

Asset management data appear to be the most general category under which several of the other types can be subsumed, and indeed are, in different organisations and/or projects as indicated by the interviewees' statements. Key asset management data types include asset registers, instruction manuals, and service level agreements. Chief among this group is the asset register, which one interviewee describes thus:

> *...in every project it's the asset register which is vitally important otherwise we just can't maintain a building going forward... one of the key things that we've struggled with a bit is the asset register, because that has to record every single piece of equipment, every tap as well as every boiler and air conditioning unit and what have you, and that is then transferred across to Maintenance so that they can create their maintenance schedules. So that's fundamentally important to get that and to get that right and that's such a huge job in collating that information...*

Echoing the above and summing up the importance of the asset register, from general maintenance through to replacement and incident prevention, another interviewee states that:

> *We've had examples where we've installed an asset and, for whatever reason, the process has broken down, where the asset was not recorded into the asset management system and then you don't actually do any maintenance. Then at some point in time someone says 'When was that last maintained?' then you look into the records and you find that assets weren't actually on that asset register, therefore it doesn't trigger any work for it to be maintained. So in terms of the assets we're dealing with, if you don't maintain them it can lead to catastrophic events where things can blow up so it's very important to us that any assets that are installed or constructed are captured from day one and go into the system.*

4.2.2 Geographical data

Geographical data on the other hand, are more applicable to infrastructure projects, such as those of utilities and transportation, and are used for location and maintenance of assets that are widely dispersed.

> *we have a strategy to develop a series of models which are aligned with each other through the establishment of a [project] grid. We have an ordinance survey type grid*

> *which is aligned […]. So all the buildings […] are designed with reference to that grid and we use differential GPS to locate things.*

Furthermore, unlike traditional building data, for many of the utilities use of GIS and GPS data extends beyond maintenance of the infrastructure into applications such as customer service.

4.2.3 Manufacturers' reference data

Manufacturers' reference data is often manipulated, and reformatted within corporate systems, and there is great interest in new ways to utilise this data. For instance, in the example below, a feature code library is cross-referenced by a GIS system, to translate data from a GPS unit on location into a format acceptable to the GIS system.

> *So that's what is called a feature code library which basically says 'I am a [manufacturers] GPS unit and I need to get myself into a [corporate] GIS format.' So my [manufacturers] piece of data must match up in terms of material, must match up with an attribute line in my GIS data, and that's the feature code library, pretty much, as well.*

Other examples of reference data shown in Table 3 are specifications and nameplate attributes, which must be referred to, to ensure accurate inspection, fault detection, replacement and general maintenance of asset components such as fixtures and fittings, plant and equipment. If there is a defective component that is recalled by manufacturers, for instance, there may be problems if the item is not recorded:

> *...although you may have as built drawings on site or even scanned, maybe electronic copies of those, if you haven't put onto your system that you've got this type of circuit breaker manufactured between these years with seal number when a type defect comes out for this type of circuit breaker and you don't know you've got it, you're not going lead the modifications, a bit like the recall on a car. If you have a Ford and Ford don't know you've got the car and there's a brake issue they're not going to give you a recall notice to come and get your brakes fixed. That's really important, that those assets are recorded.*

4.2.4 HSE/warranty/security data

Regulations can also be used as a procedural way of processing hand-over data. The Construction Design Management regulations have assisted in deciding what to hand-over in terms of health and safety.

> *...now we have the CDM regulations, which is the Construction Design Management Regulations, which also stipulate what all should go into the health and safety file, and O&Ms, the operation and maintenance manuals are a part of our health and safety file.*

There are also expected new regulations that will come into play around a green agenda which may have problems in terms of definition.

> *And there's a heck of a lot of work to do to define how you say how green things are, never mind how to capture it...*

All these data types in one way or another, relate to adverse effects and their prevention, mitigation or remedy. The ways in which these are related is reflected in the following statement:

> *It would be all the regulatory authority approvals, that's the first thing; all the residual risks that we have left, or hazards that we have left with the client,...any specialist contractors if they have done their work, contracts of all the contractors who have been involved, so if there is any problem they can at least contact them. The other thing that was important was any emergency contacts, those were included as well, and the building guarantees and warranties of products, that is the most important thing, because if anything goes wrong, if the product is still in warranty it can be replaced, so the client needs to be aware of who to contact in time.*

These data continue to be valued into the operational life of the asset, and are becoming more important.

4.3 Integration of operational issues into the project

This refers to the integration – across both technologies and processes – of the operation stages and the various related disciplines with other stages of the project life-cycle to achieve better coordination. Unlike the integration and collaboration between designers and structural engineers, or between design and fabrication (Harty, 2005), which is synchronous; the timescales involved in delivery lead to a relatively asynchronous nature of the integration of facilities management with other disciplines. This is reflected in the statement of one of the interviewees:

> *...but we're not really in that situation where we're on a project with a designer and the constructor and the facilities manager all working off the same data. It just doesn't happen in the line of business that we're in.*

It is possible that the statement is indicative of a general lack of integration (in the construction industry as a whole) of the facilities management discipline into the project lifecycle or simply the interviewee's experience in their firm. However, the phrase "in the line of business we're in" suggests the former, which is consistent with the case for BIM by proponents (Eastman, Teicholz, Sacks, *et al.*, 2008; Smith & Tardif, 2009). In order to achieve successful integration, the data suggest a number of issues that need resolving:

4.3.1 Starting early

A recurring theme from interviewees is that facilities management must be involved in some degree of interaction and collaboration right from the design stages of the project, while the hand-over procedures must begin earlier than at the point of hand-over, for instance, through training sessions for facilities management professionals during the project. Unfortunately, this happens less than advocated. Early involvement would enable the resolution of design issues that could affect the operation of the asset as well as address questions or concerns from facilities managers before the respective experts disengage from the project, after which it would be more difficult. This is evident in the statement below:

> *I think one of the lessons, when you're bringing in new methods of working, is get it in – get as early involvement as possible. It's difficult to retrospectively do things because contractual things can be thrown up quite easily. But if the Facility Manager is involved earlier in that, so that if, in first time he doesn't get it right, so he can at least ask the – maybe the M&E guys who are present onsite to explain to him again, or maybe look at the videos again that we – so it's better to have someone onsite to share that information with him, and that's one of the reasons.*

4.3.2 Appropriate tools

For the effective integration of FM into the project life-cycle, the most appropriate tools and methods have to be used. The appropriate tools and methods may not always be available, or incorporated into the contract early on, as indicated by one of the interviewees:

> *Definitely not everyone has [a proprietary CAD package], access to [this] for drawings and – or BIM software, so usually we treat our client as a common person and what a common person will actually use...[and we] try to present our information in that manner.*
>
> *...but if it's not a part of the contract or it has never been mentioned in the design stage, it is a very, very difficult task and an expensive task to include that in the end of the project. So if you're aware of it in the beginning, then we can definitely, you know, do something about it and put some research into it so that we can give the best value to the client.*

However, some of the interviewees' statements reflect a lack of awareness of, or experience in, using BIM technology and process as expressed by another interviewee:

> *Well we haven't enjoyed that and we've got no projects which enjoy that technology, so if we had it, I'm sure it would be great, but we haven't got it, so...*

This also raises questions about the current state and awareness of BIM, its adoption, efficacy, etc. Perhaps due to low adoption of BIM, lack of awareness or BIM not living up to expectations, the interviewee seems to believe that the problem of incompleteness of data cannot be addressed in reality. Another interviewee suggested that Excel is the best format for handing over data, which suggests a lack of appreciation of the various tools and applications that are part of a building information model. However, given that the person is an experienced professional who should be at the forefront of the current BIM drive, this could suggest something more fundamental, i.e., scepticism among some industry stakeholders - paying lip service to BIM while not really implementing it or believing in it.

4.3.3 Standards and Interoperability

There are attempts noted in the industry reports to use open standards for data handover. Various systems are used on a project but according to some of the interviewees, the systems should work on an open format so the data can be used on multiple systems. There are some systems that are product specific which can be very constraining.

In terms of what formats it needs to be ... ideally it would be an open format, it needs to be independent of a particular platform, that's to say formats that multiple systems can generate the information in. So for example at the moment we ask for DWG and DWF, whilst that's associated with Autodesk as a product, they license it off somebody else as a format and many other software manufacturers can actually generate files in those formats, whereas if you look at the Revit database outputs they would be product specific or platform specific and that wouldn't really meet our needs. We would feel constrained in which designers we used, I think, if we were to go that specific, but equally I'm cautious about formats that require two lots of translation.

The Industry Foundation Classes (IFC) came up on a number of occasions in the interviews as a systematic way of handing over data. Emphasis was placed by interviewees on the need for the on-going efforts at developing standards for data exchange and information sharing in the industry to be a very collaborative one that takes input from stakeholders across the construction industry supply-chain. According to one interviewee:

...I want to accelerate the wider industry filling the gaps because at the moment [our company] has its own common language that I mentioned earlier. As we exploit more and more aspects of building information modelling and as more and more architects and engineers use Uniclass, it may make more sense to migrate in that direction, but as a client using any sort of coding system like that, it's quite unusual.

However, as indicated by part of the above excerpt, while there is general acknowledgement of the need for collaboration on existing industry standards and those being developed, there is also the continued development of localised standards, i.e., those limited to particular organisations, their projects and by extension their supply-chain. This is further supported by the statement below:

...our GIS system, we've just had a new one, but even so, it's bespoke to us. The previous GIS system that we had was developed virtually in-house. The new one is an ESRI which is obviously a big player in the GIS world but it has been ... the data model behind it is [ours], it suits [our] needs, in effect. So the data that comes back, driven by the feature code library and by our standards and specifications is very much bespoke to the [company] working model.

The level of adoption, potential benefits derivable, measure of successful diffusion, etc., can all be affected by localised practices. This phenomenon was further suggested by one interviewee, who discussed the desire to use a small number of components and limits to their ability to do this due to different performance requirements in different parts of their operation, thus:

> *...there's still a fair amount of variation and the supplier's product changes as well over time. The suppliers of that sort of equipment don't seem to be set up to provide object models at the right level of detail. We don't need an object model that tells you how to make the whole lift; we need something less than that that tells us the performance of it, the key maintenance aspects in the dimensions, the speeds, those sorts of things.*

The importance of interoperability has been emphasised in recent industry reports and the academic literature (Grilo & Jardim-Goncalves, 2010; Young Jr., *et al.*, 2007; Young Jr., Jones, Bernstein, *et al.*, 2009). In relation to infrastructure more than buildings, interviewees highlighted the need for more focus on interoperability between GIS and CAD systems in operations. According to one interviewee:

> *From our perspective the interface between GIS and CAD is something that really, really needs to be solved. Certainly up until probably 18 months ago, from our perspective anyway they were seen as two different systems that couldn't talk to each other. Now they're seen as two systems that can, with a lot of tweaking, talk to each other but we know with the help there, there are things that would make that a lot more easy.*

Whereas location data might be more useful for operations management in utilities and transport infrastructure, there is a scope for achieving such interoperability for managing more traditional assets, i.e., buildings. This is suggested by interviewees' statements emphasising the importance of location data in operations.

4.3.4 Hand-over procedures

Procedures discussed in the interviews referred to the processes involved in the hand-over of data on delivery. The procedures for hand-over of data become important at the end of a project but need to be thought through right from the beginning of the project. This is more so because, in the opinion of some clients who were interviewed, the hand-over stage was *'not* *seen as the sexy end of the project'* for contractors. Two related issues were found to be salient in the interviews; specifying hand-over procedures and specifying data requirements. In the former, internal procedures are developed which aim at ensuring that the organisation is receiving what it should at handover. These are often managed by an internal governance mechanism which decides on any changes to the procedures.

> *We do we have a project management process, […] we have various procedures, checklists, policies around every stage of a project to ensure that those things are done so it was governed around collecting information.*

> *Hopefully, it will all be in an appropriate format because the hand-over process is supposed to check that the formats are okay, but I suspect that they are.*

Having this type of hand-over process in place does allow for reassurance that all the data that the organization needs will be given to the organization. However, the use of 'suspect' and 'hopefully' alludes to a lack of confidence that the process lives up to its objectives in its entirety. A follow up conversation with an asset register manager highlighted some of the difficulties associated with using checklists at handover. Sometimes the data can look like it is all there at handover. However, at times in accessing the data – it is difficult to find the specific information. For example, there was a problem with the front door of a building in its second year after delivery. They had manuals which led them on a search through other sections and documents. They had difficulty finding the information that they wanted. It turned out to be easier to contact the manufacturer of the door directly rather than trying to search through the manuals for the specific information that they needed about the door. This kind of situation of not being able to easily find the data or finding that the data is missing only was discovered when a fault occurred in an asset. There is a large amount of data that is handed over and no one has the time to check through all the details thoroughly. Hence, while the checklist reassures that the data is handed-over, the details of the data may not always be complete.

At the same time, many of the people we interviewed raised questions about what data is required at hand-over for facilities management. The 'what' is not covered by the checklists or procedures as these are usually outlining steps and naming items without specifying that detail. There were several suggestions that clients and operators often expend a lot of time and effort searching through volumes of information which could have been provided in more readily useable or supported formats. In the earlier example of data on doors, the client had to create their own spread sheets from the data that was handed over to manage door types. There is real interest from a number of the clients interviewed in making sure:

> *... that our briefs are very good, that we're very clear on what the deliverables are at different stages of the project and that we're very good at clearing obstacles out of the way for our suppliers. So going back to service clearances and things, having good data so that we can tell them where it's safe to dig or what services and things we need to ask before they can do that.*

The aim is not only to collect data that is accurate but to know what type of asset information should be collected, what is the right way to collect the data, what is the best format and who are the right people to collect it? Asking these questions ultimately leads to the key question of who is responsible for obtaining the 'right' data, which is accurate, complete, relevant, and in the most-appropriate format.

5 Discussion

In the management literatures, organizational memory is defined as: "stored information from an organization's history that can be brought to bear on present decisions" (Walsh & Ungson, 1991 p.61). Memory allows organizations to "transmit information from past to future members of the social system" (Stein 1995 p.17). While memory is important for organizational decision-making, memory can also be forgotten. De Holan and Phillips' (2004) concept of "organization forgetting" acknowledges the importance of organizational forgetting in the context of memory disappearance in its transfer to the organization long-term memory; memory decay over time leading onto organizational forgetting due to lack of maintenance and forgetting as a necessity for change.Information technology (IT) is one way in which memories permeate across different contexts by being embedded in objects. Boland *et al.* (2007) points out how IT is "permeable across boundaries, thereby enabling new knowledge to be created, and distributing it in new ways" (Boland, *et al.*, 2007 p.633) . But while the IT may be permeable, the memories embedded in IT objects are open to misinterpretation as the memory is sent from one context and received in a different context. The memory is one-way and problems may arise when an organization makes a decision based on a memory that is propagated over time (Stein 1995).

We propose the idea of "disjointed memory" to describe the partial transfer of memory across diverse groups and contexts. The involvement of any individuals and configurations of actors is relatively short-term in the organization of the design, delivery and use of long-term physical assets, which may be used over 50 years or more. The actors that create the memory traces are not available to explain its meaning, and knowledge is often forgotten or recreated. In the delivery phase, a project brings together an evolving coalition of firms. Asset owners seek to capture and use organizational memories developed by the delivery project in decision-making about the maintenance and use of the asset throughout its life-cycle.

When physical infrastructure is handed-over, the organizational memory of the design and construction rationale is usually lost. Though this is captured and stored in digital or paper based forms which are handed-over to the owner, it is in formats that do not feed into the systems that are used in the every-day operation of buildings. Hence, the transfer of contextual knowledge from the projects that deliver major buildings and infrastructure to the organizations that own them and manage their long-term operation is poor. Memory becomes disjointed. The idea of disjointed memory addresses a limitation of existing literatures on organizational memory and organizational forgetting in considering how memory is sustained and lost across diverse groups and organizational contexts. Construction industry clients want to use the information from the project for the long-term value of the physical assets. In projects, information is developed in a relatively short-term, changing, context made up of diverse professions on the project; memory traces from this short-term context are embedded into the objects of the project. However, these memory traces become disjointed as the project is handed-over t to the client. At this point memories embedded in the digital data-set, as well as in the physical asset itself, are disconnected from the skills, rationale and context in which they were created. The asset owner has to make sense of these disjointed memories for the new purposes and to suit new skills.

6 Interim Conclusions and Recommendations

This report addresses the three objectives of the research. Based on the desk-based review, the key findings include:

- Potential value of BIM(M) in operations
    - The UK government proposes that: *'government as a client can drive significant improvements in cost, value and carbon performance through the use of open shareable asset information.'*

  - There are no examples of the use of BIM created during project delivery in operations, although there are examples of BIM for facilities management, such as the Sydney Opera House and BIM for Facilities Management Portal.
  - The majority of the cost (80% is a figure often mentioned) of buildings and infrastructure is in their operation, rather than design and construction.
  - Facilities managers, tradesmen and owners interested in what is going on in the building rather than geometries.
- Evolution of BIM(M) and related practices
  - A stage-based model or evolutionary ramp is often discussed in relation to the move from drawings, lines, arcs and text; to models and objects; to integrated interoperable data. (literature based)
  - This move involves a shift in culture to an increasingly shared and systematic set of processes and systems for using data
- Project-delivery and data hand-over
  - There are a number of ways in which traditional stages of project delivery (RIBA stages; GRIP; OGC gateways, etc) are being rethought. The integrated project delivery (IPD) process is one such development; a Danish 3D working method is another.
  - Yet the issue of data hand-over to clients is still under-represented in this work. For example, IPD does not deal with the whole life cycle, beyond the project into operations.

Based on the interviews, key findings include:

- Using data in operations
  - For major clients the value of data was seen to derive from improved operational expenditure and capital expenditure decisions.
  - Big challenges at hand-over include that of data accuracy and completeness; and that of keeping data up-to-date.

    - This is mainly done in 2D at this stage, sometimes data is not used although it is available. Approaches need to enable clients to get data from both large and small projects.
- Data types that are valued
    - Data formats that are valuable in operations are asset management data; geographical data; manufacturers' reference data; performance data (environmental, HSE, warrenty, security) and geometric model and drawing data.
    - The geometric data is used for reference, rather than kept up-to-date, as the systems used for asset or facilities management are different from those used in projects.
- Integration of operational issues into the project
    - The 'what' of data hand-over is not easily extracted and clients were interested to get FM teams engaged earlier, as they often trawl through data to create their own spreadsheets.
    - 'Starting early' – getting FM teams engaged early happens less than it is advocated but is seen as a lesson.
    - Appropriate tools and methods are not always available and the skills to use BIM are not widely available in the operation of buildings and infrastructure.
    - Standards and operability are a focus of attention, with an emphasis on interoperability as well as open standards.
    - As integration between tools such as GIS and CAD start to become possible there are ways in which data may become more integrated
    - Specifying client requirements is a challenge for clients, though they have processes in place to check data at hand-over it is common to find that data is not available when required (interviews).

To evaluate how data is created, captured and refined (objective 1), we have reviewed a wide range of industry reports that propose data processes, standards and stages, but in interviews we also found that sometimes data that is available and valued is not used for contractual and legal reasons. To evaluate what data is valuable to clients and asset managers at the end of the project as it extends into operations (objective 2), we have categorised the types of data used in operations and facilities management and highlighting the different formats and systems between projects and the operation of buildings and infrastructure. The research provides information relevant to revisiting the generic infrastructure data asset life-cycle diagram (to address objective 3).

7 Next Steps

The next step is to revisit the generic infrastructure data asset life-cycle diagram with the steering committee based on the above research. A briefing sheet will be prepared for the ICE, based on this report, and feedback from the steering committee. Findings are also being disseminated through a number of academic and practitioner channels, for example:

- Lindkvist, C. (2010) ‘Progressive Life-Cycle Data from Design to Operations: An Organizational Memory Perspective’ Presentation at Innovative Construction Research Centre Steering Committee, 2 December.
- Whyte, J (2010) Value to Clients through Data Hand-Over, Presentation at *“Engineering Management in the Digital Economy”* Institution of Civil Engineers / Advanced Institute of Management workshop, 3 December.
- Lindkvist, C., Hassan Ibrahim, N. and Whyte, J. (2011) Disjointed memory: Forgetting within and across firms, *"Organizational Memory" Seventeenth Organization Science Winter Conference*, Steamboat Springs, CO, USA, 10-13 February.

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Appendix A: Asset Life-Cycle