BIM Anatomy II: Standardisation Needs & Support Systems

Hooper, Martin

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LUND UNIVERSITY

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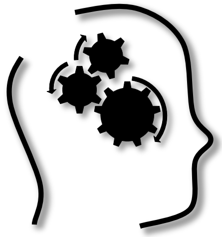

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BIM Anatomy II – Standardisation needs & support systems
Doctoral thesis by Martin Hooper

Faculty of Engineering
Lund University
P.O. Box 118
SE-221 00 Lund
Sweden
T: +46 (0)732 60 42 71
E: martin.hooper@construction.lth.se

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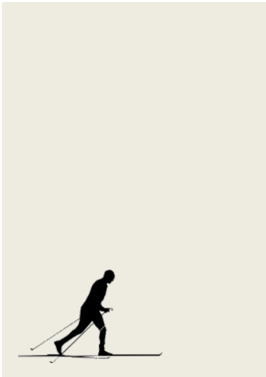


"It is within us all, it is our mysterious longing to accomplish something, to fill life with something more than a daily journey from home to the office and from the office home again. It is our ever-present longing to surmount difficulties and dangers, to see that which is hidden, and seek the places lying away from the beaten track". (Fridtjof Nansen)[1]

[1] Fridtjof Nansen (1864-1930), Norwegian explorer, scientist, diplomat, humanitarian and Nobel Peace Prize laureate.

Dedication

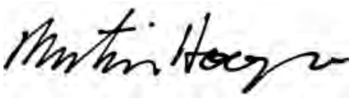
Dedicated to the memory of Patricia Lillias Woodburn Hooper, visionary extraordinaire, 1936-2014 and to Max Oskar Woodburn Hooper, my wonderful son ~ his world yet unexplored.

Preface

This work represents a Doctorate Thesis and is based on research carried out at the Division of Design Methodology, Department of Construction Sciences, Faculty of Engineering, Lund University, between 2012 and 2014. It is the continuation, extension and development of the authors licentiate research work carried out between 2010 and 2012 reported through the licentiate thesis: *BIM Anatomy - An investigation into implementation prerequisites*[2] where the author identified a number of key areas that can be seen to have a significant impact on the value and comprehensiveness of Building Information Modelling (BIM) applied in design consultant practice on a project basis.

From the beginning it has been both a practical, theoretical and intellectual challenge of life-changing proportions. It has been an expedition into a brave new world of technology, process and people. It has also in many respects been a voyage of personal and professional discovery and is a result of many things. It is first the result of ten years of observation of IT-based working in architectural practice and seeing how much we do it the wrong way. Not that there is necessarily any one right way. But to see design technology introduced in a way that undermines practice resources, compromises co-ordination of output and contributes to delay and over expenditure on construction projects has been a sobering experience. The result of this observation is a belief that there must be a better way. A better way to both use people's talents and to do so in such a fashion that we all get a taste of result, feel a part of a team conspiring to do their best, and that we can make a difference in execution.

It is hoped this book will give you deep insight into the nature of Building Information Modelling and the need for associated standards and support mechanisms. It describes traditional issues commonplace with adoption and the dynamics within and between deployment prerequisites. Much work has been put into creating a *beautiful* book to enhance the pleasure of your consumption, and it is hoped you enjoy using it as much as it has been a joy creating it.



Martin Hooper

Lund, 2015

[2] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151

Acknowledgements

This excursion was masterminded and supervised by Professor Anders Ekholm and set in motion through an initial set of tentative projects which led eventually to the breaking of new ground. My sincere thanks to Anders for his concise and wise guidance throughout the first phase (Degree of Licentiate) of the voyage, and for taking the time to introduce me to key members of the active BIM community residing both in practice and academic spheres. On Anders retirement, Kristian Widén, department of Construction Management, took over as supervisor with Professor Anne Landin continuing as second supervisor. A big thank you to you both firstly for your support and secondly for so warmly welcoming myself and fellow architect / researcher, Fredrik Wikberg into the department. Thanks to all those at Construction Management who created a pleasant environment in which to work and exchange ideas. Particularly to my nearest colleague, Fredrik for being a robust and inspiring sounding board for testing ideas and making connections with adjacent fields - an encouraging friend, confident, and provocateur in discussing matters of common interest, and Brian Atkin for his valuable comments and quality improvement suggestions.

Externally, thanks to Rogier Jongeling and the team at BIM Alliance Sweden, for tips, insights and support in reaching a wide range of BIM enthusiasts nationally and internationally. In addition, thanks to Martin Hörestrand, Gunilla Qvarnström, Pål Hansson, Pontus Bengtsson colleagues at Skanska, White, Tyréns and WSP respectively who, amongst others, have helped in accessing the right information, provided key feedback and a platform to test propositions both at a theoretical level and in practice in parallel with live construction projects. It has been a delight to see the interest in a number of ideas developed by the project in both teaching and practice. I believe that an activation of practice-research will become a decisive factor for the development and application of BIM and I look forward to the future.

This research project is funded by SBUF[3], Formas[4]-BIC[5], and members of OpenBIM (now BIM Alliance Sweden[6]).

[3] SBUF: Svenska Byggbranschens Utvecklingsfond [The Development Fund of the Swedish Construction Industry]. Accessible: http://www.sbuf.se/

[4] Forskningsrådet Formas [The Swedish Research Council Formas]. Accessible: http://www.formas.se/

[5] Byggsektons Innovationscentrum [Swedish Construction Sector Innovation Centre]. Accessible: http://www.bic.nu/

[6] BIM Alliance Sweden – Sweden's main branch organisation supporting the application and development of BIM. Accessible: http://www.bimalliance.se/

Abstract

This thesis presents the results of an investigation into BIM standardisation needs and procedural supporting mechanisms that may enable design, construction and operating (DCO) organisations to advance their deployment of Building Information Modelling (BIM) technology, and improve construction project outcomes.

To achieve sustainable development requires effective information management. Building Information Modelling is of strategic importance for the development of efficient methods to create, coordinate and share construction information. The introduction of BIM also allows the development of construction technologies and business models, and leads to greater focus on processes to achieve good urban design, architecture, and user benefit.

A prerequisite for the widespread and integrated adoption of BIM is however common guidelines and a consistent approach to the development of standards for industry concepts, information delivery, data storage formats and contract forms. Important knowledge and established methods of information management exist and the experience gained is important to utilise in this work. However, greater knowledge is needed to allow authorities and practitioners to make informed decision about the content and direction of national BIM guidelines and adoption prerequisites.

The study aims to support the development of applicable branch standards through building knowledge on methods and processes that support organisations in their use of BIM technologies. Further, within the focus domain of *design methodology & management*, it seeks to contribute towards national and international initiatives and research on BIM standardisation needs and support systems through testing *BIM-Planning* support systems, developing and testing a propositional *Digital Delivery Specification*, presenting an understanding of *Contractual and Behavioural Process Obstacles,* confronting the mystery of *Level of Development Concept and Application*, and finally validating and legitimising the current research and BIM standardisation efforts.

The research adopts a critical realism perspective, assumes BIM correlated units of analysis and combines literature reviews with qualitative case studies culminating with a quantitative survey, and is published as 5 peer-reviewed research articles. The empirical dataset consists of 14 semi-structured interviews, 10 workshops and meetings with practitioners, 67 survey responses, plus document review and 29 feedback sessions / supplementary enquiries. The thesis is divided into 2 parts: a summary of the research, and the appended papers. The summary provides a synthesis and reflection of the findings in the papers through: 1) developing knowledge about existing BIM guidelines and testing and evaluating the

application of buildingSMART's BIM PEPG[7], 2) extension of the concept *delivery specification* via a proposed standard schema and protocol for defining model information content for selected BIM-Uses, 3) validating the need for BIM collaboration support mechanisms to address contractual and behavioural process obstacles, 4) proposing a tentative novel framework for model progression scheduling using *Level of Development* (LOD)[8], 5) establishing the legitimacy of national BIM standardisation initiatives and alignment with current research efforts. Findings are drawn from empirical evidence with a focus on the Swedish context.

Based on case materials, theory and literature review, a BIM standardisation and support systems model emerges constituting a set of process-based BIM procedures / measures to support teams leverage their expertise, tools, and the data they create more effectively thereby adding value to the project. Standards developers, BIM strategists, academics and practitioners alike should be able to utilise the results from this thesis. The procedures tested are generalizable and reproducible and with some further refinement, applicable in practice. The results have implications for guidelines development and for direction finding in the advancement of BIM adoption as part of a nation vision for a fuller and more mature BIM utilisation.

It is argued that standardisation of BIM working practices, processes and methodologies is a key issue for the industry, not least for those involved in the early stages when BIM information authoring is at its most intense, but also for those downstream users of the digital asset. With so many processes and people involved over time from concept to maintenance, to reach a steady-state of information order may be impossible. However what is possible is to ensure a number of key procedures are in place to both optimise organisation and stewardship of information that is critical throughout a facilities life cycle.

Keywords

BIM, Building Information Modelling, Information Management, Standards

[7] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

[8] Level of Development – specified on an object basis, LOD is intended to give users a measure of an object's *reliability* and *specificity*. The AIA proposes 5 fundamental levels being LOD 100-500.

Svensk Sammanfattning

Denna avhandling presenterar resultat från en undersökning av BIM standardiseringsbehov och processtödjande mekanismer som möjliggör att projekterings- byggande- och förvaltningsorganisationer främjar tillämpningarna av BIM-teknik för att förbättra byggprojektens resultat.

För att uppnå en hållbar utveckling krävs effektiv informationshantering. Building Information Modelling (BIM) är av strategisk betydelse för utvecklingen av effektiva metoder för att skapa, samordna och dela bygginformation. Införandet av BIM tillåter också utvecklingen av byggtekniker och affärsmodeller, och leder till ökat fokus på processer för att uppnå god stadsplanering, arkitektur och användarnytta.

En förutsättning för ett brett genomslag för BIM är emellertid gemensamma riktlinjer och en konsekvent utvecklingsstrategi avseende standarder för begrepp, informationsleverans, datalagringsformat samt avtalsformer. Viktig kunskap och etablerade metoder för informationshantering finns och den erfarenheten är viktigt att utnyttja i detta arbete. Det krävs dock större kunskap för att myndigheter och praktiker ska kunna fatta välgrundade beslut om innehåll och inriktning av nationella riktlinjer för BIM och om implementerings förutsättningar.

Studien syftar till att stödja utvecklingen av tillämpliga branschstandarder genom att bygga kunskap om metoder och processer som stödjer organisationer i deras användning av BIM. Vidare med fokus på domänen *projekteringsmetodik* & *design information management*, vill den bidra till nationella och internationella initiativ och forskning kring BIM standardiseringsbehov och processtödjande mekanismer. Förutsättningarna studera genom att testa stödsystem för *BIM-Planering*, utveckla och testa *Digital Leveransspecifikation*, presentera en översikt av avtals och beteenderelaterade *Processhinder*, samt tydliggöra begreppet *Informationsnivå*. Studien validera och legitimerar slutligen aktuell forskning och det standardiseringsarbete som för närvarande görs på BIM-området.

Forskningen utgår från ett kritiskt realistiskt perspektiv, där analys görs på BIM-korrelerade enheter och litteraturstudier kombinerat med kvalitativa fallstudier, och kulminerar slutligen i en kvantitativ undersökning. Resultaten publiceras som 5 fackgranskade vetenskapliga artiklar. Det empiriska data-underlaget baseras på 14 semi-strukturerade intervjuer, 10 workshops/ möten med praktiker, 67 enkätsvar, kompletterande data från 29 återkopplingstillfällen samt analys av relaterad projektdokumentation. Avhandlingen är indelad i två delar: Dels kappan som sammanfattar och kontextualisera den aktuella forskningen och dels bilagorna som innehåller de publicerade artiklarna. Kappan ger en syntes och reflektion av resultaten i artiklarna genom att: 1) utveckla kunskap om befintliga

BIM riktlinjer och testa och utvärdera tillämpningen av buildingSMART's BIM PEPG[9]; 2) utvidga begreppet leveransspecifikation via ett föreslaget schema för standardisering och protokoll för att definiera modellinformationsinnehåll för olika BIM-nyttor; 3) validera behovet av BIM-samverkan och stödinsatser för att hantera avtals- och beteenderelaterade processhinder; 4) föreslå ett ramverk för schemalagd generativ modell-framväxt enligt LOD[10]; 5) skapa legitimitet för nationella BIM standardiseringsinitiativ och relatera till pågående forskning. Argumenten baseras på tolkning av empiriska bevis funna i en studerad svensk kontexten.

Baserat på fallstudier, teori- och litteraturgenomgång, framkommer en modell för BIM-standardisering och organisation av stödsystem som kan utgöra ett processbaserat stöd för projektteamet att utnyttja deras expertis, verktyg, och data på ett mer effektivt sätt och därmed höja värdet i projektet. Avsikten är att praktiker såväl som BIM-strateger, standard-utvecklare, och forskare ska kunna utnyttja resultaten från denna avhandling. De utvecklade modellerna är generaliserbara och reproducerbara och kan efter viss anpassning tillämpas i praktiken. Resultaten har betydelse för utveckling av branschgemensamma riktlinjer och för en nationell handlingsplan för BIM i avsikt att nå ett genomgripande och mer moget utnyttjande av BIM.

Det hävdas att standardisering av BIM-relaterade tillämpningar, processer och metoder är en nyckelfråga för branschen. Detta gäller såväl de som deltar i tidiga skeden, där skapandet av BIM information är mest intensiv, som de i senare skeden där vinsterna från detta digitala kapital mest gör sig gällande. Med så många delprocesser och aktörer engagerade från tidig idé till slutlig förvaltning, kan det synas omöjligt att uppnå ett stabilt tillstånd av koordinerad information. Men det som trots allt är möjligt, är att säkerställa att ett antal viktiga rutiner finns för att både optimera processorganisationen och hanteringen av den bygginformation som följer byggnadsverkets livscykel.

[9] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

[10] Level of Development – specified on an object basis, LOD is intended to give users a measure of an object's *reliability* and *specificity*. The AIA proposes 5 fundamental levels being LOD 100-500.

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Abbreviations

Acronym	Description
AEC	Architecture, Engineering and Construction (Industry sector)
AIA	American Institute of Architects
AMA	Common Material & Work Specification
BIM	Building Information Modelling / Management
BSAB	Swedish Construction Classification System
bsDD	buildingSMART Data Dictionary
buildingSMART	Industry body responsible for developing IFC's, IFD, IDM, MVD's
COBie	Construction Operations Building Information Exchange
DCO	Design - Construct - Operate (Industry process)
FGI	Focus Group Interview
FM	Facilities Management
IT	Information Technology
IFC	Industry Foundation Classes (Data structures for representing information used in BIM)
IFD	International Framework for Dictionaries
IDM	Information Delivery Manual
IPD	Integrated Project Delivery
LOD	Level of Development
MVD	Model View Definition
oBCF	Open Building Collaboration Format
OCCS	OmniClass Construction Classification System
VDC	Virtual Design & Construction

A Guide to this Thesis

Target Audience

This thesis is written as an academic assignment for the degree of Technical Doctor of Engineering. The work is designed to offer a contribution to the furthering of the construction industry and, since the particular subject matters affects virtually the whole spectrum of disciplines and support disciplines, it is hoped and anticipated that the work will be of interest to a broad range of sector participants: academics and practitioners alike. Individuals engaged or observing in all stages of construction projects: clients, designers, estimators, purchasers, contractors and facility managers, it is hoped, will find the material and findings interesting and of practical inspiration for further development in the area.

An awareness of BIM and its potential benefits to the industry sector wide is already well established, but a text providing further insight into resolving adoption matters and planning the execution of BIM processes may catch the interest of those struggling either to leverage value or educate students in modern practice. This thesis attempts to draw at least the curiosity of all those concerned with design, construction and operations information management and process improvement.

Thesis Structure

This thesis is a compilation of scientific articles with a summarising cover text that pulls together the constituent mini-studies into a meaningful collective whole. The thesis is structured as follows:

Part 1: The Cover

Chapter 1: *Introduction* – introduces the reader to the research field, provides a brief state-of-the-art account of specific BIM-related themes, identifies research gaps and presents a comprehensive context for the research questions.

Chapter 2: *Theory* – a background on which this research aims to build, this section presents a variety of existing theories deemed to have an impact on the investigation or held to have bearing on the results.

Chapter 3: *Methodology* – presents the chosen methodology for the research and the different methods for collecting, organising and analysing empirical data supporting the various studies and findings.

Chapter 4: *Findings* – presents a summary of the empirical findings collected through the course of the research project. The results, emerging from the case materials examined and empirical evidence collected, are presented as extended abstracts and provide a set of preliminary responses to the objectives of this research.

Chapter 5: *Discussions & Conclusions* – here the impact of results and their meaning in context are discussed. The research questions are re-visited and responses formulated, reconnecting the aim of the study with the findings. The contribution to the field is evaluated and suggestions for further research considered.

Part 2: The Papers

Part 2 comprises 5 scientific papers which are appended at the end of the thesis.

Paper #1:

- Hooper, M. & Ekholm, A., (2010) A Pilot Project - Toward BIM Integration - An Analysis of Design Information Exchange & Coordination*, Proceedings of the 27th Annual CIB W78 International Conference - Applications of IT in the AEC Industry*, Cairo, Egypt. 15-17 November 2010.

Conference Paper: Published

Paper #2:

- Hooper, M. & Ekholm, A., (2011) A BIM-Info Delivery Protocol, *Australasian Journal of Construction Economics and Building, Special Issue on BIM*, Sydney, Australia.

Journal Article: Published

Paper #3:

- Hooper, M. & Widén, K. (2014), *BIM Inertia – Contracts & Behaviours*.

Book Chapter: Accepted, In Press in:

- Issa, R.R.A. & Olbina, S. (Eds.), *Building Information Modeling: Applications and practices in the AEC Industry*, ASCE Press, in production.

Paper #4:

- Hooper, M. (2014), *Automated Model Progression using Level of Development (LOD)*, Construction Innovation, 2014.

Journal Article: Submitted &Under Review

Paper #5:

- Hooper, M. (2014), *BIM Standardisation Efforts – The Case of Sweden*, IT in Construction, 2014.

  Journal Article: Accepted subject to revisions

Thesis Outline

Figure 1 provides an overview of the constituent parts of this thesis and illustrates their chronology and relationship to the whole. The main text presents a research continuum while the attached articles offer an opportunity for enhanced understanding of each enquiry. This figure was augmented as the work progressed and a complete map illustrating the studies included, the associated empirical data collected and case materials that came to bear on the particular investigations is presented as Appendix 2.

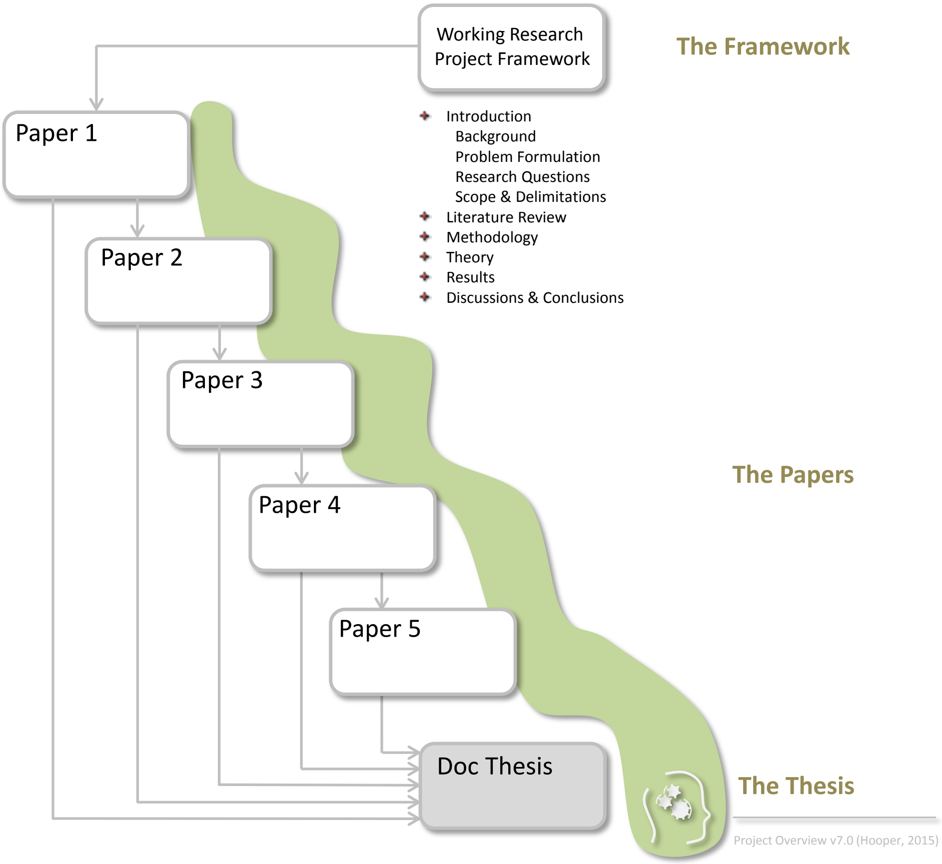
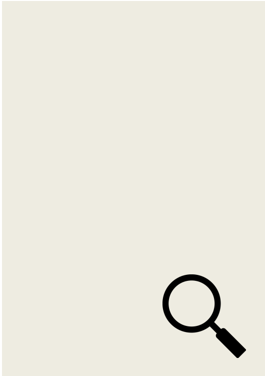


Figure 1: Research Project Overview

On carrying out research:



"In writing a problem down or airing it in conversation we let its essential aspects emerge. And by knowing its character, we remove, if not the problem itself, then it's secondary, aggravating characteristics: confusion, displacement, surprise". (De Botton, 2009)[11]

1.0 Introduction

This chapter provides a background to the research field including: context, recent history, challenges and opportunity for contribution. A brief state-of-the-art review is provided which leads to the research questions. Notes on purpose, objectives and limitations are included.

1.1 BIM in Construction: A recent history

During the last decade, a major shift in ITC for construction has proliferated as Building Information Modelling in industrial and academic circles as the new Computer Aided Design (CAD) paradigm.[12,13] Building information modelling is a process of representation, which creates and maintains multidimensional, data-rich views throughout a project lifecycle to support communication (sharing data); collaboration (acting on shared data); simulation (using data for prediction); and optimization (using feedback to improve design,

[11] De Botton, A. (2000), *The Consolations of Philosophy*, London: Penguin

[12] Succar, B (2009), Building Information Modelling: A Research and Delivery Foundation for Industry Stakeholders, *Automation in Construction*, Vol. 18, pp. 357-375.

[13] Bryde, D., Broquetas, M. Volm, J.M. (2013), The project benefits of Building Information Modelling (BIM), *International Journal of Project Management*.

documentation and delivery).[14] It is currently the most common denomination for a new way of approaching the design, construct and operation (DCO)[15] processes of buildings and has been deployed on many high profile projects worldwide where measured successes have been realised (Table 1).

High Profile BIM Project	Impact
Terminal 2 at London Heathrow International Airport	The use of BIM helped the company coordinate over 30 active stakeholders through 13 interfacing projects and enabled a peak workforce of 1,600 to complete work, including a 2 km diaphragm wall, the largest in Europe, ahead of schedule.
New Akershus University Hospital, Norway	IFC BIM required from the earliest stage including completion submission and programme scheduling. IFC BIM Cost Estimation was used in parallel to traditional methods and proved much more accurate. Clash detection was deployed and lead to the avoidance of potentially 1000's of coordination errors in a very complex project. Some design information issued as BIM deliveries instead of 2D drawings, economising on weight of documentation and increasing accuracy and efficiency.
New Karolinska Solna (NKS), Sweden	BIM 2.0 cloud collaboration system deployed based on agile design methods, SCRUM planning and LEAN as a methodology to target construction planning which meant better project progress for all partners. Massive improvements experienced in document management through united cloud-based database being quality assured, consistent and fully coordinated.
Sutter Medical Center Castro Valley, US	Design time for structural was reduced from an expected 15 months to 8 months, and was informed by far more information from other disciplines than is usually available which led to better design quality.

BIM Projects & Impacts v1.0 (Hooper, 2014)

Table 1: High Profile BIM Projects & Impacts

A view over the last 10 years of BIM use, driven by a combination of national policy, the development and deployment of advanced technology and need for efficiency gains, tells us that the level of demand and desire for integration is gathering pace and becoming increasingly all-encompassing (Figure 2a & b). In 2002 Singapore launched its CORENET[16], an e-submission system for planning applications, where a model is required to enable automatic checking of local regulation compliance. In Norway, the public sector property

[14] Laiserin, J. (2007) *To BIMfinity and Beyond! – Building Information Modelling for Today and Tommorrow,* CADalyst. Available: http://www.cadalyst.com/aec/to-bimfinity-and-beyond-aec-insight-column-3686?page_id=2&print=1
[15] There is no widely used term-definition which is equally representative of all planning-to-demolition *activities* within the construction industry. Whilst acronyms like AEC, AECO, AECOO and AEC/FM refer to the industry itself, the author in concurrence with Succar prefers to adopt DCO as it builds upon the three major project lifecycles and, central to the research matter, provides an accent on key activities: Design - Construction - Operation.
[16] http://www.corenet.gov.sg/index.html

organisation Statsbygg,[17] mandated BIM with open standard IFC compliant buildings models as early as 2005. Denmark and Finland followed suit shortly after. More recently in 2011 the UK released a new BIM based government construction strategy[18,19] stipulating a level 2 collaborative BIM by 2016. This together with updates and extensions to BS1192[20,21] the RIBA plan of work[22] and new digital services from the NBS[23] represent a powerful collection of initiatives set to bring BIM mainstream and support a more sustainable construction. Today Sweden has at last started to develop BIM requirements[24] on selected public projects, with the realisation that an element of client-driven compulsion is necessary to leverage project lifecycle BIM benefits.

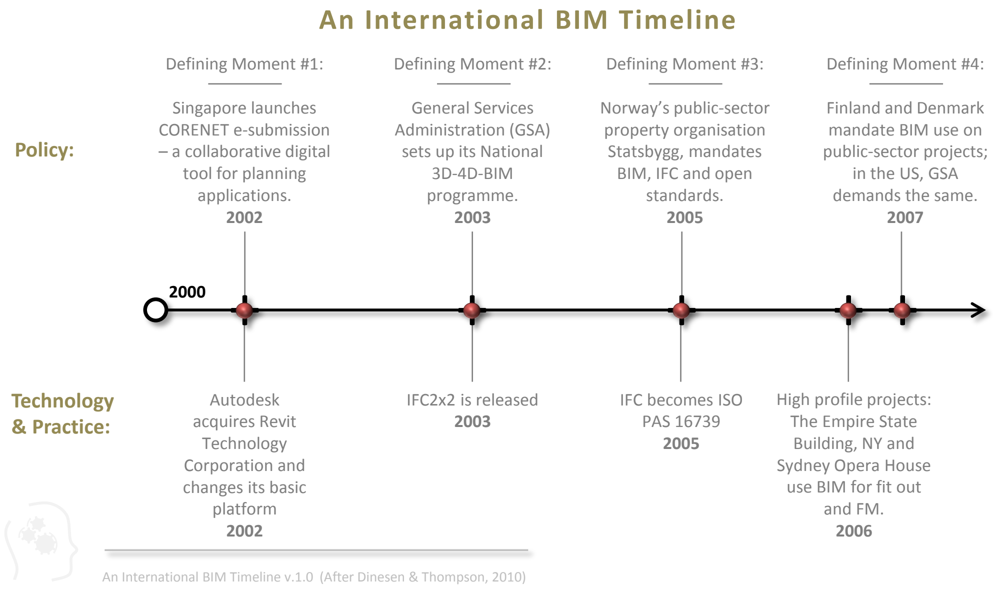


Figure 2a: An International BIM Timeline

[17] http://www.statsbygg.no

[18] BIS (2011), *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London.

[19] UK Government Cabinet Office (2011), *The UK Government Construction Strategy*, London: The Cabinet Office.

[20] BSI (2013), *PAS 1192-2:2013 - Specification for information management of the capital delivery phase of construction projects using building information modelling*, British Standards Institution, London: BSI.

[21] BSI (2014). *BS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling*, British Standards Institution, London: BSI.

[22] RIBA (2013b), *RIBA Plan of Work*, RIBA Publications, London.

[23] http://www.nationalbimlibrary.com/

[24] 5 State organisations; Akademiska Hus, Specialfastigheter, Riksdagsförvaltningen, Fortifikationsverket & Statens Fastighetsverksomhet, are working together to formulate common BIM Requirements, 2014.

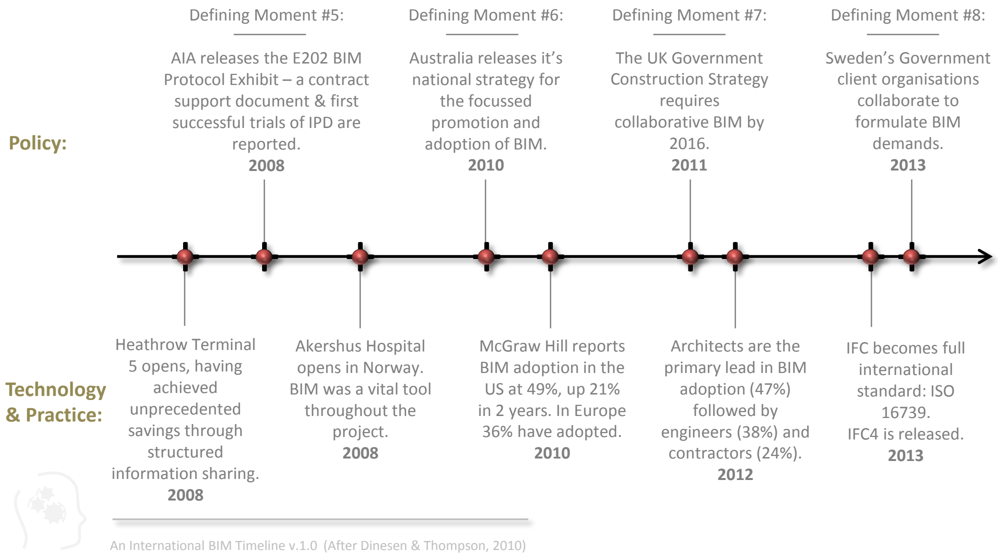


Figure 2b: An International BIM Timeline

On the technology and practice side, ever more advanced parametric authoring tools are being released with improved interoperability through implementation of developed versions of the Industry Foundation Classes (IFC) data model. We have also seen widespread improvements in project outcomes measured in relation to traditional key performance indicators (KPIs) such as cost, time and quality.[25] However, where client compulsion and guidelines / standards are missing, practitioners tend to adopt ad hoc measures and quick-fix solutions.[26] Amongst others, process standards need to catch up with technological possibilities.

Meanwhile in academic circles there has been much research on the development and usage of the IFC's,[27,28,29] defining BIM benefits,[30,31,32] and adoption[33,34] but little examining BIM

[25] Barlish, K. & Sullivan, K. (2012), How to measure the benefits of BIM – A case study approach, *Automation in Construction*, Vol.24, pp149-159.
[26] Jongeling, R., Lindström, M., Samuelson, O. (2013), *BIM Special – Dags att focusera på standardiseringen*, Byggindustrin 30/2013.
[27] Kiviniemi, A., Tarandi, V., Karlshøj, J., Bell, H., Karud, O.J. (2008), *Review of the Development and Implementation of IFC Compatible BIM*, Erabuild.
[28] Pazlar, T. & Turk, Z. (2008) *Interoperability in Practice: Geometric Data Exchange using the IFC Standard,* ITcon Vol.13, pg362-380.
[29] Pfitzner, M., Benning, P., Tulke, J., Outter, N., Nummelin, O., Fies, B. (2010), *InPro – D29 – Barriers and Opportunities – Future ICT and Organisational Requirements*, The InPro Consortium.
[30] Azhar, S. (2011), Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry, *Leadership and Management in Engineering*, 2011.11:241-252.
[31] Barlish, K. & Sullivan, K. (2012), How to measure the benefits of BIM – A case study approach, *Automation in Construction*, Vol.24, pp149-159.

challenges and opportunities in the context of Sweden.[35] Gustavsson et al[36] recommend further knowledge and understanding is needed in defining clear work processes or strategies on how to organise, manage or benefit from BIM since expected benefits are often not realised. Further, Rezgui et al[37] highlight the need for research on methods of maintaining and re-using knowledge, best practice and absorbing technology. Whilst, Howard & Björk[38] and Ekholm[39,40,41] discuss the important role that standards play in organising BIM project information and methodology. Finally, Ekholm's[42] roadmap sets out a series of tentative activities with milestones for work on the design of interoperable standards for data models, common concepts and processes with information deliveries. This work points toward opportunity for scientific contribution.

1.2 BIM: what it is, what is isn't and how it is defined in this thesis

There are many rather disparate definitions available to describe what BIM is and means.[43] Varying understandings of a single concept within a single field has already led to much unnecessary confusion and cross purposes. It is not good enough to say it means different things to different players (depending on discipline and background). However there is no single definition.[44] Here, a selection of available extracts that attempt to provide a necessarily broad insight are presented:

'Building Information Modelling [BIM] is the most commonly used term to describe a set of ***parametric tools*** *and* ***processes*** *for the* ***creation*** *and* ***maintenance*** *of* ***an integrated***

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[32] Bryde, D., Broquetas, M. Volm, J.M. (2013), The project benefits of Building Information Modelling (BIM), *International Journal of Project Management*.

[33] Gu, N. & London, K. (2010), Understanding and facilitating BIM adoption in the AEC industry, *Automation in Construction*, 19 (2010) 988-999.

[34] Linderoth, H. (2009) Understanding adoption and use of BIM as the creation of actor networks, *Automation in Construction*, 19 (2010) 66-72.

[35] Being one of the most expensive countries in the world to build, strong contractor and client lead construction industry, architects with traditionally a non-leadership position and currently (2014) no central government mandate for BIM or national guidelines.

[36] Gustavsson, T. K., Samuelson, O. & Wikforss, Ö. (2012), *Organising IT in Construction: Present State and Future Challenges in Sweden*, ITcon, Vol. 17, pp. 520-533.

[37] Rezgui Y, Zarli A, Hopfe C J (2009), *Editorial - Building Information Modeling Applications, Challenges and Future Directions*, ITcon Vol. 14.

[38] Howard, R. & Björk, B-C. (2008), *Building Information Modelling – Experts views on standardisation and industry deployment*, Advanced Engineering Informatics, 22 (2008) 271-280.

[39] Ekholm, A. (2012b), *Standardisering för BIM*, Lund University, Sweden.

[40] Ekholm, A. (2012c), *Studier för främjandet av BIM*, Lund University, Sweden.

[41] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*

[42] Ekholm A., Häggström L., Johansson B., Tarandi V., & Tyrefors B. (2010), *RoadMap för digital information om byggd miljö*, Lund University, Lund, Sweden.

[43] Samuelson, O. (2010), *IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium*, Hanken School of Economics, Helsinki.

[44] Suermann & Issa (2009), *Evaluation Industry Perceptions of Building Information Modeling (BIM) Impact on Construction*, ITcon Vol. 14, pp574-594.

collaborative database *of multi-dimensional information regarding the design, construction and/or operations of a building, with the purpose of improving collaboration between stakeholders, reducing the time needed for documentation of the project and producing more predictable project outcomes'*.[45] The Australian National Guidelines for Digital Modelling defines BIM as a ***model*** that has two essential characteristics: 1) *'that it must be a three-dimensional* ***object-oriented*** *representation of a building (or other facility);* 2) *it must include some* ***information*** *in the model or the* ***properties*** *about the objects beyond the* ***graphical****'.* [46] Meanwhile Eastman et al. defines BIM as: [...] '*a modelling* ***technology*** *and associated* ***set of processes*** *to produce, communicate and analyse building models'.*[47] In the United States, McGraw Hill defines BIM as: '*The* ***process of creating*** *and using* ***digital models*** *for design, construction and/or operations of projects'.*[48] Finally, Kiviniemi et al defines BIM as: [...] '*an object-oriented* ***model*** *— a digital representation of a building* ***to facilitate exchange and interoperability of information*** *in digital format*'.[49]

Other definitions include: '*a* ***shared resource of knowledge*** *about a facility that can be used to make decisions throughout its life cycle, from the initial idea, to design and construction, through daily operations and eventual demolition'.*[50] Or simply: '*an end to end* ***delivery methodology***'.[51] The important thing to note is that BIM is not simply proprietary software. The position adopted here draws from theses selected definitions and emphasises aspects of BIM constituting a combination of ***process, technology*** and ***people*** who endeavour to ***create***, ***enable*** and ***manage*** construction information. Figure 3 consolidates the essential concepts behind the acronym and acknowledges a pertinent constellation of definitions.

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[45] Broquetas, M. (2011) *Using BIM as a Project Management Tool : How can BIM improve the delivery of complex construction projects,* HFT Stuttgart. Available at : http://www.cad-addict.com/2011/02/summary-using-bim-as-project-management.html

[46] CRC Construction Innovation (2009), *National Guidelines for Digital Modelling*, Brisbane: CRC

[47] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 2nd Ed., London: John Wiley & Sons.

[48] McGraw Hill Construction (2008), *SmartMarket Report: BIM - Transforming Design and Construction to Achieve Greater Industry Productivity*, New York: McGraw Hill Construction.

[49] Kiviniemi, A., Tarandi, V., Karlshøj, J., Bell, H., Karud, O.J. (2008), *Review of the Development and Implementation of IFC Compatible BIM*, Erabuild.

[50] http://www.nibs.org/news/127862/ NBIMS

[51] Millard, C. (2014) Business efficiency director at Balfour Beatty, #nbsbim

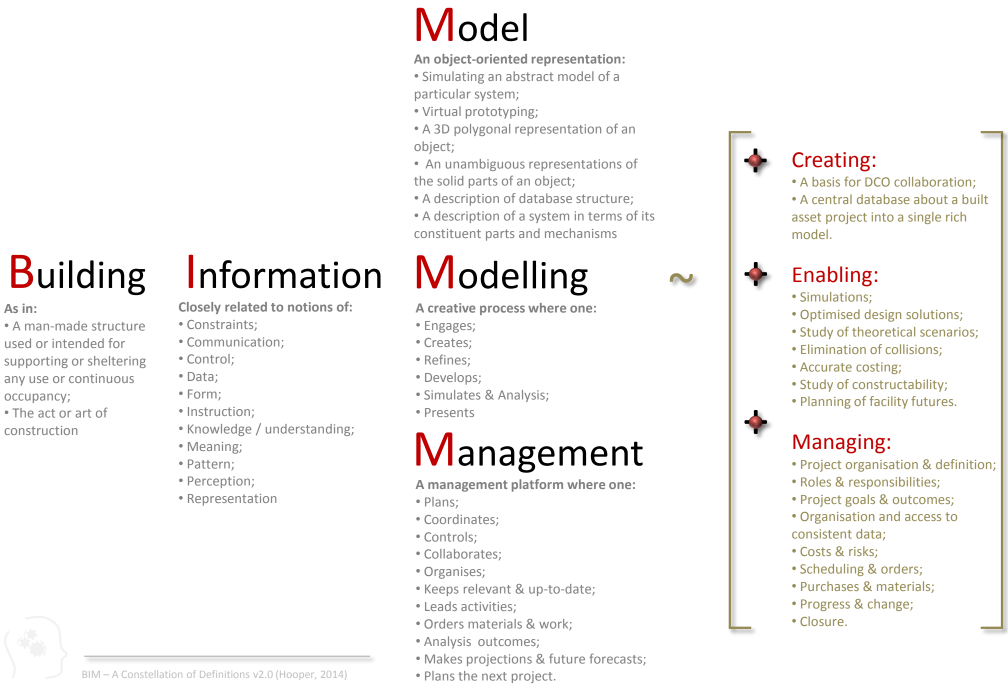

Figure 3: BIM – A Constellation of Definitions

1.3 BIM: Opportunities & Challenges

Sustainable development in construction requires effective information management.[52,53] BIM is of strategic importance for the development of efficient methods to create, coordinate and share information about the built environment, both in design, construction and operation of facilities.[54]

There have been many attempts to measure the impact of BIM,[55,56,57] but the difficulty is that the benefits are spread among different players and project stages.[58,59] One of the obvious

[52] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*

[53] Krygiel, E. & Nies, B. (2008), *Green BIM: Successful sustainable design with building information modeling*, Wiley Publishing, Indianapolis, Indiana.

[54] Race, S. (2012), *BIM Demystified*, London: RIBA Publishing.

[55] Bryde, D., Broquetas, M. Volm, J.M. (2013), The project benefits of Building Information Modelling (BIM), *International Journal of Project Management*.

[56] Barlish, K. & Sullivan, K. (2012), How to measure the benefits of BIM – A case study approach, *Automation in Construction*, Vol.24, pp149-159.

[57] Azhar, S. (2011), Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry, *Leadership and Management in Engineering*, 2011.11:241-252.

[58] Vestergaard, F., Karlshøj, J., Hauch, P., Lambrecht, J. och Mouritsen, J. (2011) *Måling af økonomiske gevinster ved Det Digitale Byggeri*, Rapport SR 12-02—SR 12-07, DTU Byg, Danmarks Tekniske Universitet.

economic benefits of BIM utility lies in project coordination which later reveals itself downstream in the construction stages to the benefit of the contractor. Succar[60] and McGraw Hill[61] highlight difficulties for investors in BIM to see a speedy return. Meanwhile in Australia, Allen Consulting Group[62] report the overall benefit of implementing BIM throughout the period 2011-2015 is estimated to correspond to a one-off contribution to GDP of between 4.8 to 7.6 billion dollars.[63] This kind of reporting is making construction clients think twice about their requirements.

In Sweden, the Swedish Transport Authority (Trafikverket) has a strategy for the development of BIM in collaboration with industry stakeholders.[64] They have stipulated that: '*all investment projects from 2015 will require to be delivered by a pre-defined BIM maturity level'.* The ambition being that all consequent BIM projects will incur reduced construction costs by rationalising their supply chain from planning, design, construction through to operation and maintenance. Samuelson[65] however, highlights a wide divergence of capabilities to deliver.

At the heart of BIM is the ability to structure and share information. BIM offers the opportunity to achieve accuracy and certainty in the delivery of products and services. It improves efficiency and allows design processes to be repeated, even standardised.[66] But how and why does BIM deliver this outcome? To understand what BIM does and the benefits it brings, we need to look at traditional approaches and their drawbacks. The AEC & FM industry traditionally uses a document-based way of working, through drawings, specifications and reports, and communicates through unstructured text such as letters and emails. Documents are embedded in contractual arrangements – and in the very culture of the industry. Life before BIM was characterised by a massive amount of unstructured documentation that had to be printed and stored and resultantly had little long-term value.[67] BIM is inherently efficient because it brings project partners together to use and share information through, in principle, a single structured database with multiple interfaces. However Rezgui et al,[68] highlights that maintaining and re-using knowledge, adopting best

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[59] Succar, B. (2010), *BIM ThinkSpace: Episode 14: Industry Leadership vs. BIM Benefits*. Available at: http://changeagents.blogs.com/thinkspace

[60] Ibid.

[61] McGraw Hill Construction (2009), *SmartMarket Report: The Business Value of BIM - Getting Building Information Modeling to the Bottom Line*, New York: McGraw Hill Construction.

[62] Allen Consulting Group (2010), *Productivity in the buildings network: assessing the impacts of Building Information Models*, Report to the Built Environment Innovation and Industry Council, Sydney.

[63] Ibid.

[64] Trafikverket (2013), *Öppen BIM-standard: Begrepp, process och datamodell*, Stockholm: Trafikverket.

[65] Samuelson, O. (2010), *IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium*, Hanken School of Economics, Helsinki.

[66] BSI (2010), *Constructing the Business Case – Building Information Modelling*, London: BSI.

[67] Ibid.

[68] Rezgui Y, Zarli A, Hopfe C J (2009), Editorial - Building Information Modeling Applications, Challenges and Future Directions, *ITcon* Vol. 14.

practice, and absorbing technology presents a major challenge to the industry and that traditional process models need reconsidered and continuously adapted to suit local conditions and stakeholder relationships. Furthermore, that the ability to innovate and remain competitive in a fierce business environment in extremely important in particular to SME's.[69]

According to Gu & London[70] the factors affecting BIM adoption can be divided loosely into 2 main areas: technical tool functionality requirements and needs, and non-technical strategic issues. They report that the challenges for the research community lie not only in addressing the technical solutions and human centred issues but also in creating the enabling a conscientious decision-making environment, which integrates both the technical and non-technical challenges.

Locally, Sweden's national initiative for digital information, driven by BIM Alliance Sweden,[71] highlights that our AEC sector is characterised by '*increasingly demanding integrated and flexible functions, efficient production, environmental and energy efficiency requirements*'.[72] Furthermore that information management throughout a built assets lifecycle is vital to the quality and efficiency seen from an economic, environmental and social sustainability perspective. However, today's demands for requirements on information, organisation and management don't meet these needs.[73]

The introduction of *requirements* relating to the application of BIM has been shown to increase quality and efficiency in information management in the design and construction through to facilities management.[74,75,76] In Sweden however, only a few public sector authorities[77] have launched initiatives to formulate BIM requirements. The government client remains one of the largest single industry actors with the most to gain.[78] However, there is (still) no central government directive or common guidelines which leads to sub-

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[69] Small & Medium (sized) Enterprises

[70] Gu, N. & London, K. (2010) Understanding and facilitating BIM adoption in the AEC industry, *Automation in Construction*, Vol.19, pp 988-999.

[71] http://www.bimalliance.se

[72] Lindström, M. & Jongeling, R (2012), *Nationellt Initiativ för Digital Information - För ett bättre samhällsbyggande*, OpenBIM Presentation.

[73] Lindström, M. & Jongeling, R (2012), *Nationellt Initiativ för Digital Information - För ett bättre samhällsbyggande*, OpenBIM Presentation.

[74] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 2nd Ed., London: John Wiley & Sons.

[75] Jansson, G., Schade, J., Olofsson, T. (2013) Requirements management for the design of energy efficient buildings, *ITcon*, Vol.18, pp.321-337.

[76] Svidt, K & Christiansson, P. (2008), *Requirements on 3D building information models and electronic communication – experiences from an architectural competition*, CIB W78 2008 International Conference on Information Technology in Construction, Santiago, Chile.

[77] Examples include: Trafikverket, Akademiska Hus, Specialfastigheter.

[78] BIS (2011), *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London.

optimisation and unnecessary cost for production, energy in use, environment (including waste) and a poor competitive environment.[79]

The UK, Denmark, Norway and Finland are examples of countries whose governments have encouraged early adoption of BIM through compulsion, standards, and guidelines.[80,81,82,83] These governments have already taken the lead in developing applicable requirements for digital information management based on BIM. However, Sweden is making a comeback and 5 state organisations[84] are now collaborating with industry to define the necessary input and components of a future possible set of standard requirements. This and other standardisation work is centred on achieving national consensus on relevant practical demands relating to *Data Model*, *Concept* and *Process Rules* (Figure 4) with cognisance to related international standardisation work.

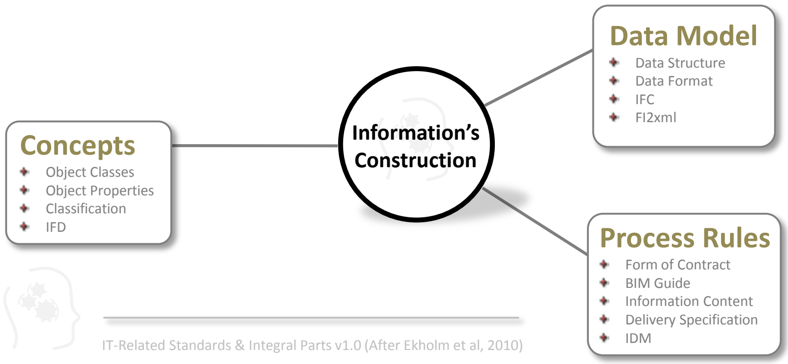

Figure 4: IT-Related BIM Standards & Integral Parts (After Ekholm et al, 2010)[85]

One cannot talk about BIM challenges without mentioning the monumental task of achieving full industry interoperability. Interoperability is the ability of BIM tools from multiple vendors to exchange building model data – a significant requirement for team collaboration and data movement between different BIM platforms.[86] There have been many studies into

[79] Lindström, M. & Jongeling, R (2012), *Nationellt Initiativ för Digital Information - För ett bättre samhällsbyggande*, OpenBIM Presentation.
[80] BIS (2011) *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London.
[81] bips (2006), *3D Arbejdsmetode 2006*, Denmark: bips.
[82] Statsbygg (2013), *BIM-Manual 1.2.1: Statsbygg Building Information Modeling Manual - version 1.2.1*, Oslo: Statsbygg.
[83] COBIM (2012), *Common BIM Requirements,* V.1.0, Finland: COBIM Project.
[84] 5 State organisations; Akademiska Hus, Specialfastigheter, Riksdagsförvaltningen, Fortifikationsverket & Statens Fastighetsverksomhet, are working together to formulate common BIM demands, 2014.
[85] Ekholm A., Häggström L., Johansson B., Tarandi V., & Tyrefors B. (2010), *RoadMap för digital information om byggd miljö*, Lund University, Lund, Sweden.
[86] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 2nd Ed., London: John Wiley & Sons.

interoperability issues.[87,88,89] BuildingSMART[90] is the international organisation responsible for developing and maintaining the IFC's – one of the most recognised interoperable open data standards using ISO-STEP technology and libraries. However, certain criticism exists in respect to the length of time IFC compliant tools have taken to reach the market and the level of implementation.[91] Today, there is still confusion over levels of IFC-compliant software and the realities of the limitations of application.[92,93] Further, rightly or wrongly the IFC data model is all too often seen as an export function which may or may not function as expected and is too complicated for many creators and users of digital construction data to understand. Worst of all, Kiviniemi reports: *Lack of funding, too few people, ad-hoc extensions, nobody is paid for implementation support – leaving users severely exposed to difficulties*.[94] However, since then there have been vast improvements in versions and implementations and more resent case evidence supports many interoperability success stories.[95]

1.4 State of the Art – Themed Reviews

BIM and its associated delivery methodology plays an increasingly significant role in the construction industry. Today it is high on the agenda of most public sector clients,[96,97] who are beginning to demand BIM utilisation and even specify particular data drops through the design, construction and handover phases. Used expediently, it is claimed that it can reduce waste (in time, money, human resources and materials), increase productivity, efficiency and transparency, improve communication, understanding of the project, relationships and ROI,[98]

[87] Grilo, A. & Jardim-Goncalves, R. (2010), Value proposition on interoperability of BIM and collaborative working environments, *Automation in Construction*, Vol.19, pp.522-530
[88] Pazlar, T. & Turk, Z. (2008), Interoperability in Practice: Geometric Data Exchange Using the IFC Standard, *ITcon* Vol.13 (2008).
[89] Steel, J., Drogemuller, R., Toth, B. (2012), Model interoperability in building information modelling, *Software & Systems Modeling*, 2012, Springer.
[90] http://www.buildingsmart.org/ & http://www.buildingsmart.com/
[91] Kiviniemi, A., Tarandi, V., Karlshøj, J., Bell, H., Karud, O.J. (2008), *Review of the Development and Implementation of IFC Compatible BIM*, Erabuild.
[92] Coates, P., Arayici, Y., Koskela, L., Kagioglou, M., Usher, C., O' Reilly, K., (2010), The Limitation of BIM in the Architectural Process, *First International Conference on Sustainable Urbanization* (ICSU 2010), Hong Kong, China, 15-17 December 2010.
[93] Grilo, A. & Jardim-Goncalves, R. (2010), Value proposition on interoperability of BIM and collaborative working environments, *Automation in Construction*, Vol.19, pp.522-530
[94] Kiviniemi, A. (2006) *Ten Years of IFC Development* – CIB W78 Montreal Keynote Presentation
[95] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 2nd Ed., London: John Wiley & Sons.
[96] In Sweden: 5 State organisations: Akademiska Hus, Specialfastigheter, Riksdagsförvaltningen, Fortifikationsverket & Statens Fastighetsverksomhet are working together to formulate common BIM demands. http://www.tyrens.se/sv/Artiklar/Nyheter/2014/Tyrens-hjalper-statliga-organisationer-/
[97] Also governments internationally including: US, UK, DK, NO, Fin, NL, Singapore.
[98] Suermann & Issa (2009), *Evaluation Industry Perceptions of Building Information Modeling (BIM) Impact on Construction*, ITcon Vol. 14.

however, standards and deployment of support mechanisms that may enable organisations to realise the benefits of BIM, need further investigation.

Hitherto studies have tended to focus on technical application of IFC and case implementations leaving those standards and support systems relating to process and organisation largely untreated. Gu & London[99] highlight a lack of available guidance and a need for further research which integrates both technical and non-technical challenges. Meanwhile Ekholm et al,[100] and OpenBIM[101] advise further knowledge is needed around the development of standards (Figure 5) and current debates[102,103,104] remind us that requirements on deliverables demand changes and improvements in working methodologies, standards around internal the external working processes and that each player's response to change alters the potential for the others.

We have provided a general overview of the context of the study. The following sub-sections present a series of themed reviews spearheading the state-of-the-art in specific areas, and problematizing key topics that enable the research questions to emerge.

1.4.1 BIM Guidelines

The literature is largely silent on the status of BIM guidance however Wong et al.[105] highlight that very few nations have developed their own *national* BIM guidelines. Denmark (bips)[106] and Finland (Senate)[107] being exceptions. Australia presents a distinct BIM vision through their so-called *National BIM Guidelines*,[108] however lacks the scope that may enable BIM teams to organised themselves to adopt BIM in a consistent fashion. In the US, the *National BIM Standard,*[109] the *Contractors' Guide to BIM,*[110] the *BIM Project Execution Planning Guide*,[111] are some of the several BIM guidelines that are currently available.[112] In the UK

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[99] Gu, N. & London, K. (2010), Understanding and facilitating BIM adoption in the AEC industry, *Automation in Construction*, 19 (2010) 988-999.
[100] Ekholm A., Häggström L., Johansson B., Tarandi V., & Tyrefors B. (2010), *RoadMap för digital information om byggd miljö*, Lund University, Lund, Sweden.
[101] http://www.bimalliance.se
[102] Jongeling, R., Samuelson, O. (2014), *Krav ger bättre BIM-beställningar*, Byggindustrin 26/2014.
[103] RIBA (2012b), *A New Way of Working, RIBA Journal: November 2012*, RIBA Publications, London.
[104] RIBA (2011a), *A Model Procedure, RIBA Journal: August 2011*, RIBA Publications, London.
[105] Wong, A., Wong, F. & Nadeem, A. (2011), Attributes of Building Information Modelling Implementations in Various Countries, *Architectural Engineering and Design Management*, Vol.6, Issue 4, pp288-302.
[106] http://bips.dk/
[107] http://www.en.buildingsmart.kotisivukone.com/3
[108] CRC Construction Innovation (2009), *National Guidelines for Digital Modelling*, Brisbane: CRC
[109] NIBS (National Institute of Building Sciences) (2007), *National Building Information Modeling Standard - Version - Part 1- Overview, Principles, and Methodologi*es, NBIMS, US.
[110] AGC (2006), *Contractors' Guide to BIM*, AGC of America, US.
[111] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

standards produced by BSI[113] and a Governmental national BIM vision[114,115] have been published. Sweden however lacks both an endorsed national vision and practice adoption guidelines. Azhar[116] advises there is no common way to adopt BIM. Meanwhile BIS[117] highlight there is a risk associated with the failure to have a strategic and consistent approach to BIM, that is '*the unnecessary and avoidable divergence in the strategic direction of BIM to the norm encountered on the international stage'.*[118]

Previous research has highlighted a number of factors that impact on the spread of adoption and development of industry BIM maturity and capability. Previous investigations show that the availability, scope and positioning of guidance and standards to support users in adopting BIM varies as does the content and structure of such documents.[119,120] Whilst there are new guideline and standards documents emerging directed at BIM project teams such as the AIA's E202[121] and the PEPG[122] and even more recently the new BS1192's[123,124] and CIC BIM-Protocols,[125] applicable corresponding BIM guidance and standards are missing in Sweden.[126] Notwithstanding, *Construction Documents 90* (Bygghandlingar 90)[127] and *CAD-Layer* (CAD-Lager)[128] provide local practitioners administrative recommendations; however they are based on 2D paper drawing practice and lack high level strategic appeal.

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[112] Sattineni, A. & Mead, K. (2013), *Coordination guidelines for virtual design and construction*, 2013 Proceedings of the 30th ISARC, Montréal, Canada, pp1491-1499.
[113] http://www.bsigroup.com/
[114] UK Government Cabinet Office (2011), *The UK Government Construction Strategy*, London: The Cabinet Office.
[115] BIS (2011) BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper, London.
[116] Azhar, S. (2011), *Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry*, Leadership and Management in Engineering, 2011.11:241-252.
[117] BIS (2011) BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper, London.
[118] Ibid.
[119] Sattineni, A. & Mead, K. (2013), *Coordination guidelines for virtual design and construction*, 2013 Proceedings of the 30th ISARC, Montréal, Canada, pp1491-1499.
[120] Gobar Adviseurs (2010), *An International Scope of BIM – A systematic review of BIM guideline documents*, Gobar Adviseurs, Netherlands.
[121] AIA (2008), *AIA Document E202-2008: Building Information Modeling Protocol Exhibit*, AIA and AIA California Council, California, USA.
[122] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.
[123] BSI (2013), *PAS 1192-2:2013 - Specification for information management of the capital delivery phase of construction projects using building information modelling*, British Standards Institution, London: BSI.
[124] BSI (2014). *BS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling*, British Standards Institution, London: BSI.
[125] CIC (2013), *Building Information Model (BIM) Protocol*, Construction Industry Council, London.
[126] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*
[127] SI, Swedish Standards Institute (2008*), Bygghandlingar 90: byggsektorns rekommendationer för redovisning av byggprojekt. D. 8, Digitala leveranser för bygg och förvaltning*, Stockholm : SIS Förlag AB.
[128] Svensk Byggtjänst (2011), *CAD-lager: Rekommendationer för tillämpning av SS-ISO 13567 med BSAB 96 och kodlista BH90 för landskapsinformation,* Stockholm: Svensk byggtjänst.

1.4.2 National & International BIM Standards

Many national and international standards exist relating to IT and the use of BIM in practice. These can be grouped, according to buildingSMART's model, adopted by Ekholm[129] (Figure 4), namely, under the headings: *standards for* ***process****, standards for* ***concepts****,* and *standards for* ***data model*** (Tables 2, 3 & 4 provides examples).

Standards for Process	**Description**
ISO/TS 12911:2012 Framework for building information modelling (BIM) guidance;	This standard defines a framework for the development of guidelines for BIM. Users may adopt the standard as support to structure national or project-based guidelines, even guidelines for software suppliers.
COBie	Construction Operations Building information exchange is a format for extracting information for operations & maintenance. Developed in the US, is now use in the UK and elsewhere. It captures important project data such as equipment lists, product information, warranties, replacement parts lists and a schedule for proactive maintenance.
IDM	Information Delivery Manual is a process standard, developed by buildingSMART, for creating a common understanding of a particular information exchange, including: what, when, who, why, by whom. It has been ratified into a formal ISO-standard, ISO 29481-1:2010 Building Information Modeling – Information Delivery Manual – Part 1: Method and format.
LOD	Level of Development has recently become a standardised specification to describe object maturity. Its purpose is to provide greater certainty in describing exchange content and align sender & receiver expectations.

Standards for Process v1.0 (After Ekholm et al., 2013)

Table 2: Standards for Process

These are recognised standards, however the threshold to adoption has bestowed execution difficulties, and transition to embracement so far has been neither comprehensive nor consistent.

[129] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*

Standards for Concepts	Description
EN ISO 12006-2 Building construction - Organisation of information about construction works – Part 2: Framework for classification of information;	This standard provides for definitions and a framework for recommended classification tables including construction work, building parts, spaces and functions from a production perspective. Nation building classification systems such as Omniclass, Uniclass and BSAB are based on this base standard.
EN ISO 12006-3 Building construction – Organisation of information about construction works – Part 3: Framework for object-oriented information;	This standard provides for definitions and a base data model to organise information about an (BIM) object and its properties. Application is primarily in the creation of databases for objects and properties such as buildingSMART data dictionary (bSdd).
BSAB 96	This is the Swedish construction classification system which includes tables for infrastructure, buildings, building parts, spaces, and production results.
CAD-Lager	Derived from ISO 13567, Sweden has defined a national code list of CAD layer and file naming conventions, connected to the BSAB system.
Fi2	Used for property administration, Fi2 is a Swedish conceptual model which goes beyond object geometry and properties to include administration activities, resources, organisation and agreements.

Standards for Concepts v1.0 (After Ekholm et al., 2013)

Table 3: Standards for Concepts

Standards for Data Model	Description
IFC (ISO 16739)	IFC, developed and maintained by buildingSMART, is a comprehensive, stable and open international standard for exchanging BIM data in the AEC & FM sector. Version IFC 4 was published as a ISO-standard in March 2013.
LandXML	LandXML is an open specification for exchange of building and terrain data. The standard includes for map data, plot data, 3d roads, streets, and railway models, also waterways and piped networks.
CityXML	CityGML is an open data model standard based on XML developed for managing virtual 3d cities and landscape models.
PLCS	Product Life- Cycle Support is an ISO-standard within the STEP family. It supports the creation and management over time quality controlled information for a product and its maintenance.
Fi2XML	Fi2XML is a Swedish exchange format based on XML for managing property administrative and maintenance information.
oBCF	Open Building Collaboration Format is an open standard for communicating information about a model between BIM tools. It can be used in model checking regimes to ensure authors action editing tasks.
mvdXML	Model View Definintion XML is a standard developed by buildingSMART, accessible since 2012. MVD defines a subset of an IFC model for data exchange.

Standards for Data Model v1.0 (After Ekholm et al., 2013)

Table 4: Standards for Data Model

Schäfermeyer & Rosenkranz[130] highlight the benefits of standards adoption and Lighthart[131] postulates that the more industrialised and standardised a construction industry, the greater the advantages of BIM to those in it. Further, that Governments can be passive or active; supportive or dismissive with respect to BIM adoption, however without standards ad hoc approaches and sub-optimisation will prevail. The UK Government BIM Working Party Strategy[132] proposes '*push*' (top-down) and '*pull*' (bottom-up) approach targeting incremental operational capability, mandating a minimum level 2 maturity by 2016. To facilitate, a new RIBA plan of work,[133] new British Standards,[134,135] and new guideline documents[136] have been made available. In Sweden, Ekholm et al, highlight the need for a comprehensive review of applicable standards.[137] Accordingly, in their report on BIM standardisation needs,[138] 10 standardisation projects are proposed, testimony to the need to overhaul the sectors' requisite for standards that are coordinated so that they can support BIM use in a comprehensive way.

Research on BIM benefits[139] and IT in construction generally[140,141,142&143] confirms expectations are not yet being met whilst also indicating that a lack of consistent adoption of particular standards represent a barrier to realisation of expected benefits such as improved productivity[144]. Gustavsson et al.[145] furthermore advises that much that has been written

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[130] Schäfermeyer, M. & Rosenkranz, C. (2011). *To Standardize or not to Standardise? – Understanding the effect of business process complexity on business process standardization*, ECIS 2011 Proceedings. Paper 32. http://aisel.aisnet.org/ecis2011/32

[131] Lighthart et al. (2014), *BIM in the States vs BIM in the World*, Linked-In Discussion: https://www.linkedin.com/groups/BIM-in-States-vs-BIM-98421.S.5916172179065565188?trk=groups_items_see_more-0-b-ttl

[132] BIS (2011) BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper, London.

[133] RIBA (2013b), *RIBA Plan of Work*, RIBA Publications, London.

[134] BSI (2013), *PAS 1192-2:2013 - Specification for information management of the capital delivery phase of construction projects using building information modelling*, British Standards Institution, London: BSI.

[135] BSI (2014). *BS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling*, British Standards Institution, London: BSI.

[136] CIC (2013), *Building Information Model (BIM) Protocol*, Construction Industry Council, London.

[137] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*

[138] Ibid.

[139] Azhar, S. (2011), *Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry*, Leadership and Management in Engineering, 2011.11:241-252.

[140] Samuelson, O. (2010). IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium, Hanken School of Economics, Helsinki.

[141] Samuelson, O. (2011). Adoption Processes for EDM, EDI and BIM in the Construction Industry, Proceedings of the CIB W078-W102: 2011 Joint International Conference, Sophia Antipolis, France, 26-28 October 2011.

[142] Samuelson, O. (2012). IT-Barometern. En mätning av bygg- och fastighetssektorns IT-användning,TRITA-FOB-Rapport 2012:1, Stockholm: KTH-Royal Institute of Technology.

[143] Gustavsson, T. K., Samuelson, O. & Wikforss, Ö. (2012), Organising IT in Construction: Present State and Future Challenges in Sweden, ITcon, Vol. 17, pp. 520-533.

[144] Sacks, R., Barak, R. (2008) Impact of three-dimensional pararmetric modelling of buildings on productivity in structural engineering practice, *Automation in Construction,* Vol.17 (2008), pp.439-449.

about BIM aims to convince others on the possible benefits of using IT-tools whilst side-stepping in-depth reflective discussions on the organisational prerequisites needed for these benefits to be realised. Meanwhile, Samuelson[146] suggests the industry has a tendency to optimise at individual or organisation level only, not the entire process and that standards are lacking.

1.4.3 BIM Project Planning

Organising project teams to work closely together towards common goals in construction is not easy.[147] Not only because of sector fragmentation and diverse business interests but because different organisations have different working methodologies and delivery standards. Working in a BIM mode necessitates common working methods, standards and close collaboration.[148,149] Furthermore, Singh[150] highlights that successful adoption of technical innovations requires introduction of corresponding process and organisation innovations. Accordingly, Wallbank[151] recommends some form of BIM protocol is essential to propose and agree project wide goals, methodology and standards. Whilst Shennan[152] argues that owners should set out BIM protocols that define overall requirements, and ask their supply chain to respond with their *BIM execution plans*.

In the US, Penn State University in collaboration with buildingSMART have developed and published a generic *BIM Project Execution and Planning Guide*[153] that can be deployed by teams on a project basis to align their BIM ambitions and pull resources to deliver them. Similar alternative protocols have emerged more recently elsewhere such as the CIC's BIM Protocol.[154] However, studies reporting on their application are limited, further the use of standardised BIM execution plans in Sweden warrants investigation since existing national guideline, after initial investigations are shown to have limited scope.

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[145] Gustavsson, T. K., Samuelson, O. & Wikforss, Ö. (2012), Organising IT in Construction: Present State and Future Challenges in Sweden, ITcon, Vol. 17, pp. 520-533.
[146] Samuelson, O. (2011). Adoption Processes for EDM, EDI and BIM in the Construction Industry, Proceedings of the CIB W078-W102: 2011 Joint International Conference, Sophia Antipolis, France, 26-28 October 2011.
[147] Winch, G. (2010), *Managing Construction Projects*, London: Wiley Blackwell.
[148] Dana K. Smith, Michael Tardif (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, New Jersey: John Wiley & Sons.
[149] Race, S. (2012), *BIM Demystified*, London: RIBA Publishing.
[150]Singh, V. (2014),BIM and Systemic ICT innovation in AEC, *Construction Innovation,* Vol.14, No. 3, 2024, pp.292-306.
[151] RIBA (2011a), *A Model Procedure, RIBA Journal: August 2011*, RIBA Publications, London.
[152] RIBA (2012b), *A New Way of Working, RIBA Journal: November 2012*, RIBA Publications, London.
[153] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.
[154] CIC (2013), *Building Information Model (BIM) Protocol*, Construction Industry Council, London.

1.4.4 Digital Deliveries

Deliveries need to be specified and controlled. *Construction Documents 90* (Bygghandlingar 90)[155,156] sets out a framework for specifying and managing deliveries but lacks concrete examples of what should be included, and leaves the 'who, what, when, how' questions open. Meanwhile buildingSMART have developed the concept of Information Delivery Manual (IDM) to support specification and later automate control of model content and object properties. However, few IDM's exist and are not yet in practical use.[157] There is a gap between the need to align information delivery expectations and practical methods to deliver. More knowledge is need about IDM for particular standardisable use cases. Working delivery specifications for common BIM uses need to be developed, tested and deployed that can firstly enable practitioners to move ahead in earnest, independently of software implementations, and secondly feed into the development of buildingSMART's IDM's and Model View Definitions (MVD's).

1.4.5 Obstacles to BIM

Highlighted in the literature are many obstacles to BIM and, like benefits, can be grouped under the categories of *people*/*organisational*, *process* and *technological*. Examples include: interoperability; investment costs; time to up-skill; lack of high level leadership / mandate; fear of change; lack of awareness and adoption of standards; and lack of contractual agreements that support BIM usage.[158,159,160]

While proprietary systems vendors are slowly aligning with each other in terms of interoperability through implementation of buildingSMART's IFC data model, allowing BIM data to be exchanged between software platforms, the industry has some catching-up to do in terms of contracts, liabilities and risk management for professional indemnity.[161] Exploitation of the advantages BIM can offer demands renewal and changes in processes and incentives, which in turn creates to new roles and business models.[162] Accordingly, Volk et

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[155] SI, Swedish Standards Institute (2008*), Bygghandlingar 90: byggsektorns rekommendationer för redovisning av byggprojekt. D. 8, Digitala leveranser för bygg och förvaltning*, Stockholm : SIS Förlag AB.
[156] FFi (2011), *Digital Informationsleveranser till och frän Förvaltning – Tillämpningsanvisning: FFi – baserad på Bygghandlingar 90 del 8 utgåva 2*, Version 2011, FFi, Sweden.
[157] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*
[158] Migilinskas, D., Popov, V., Juocevicius, V., Ustinovichius, L. (2013), *The benefits, obstacles and problems of practical BIM implementation*, Procedia Engineering, 57 (2013) pp767-774.
[159] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 2nd Ed., London: John Wiley & Sons.
[160] Dana K. Smith, Michael Tardif (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, New Jersey: John Wiley & Sons.
[161] RIBA (2011), *Adopt and Adapt, RIBA Journal: August 2011*, RIBA Publications, London.
[162] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*

al.[163] highlight traditional processes and contractual agreements are being adapted at difference rates and scopes to better support BIM around the world. State pressure in counties like the UK and US have accelerated process change, however different stages of development and their effect on adoption levels are not reported or examined in the literature yet.

1.4.6 Level of Development – Confronting the Mystery

Common sector concepts are essential to BIM integration. Level of Development (LOD) is an example of a newly standardised concept. It refers to *the degree to which an element's (object) geometry and attached information* (properties) *have been thought through, the degree to which project team members may rely on the information when using the model.*[164] Lighthart[165] refers to it as a measure of an object's *reliability* and *specificity*. However, it's adoption and utilisation in BIM projects has not been without difficulties. The literature highlights number of re-occurring issues concerning LOD concept and application, namely: 1) a lack of consistent understanding and utilisation in practice; 2) scepticism over its usefulness; and 3) difficulty in integrating LOD & MPS[166] into a BIM-like work flow, vis-á-vis a dissatisfaction with the management of it outside the BIM in high maintenance stand-alone documents. These issues are echoed by Lighthart[167] (McPhee et al. 2013b) who reports widespread confusion as to how it can be applied, frustration over its high maintenance legacy and division over its usefulness.

Existing studies[168] note a lack of research on this topic and underline a need to research mechanism (such as LOD) that may go some way to providing standardised solution to questions like: *what level of information is needed at each stage / data drop and who is responsible for it?*

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[163] Volk, R., Stengel, J. & Schultmann, F. (2014) BIM for existing buildings – Literature review and future needs, *Automation in Construction*, Vol.38 (2014), pp109-127.
[164] Bedrick, J. (2013), *A Level of Development Specification for BIM Processes*, AECBytes, Australia. Available: http://www.aecbytes.com/viewpoint/2013/issue_68_pr.html
[165] McPhee, A. et al. (2013c) *What is LOD, is it useful or just another pointless BIM deliverable?*, Linked-In Discussion: http://www.linkedin.com/groups/What-is-LOD-is-it-98421.S.218542523?view=&srchtype=discussedNews&gid=98421&item=218542523&type=member&trk=eml-%E2%80%A61/20
[166] Model Progression Specification
[167] McPhee, A. et al. (2013c) *What is LOD, is it useful or just another pointless BIM deliverable?*, Linked-In Discussion: http://www.linkedin.com/groups/What-is-LOD-is-it-98421.S.218542523?view=&srchtype=discussedNews&gid=98421&item=218542523&type=member&trk=eml-%E2%80%A61/20
[168] Burcin Becerik-Gerber, A. M. A., & Kensek, K. (2010), *Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends*, Journal of Professional Issues in Engineering Education and Practice, 136(3), 139–147.

LOD matrices are available for use[169] however little case evidence supports their supposed usefulness and barriers to adoption remain high. Accordingly, further knowledge is needed to unravel LOD and review methodologies for its application.

1.5 Research Gap & Positioning Contribution

The previous section highlights a number of potential research gaps. To position the current work Table 5 presents a non-exhaustive list of current research themes, brief notes on investigation carried out so far, authors and perceived shortcomings. The noted shortcomings or gaps in the literature highlight the need for further work within the selected research themes and links them to existing work and authors. The aim is that new knowledge is created that may allow this research to build on that by others.

The conclusion of this review supports the need for further research under the selected themes of *BIM-Planning*, *Digital Delivery Specification*, *BIM Process Obstacles*, *LOD Concept & Application*, and efforts to *validate and legitimise standardisation efforts*. The key players in the research field are identified and this work positioned accordingly. The proposed research themes can be viewed to be linked and seek to provide new insight against the backdrop of existing research, the existing and emerging national standards and AEC industry initiatives including BIM Alliance Sweden[170] and buildingSMART[171]. The thread that joins these themes is BIM standardisation needs and support systems which can be positioned firmly within the fields of BIM process and policy as described by Succar.[172]

Research building on the aforementioned themes may help us understand the importance of standards where teams are expected to deliver projects adopting BIM technology and processes, and provide insight into how traditional difficulties in realising the much publicised BIM benefits might be overcome. Ekholm[173] highlights that: *"Object-oriented information management is dependent on increased standardisation and coordination of data models, concepts and processes, […] branch standards are missing or fragmented, and the sector suffers from a lack of agreement about object-oriented information management and delivery.* [Furthermore…] *there is strong sector need to coordinate experience and create standards for object-oriented information exchange throughout the design, construct and operate processes.* Here contribution can be made.

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[169] Such as the AIA's Digital Practice Documents: E203-2012, Building Information Modeling and Digital Data Exhibit; G201-2012 Project Digital Data Protocol Form; and G202-2012 Building Information Modeling Protocol Form. AIA, California, USA.
[170] http://www.bimalliance.se
[171] http://www.buildingsmart.org/ & http://www.buildingsmart.com/
[172] Succar, B (2009), Building Information Modelling: A Research and Delivery Foundation for Industry Stakeholders, *Automation in Construction*, Vol. 18, pp. 357-375.
[173] Ekholm A., Häggström L., Johansson B., Tarandi V., & Tyrefors B. (2010), *RoadMap för digital information om byggd miljö*, Lund University, Lund, Sweden.

Spotlighted Themes	**Investigations**	**Authors**	**Shortfalls / Comments**
BIM Guidelines	A systematic review of BIM guideline documents. Attributes of national BIM adoption. Coordination Guidelines. Need for guidelines. National BIM Standards	Gobar Adviseurs (2010) Succar, B. (2009) Wong et al. (2011) Azhar, S. (2011) Sattineni et al. (2013) Ekholm et al. (2013)	Inventory of current BIM guidelines. Content, scope & positioning of Swedish BIM guidelines. Impact of in-house BIM Manuals on national BIM vision & consistent approach.
National BIM Standards	Importance of standards adoption for productivity. Need for BIM Standards Impact of BIM Standards	Schäfermeyer & Rosenkranz (2011) Azhar, S. (2011) Samuelson, O. (2011) Ekholm et al. (2013) Jongeling et al, (2013) Lighthart et al. (2014)	Alignment of standardisation work and research efforts. Identification of the most important standards for here & now solutions. Importance of state demand.
BIM Project Planning BIM Protocols	BIM Project Planning purpose & application. BIM Protocols purpose & application. Limitations Importance of goal alignment.	Winch, G. (2010) Anumba, C. et al. (2010) Gustavsson et al. (2012) Race, S. (2012) Singh, V. (2014)	Reporting on test cases of applied BIM protocols / project planning and execution plans. Impact on project outcomes. Capacity to fill gaps in existing national guidelines.
Digital Deliveries Information Delivery Specification	Guide to IDM Product Manufacturer info & IDM. New IDM framework IDM for precast concrete	Eastman et al. (2009) Anumba, C. et al. (2010) Wix, J. & Karlshøj, J. (2010) Berard, O. & Karlshoej, J. (2012) Mondrup et al. (2014)	Lack of reporting of IDM in practice. Lack of reporting on here and now alternative solutions to information exchange standardisation.
Barriers to BIM BIM Obstacles BIM Process Obstacles BIM Behaviours BIM Contractual Support	Technical, organisational and process related obstacles.	Kiviniemi, A. et al. (2008) Gu, N. & London, K. (2010) Azhar, S. (2010) Linderoth, H. (2009) Rezgui Y. et al. (2009) Pfitzner, M. et al. (2010) Steel, J. et al. (2012) Vestergård, F. et al. (2011) Gustavsson et al. (2012) Ashcraft, H. (2008) Race, S. (2012)	Insight into connections between contracts, behaviours and BIM inertia. Impact of supporting mechanisms to enable / actively support intelligent downstream use of digital information.
Level of Development Model Progression Specification	Generic specification of levels. Adoption to support quantification of modelling effort. Alternative nomenclature / taxonomy scale.	AIA (2008) & (2013) BIM Forum (2013) Bips (2009) Bedrick, J. (2008) & (2013) Choi, H.-J. (2011) Kastell, M. et al. (2013) Leite, F. et al. (2011) McPhee, A. et al. (2013) Renehan, B. (2013) Vico (2012)	A common understanding of the concept and meaning in a BIM context. Reporting on cases of expedient application. How it is useful. Integration into a BIM-like workflow.

A non-exhaustive list of connecting *Themes, Investigations*, *Authors* & *Shortfalls* v3.0 (Hooper, 2014)

Table 5: A non-exhaustive list of connecting *Themes*, *Investigations*, *Authors* & *Shortfalls*

1.6 The Research Questions

The definition of the central research question for this study ultimately focuses on an investigation into BIM standardisation needs and support systems which may contribute to the existing body of knowledge concerning BIM and its integration into practice. The primary research question this study is formulated as follows: *How can particular standardisation efforts and support systems support an increasingly integrated BIM adoption?*

To unlock responses to this fundamental question, this study seeks to answer the following sub-questions which are tackled in turn through each research paper and brought together in this thesis.

Sub-Question #1:

What development / standards / guidelines are needed to support the implementation of BIM in connection with construction projects in Sweden with a specific focus on information exchange and delivery specifications?

This question aims to provide an insight into firstly, what is out there in the way of standards and guidelines, secondly identify what is lacking in Sweden and lastly, to test industry appetite for applying a pedagogical approach to BIM-Planning to support information exchanges.

Sub-Question #2 (in 2 parts):

How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis? Could a standard exchange matrix be established for various BIM-Uses at various project stages that would help align information delivery expectations?

The second research question provides a deeper understanding and a development of the concept of *Delivery Specification* introduced in BH90[174] but not developed into a working tool.

Sub-Question #3 (in 2 parts):

What is the connection between traditional contracting and BIM inertia? What are the necessary components that may facilitate more effective early BIM collaboration?

The third research question, revealed itself of paramount importance during the data collection phases in connection with Papers #1 and #2 and in tackling research questions 1 and 2. In dealing with the application of project specific BIM-Plans and defining information

[174] SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

deliveries for BIM-Uses, a logical next step was to understand what the barriers are to the uptake and the execution common strategic BIM plans and digital information stewardship in practice.

Sub-Question #4 (in 2 parts):

Can we better facilitate adoption of LOD and associated responsibility matrices by improving their integration into BIM workflow? Is there a way of automatically verifying model content against intended use and programme that could be standardised?

The question of LOD: concept and application, arose from a gap in the literature and a lack of consistent use and understanding of it as primary parameter of Digital Delivery Specification. Later validated through literature review and case investigations, LOD is shown to serve as something of a linchpin to BIM.

Sub-Question #5 (in 2 parts):

Which BIM standardisation initiatives are of most interest and to whom? To what extent are these standardisation needs aligned with existing research efforts?

Seeking validation of the value and contribution of current research efforts and position them in a landscape of other national strategic BIM development and standardisation initiatives, this question is designed to add legitimacy to this and other work using quantitative as well as qualitative data.

The resolution of these research questions seeks to unlock the difficulties in moving from BIM *organisational optimization* (Level 2) towards BIM *project optimization* (Level 3) (see Figure 5).[175] Overall they may go some way to identifying and binding together the prerequisite process standards and decisions support mechanisms required for improved BIM-project delivery.

Whilst some of these matters may be obvious in a traditional design process or design methodology, new processes with new responsibilities are emerging which need to be defined in order to facilitate *optimised* design co-ordination and integrate BIM into working practices. The broad research question investigated in this study is about how the new process requirements may be handled in a systematic way.

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[175] Notional levels of BIM implementation maturity range from 0-3. See: BIS (2011) *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London. Also implied in: WSP (2011), *Lilla Boken om BIM – Så förändras en bransch*, WSP, Stockholm, Sweden.

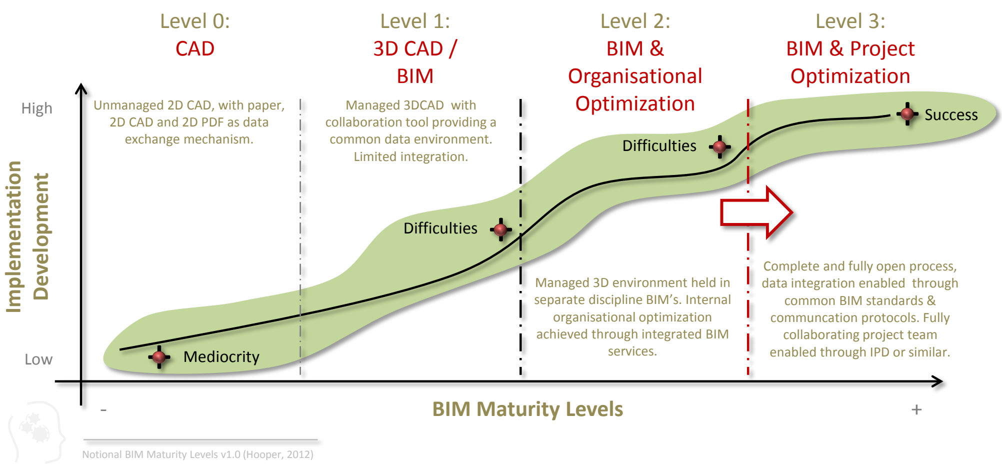

Figure 5: Notional BIM Maturity Levels (after Bew, 2011)

1.7 Purpose & Objectives

The primary purpose of this work is to contribute towards the body of knowledge that may inform the shaping of the standardisation of the construction industry's production information and administration structure and scope. In time this may enable a greater co-operation and collaboration between industry and project participants already possible through BIM but currently hindered due, amongst other things, to a lack of standardised platforms for digital information sharing and support systems. The work is orientated towards specific needs of the industry,[176] and through collaboration with user-groups and existing BIM-user organisations, seeks to support the sector's needs by testing, evaluating and developing novel BIM methodologies that may serve to effect incremental industry improvements. The specific scientific objectives are to:

- Review existing BIM guides and standards to identify gaps, test and evaluate the industry's appetite for utilisation of a project-based strategic BIM implementation plan based on buildingSMART Alliances' *Building Information Modelling Project Execution Planning Guide*[177] (PEPG).

- Establish a process model for defining BIM information content for specific BIM deliveries, extending the concept of Digital Delivery Specification.

[176] See: Note #1: An Analysis of Industry Needs, pp.#132

[177] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

- Examine the connections between the legal and commercial environment of construction contracts and the resulting procedures and behaviours that may be seen to hinder BIM collaboration and the expedient usage of data rich models downstream.

- Uncover mechanisms facilitating and constraining utilisation of Level of Development (LOD) to support information stewardship and explore the plausibility of automated model progression scheduling.

- Identify which BIM standardisation initiatives are of interest and to whom, assess the extent to which standardisation needs are aligned with research efforts and legitimise current research efforts.

Furthermore, the study considers how these efforts could be supplemented by coordinating efforts at sector level to avoid problems of sub-optimization and conceptual divergence. The research remit also includes testing and disseminating results through teaching at learning at the University based lab.

1.8 Focus & Delimitations

This research project focuses on *process-orientated standards and support* for digital information stewardship through the Design, Construct, Operate (DCO) phases of construction projects. Aligned with national initiatives and emerging trends, this research aims to contribute to the current body of knowledge through testing and validating BIM standardisation and support mechanism propositions based on cumulative results emerging from industry collaborations. Notwithstanding, the world of BIM is vast and the problems and difficulties experienced in connection with adoption and leveraging benefits amongst DCO participants equally large. Therefore, one needs to be assertively selective when defining the limitations of a study in this field.

First, the results of this research project are based on empirical data largely collected from case construction projects in Sweden or interview data involving AEC participants operating in Sweden. Part of the study has been to understand Sweden's construction industry's idiosyncrasies, however, the issues associated with BIM maturity progression are by no means unique to Sweden and the emerging conclusions can be viewed to have broader international relevance and implications. Opportunities to collaborate and exchange views with representatives from other Nordic and European BIM communities have been exercised to provide an international context to the work.

Second, this study is not a software or IT-orientated technical report; nor does it cover in-depth usage of technical standards such as those maintained by buildingSMART[178] (these being addressed by, amongst others, Kiviniemi;[179] Pazlar & Turk;[180] Kiviniemi et al.;[181] and Venugopal et al.[182]). However this work does reflect on the linkages to buildingSMART's initiatives and how it may contribute towards their goals. Rather, this work aims to be of both theoretical and practical value and application primarily independent of technical / software implementations. Whilst interoperability remains one of the chief obstacles to BIM and associated data integrity, this study does not attempt to tackle this particular irksome, technical-implementation related difficulty, albeit does reflect on its relativity to the main themes.

Third, the focus is mainly on the *design (methodology and management) domain* with the necessary strategic cognisance to the downstream use of digital project information, through the DCO lifecycle (Figure 6). This is for 4 key reasons:

- Design is where the main BIM-authoring activities reside which in turn have the biggest impact on the quality and downstream usability of the digit asset.
- Architects and Engineers are seen to invest the most in BIM, however benefit the least.[183] They struggle the most with BIM process improvement which impacts heavily on construction and operation activities using their data.
- It is projected that the volume of information created through design development phases with see the most dramatic increase and thus the management of it is critical.
- The adopted frame of reference leans on the author's previous experience as an Architect in the field of study, which here is considered advantageous for applying practical knowledge of the trade and understanding the often jarring peculiarities of the profession.

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[178] Industry body responsible for developing IFC's, IFD, IDM, MVD's.
[179] Kiviniemi, A. (2006) Ten Years of IFC Development – CIB W78 Montreal Keynote Presentation.
[180] Pazlar, T. & Turk, Z. (2008) *Interoperability in Practice: Geometric Data Exchange using the IFC Standard,* ITcon Vol.13, pg362-380.
[181] Kiviniemi, A., Tarandi, V., Karlshøj, J., Bell, H., Karud, O.J. (2008), *Review of the Development and Implementation of IFC Compatible BIM*, Erabuild 2008.
[182] Venugopal, M., Eastman, C.M., Sacks, R., Teizer, J. (2012), *Semantics of model views for information exchanges using the industry foundation class schema,* Advanced Engineering Informatics, Vol.20, pg411-428.
[183] Succar, B. (2010), *BIM ThinkSpace: Episode 14: Industry Leadership vs. BIM Benefits*. Available at: http://changeagents.blogs.com/thinkspace

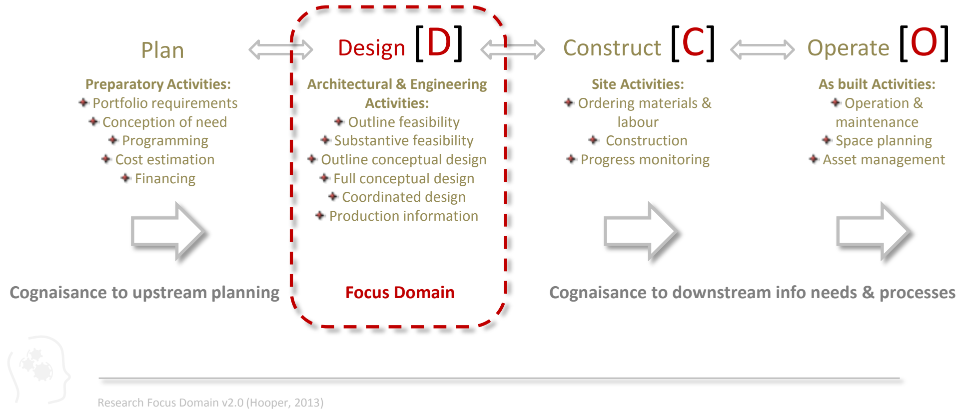

Figure 6: Research Focus Domain

Fourth, in accordance with the objectives and identified focus domain, only standardisation needs and support systems related to their activities and integrity of their deliverables are investigated.

Finally, this research builds on that reported through the author's licentiate thesis,[184] and endeavours to develop a selection of those early field investigations to construct a niche contribution. Figure 7, illustrates the breadth and depth of the research project and highlights the key themes. The initially broad research project, focusing on standards and BIM deployment planning, delivery specification, and process obstacles takes the aspects of BIM inertia, Level of Development (LOD) and standardisation efforts deeper.

[184] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151

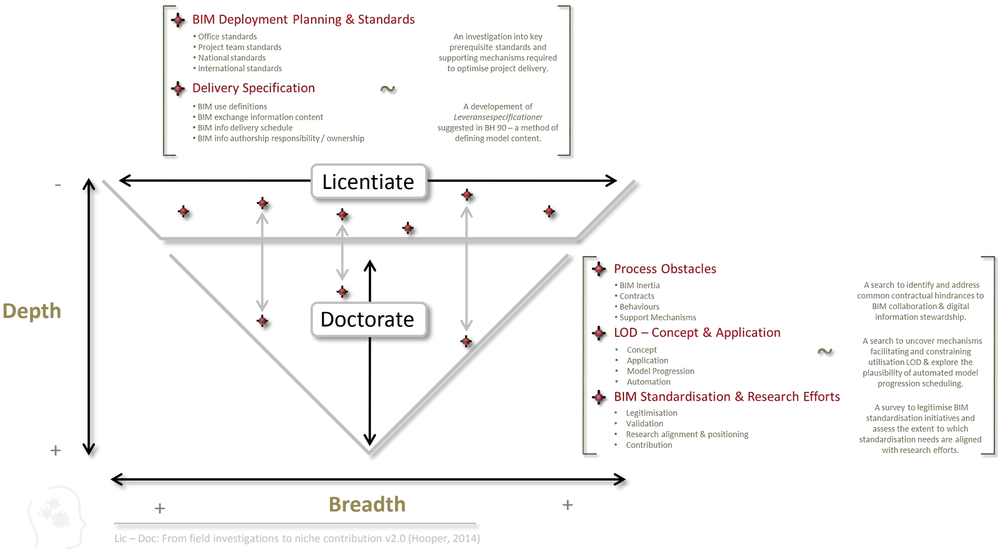

Figure 7: Lic ~ Doc: From field investigations to niche contribution

The next chapter introduces the theory, the knowledge deemed relevant to tackle the research questions in a scientific way.

On Theory:

"Experience without theory is blind, but theory without experience is mere intellectual play". (Immanuel Kant)[185]

2.0 Theory

The previous chapter identified shortcomings in the existing research and presented a convergent collection of work that aims to position this research alongside the existing body of knowledge. Here we introduce a focused selection of applicable theories that have an impact on the thought processes associated with tackling the research questions. As such the theory forms the background to the findings and provides something of a springboard to launch the empirical work.

The theory is built up from a number of related threads including: *guidelines & standards, construction classification,* and *interoperability*, set against a background of existing circumstances and trends such as: *the need for improvement & current industry initiatives.*

2.1 Building Information Management & Emerging New Roles

The capabilities of BIM allow for better transition from design to construction to operations and facilities management, where information acquisition and decision making become a bigger task than documentation and processing of materials.[186] BIM allows for work processes and information to be collected from multiple disciplines, multiple companies, and multiple project phases through collaborative processes.[187] This results in savings in time and

[185] Immanuel Kant (1724-1804), German Philosopher.
[186] Bynum, P., Issa, R. & Olbina, S. (2013) Building Information Modeling in Support of Sustainable Design and Construction, *Journal of Construction Engineering and Management,* Vol. 139, pp24-24, ASCE.
[187] Grilo, A. & Jardim-Goncalves, R. (2010), Value proposition on interoperability of BIM and collaborative working environments, *Automation in Construction*, Vol.19, Issue 5, pp522-530.

resources, improved quality, and overall more efficient buildings.[188] However, BIM as defined in the introduction is about not only the model or the process of modelling, it is about the management of the fusion between *technology* (the application of scientific knowledge for practical purposes)[189], *process* (being a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure of action),[190] and *policy* (written principles or rules to guide decision-making).[191] Succar[192] assembles these constructs as *interlocking fields of BIM activity* with two sub-fields each of players and deliverables (Figure 8).

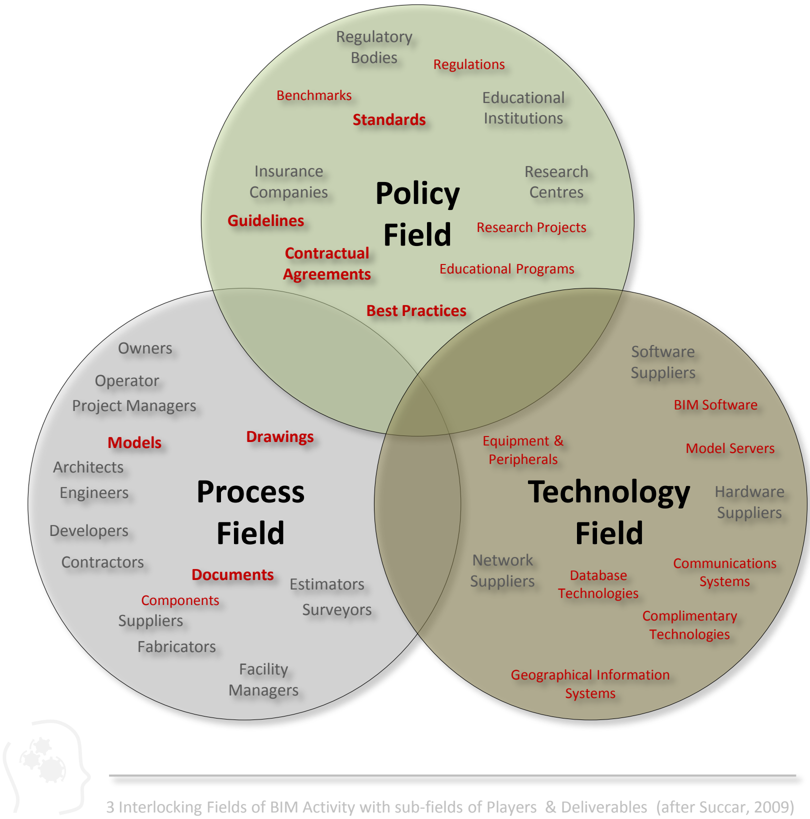

Figure 8: Three Interlocking Fields of BIM Activity (after Succar, 2009)

188 Suermann & Issa (2009), *Evaluation Industry Perceptions of Building Information Modeling (BIM) Impact on Construction*, ITcon Vol. 14.
189 Oxford, 'Technology' – Oxford Dictionary: http://www.oxforddictionaries.com/definition/english/technology
190 Davenport, T.H. (1992), Process Innovation: Re-engineering work through information technology, Harvard Business School Press.
191 Clemson, Definition of Policy, Clemson University – Office of Research Compliance, Definitions of Research Compliance Terms. Accessible: http://www.clemson.edu/research/orcSite/orcIRB_DefsP.htm
192 Succar, B (2009), Building Information Modelling: A Research and Delivery Foundation for Industry Stakeholders, *Automation in Construction*, Vol. 18, pp. 357-375.

Highlighted are *standards*, *guidelines*, and *contractual agreements* which fall within the policy field as deliverables in Succar's model. Policy deliverables are viewed to have a direct impact on the process field deliverables of *models*, *drawings* and *documents* in terms of the way such process deliverables are structured, organised and assembled, then utilised downstream. Theory behind BIM, touched on previously in the introduction and literature review, calls for a more effective integration between these fields.

A consequence of BIM ultimately affecting all disciplines in the construction supply chain is the emergence of new roles and responsibilities. One example is the *BIM Manager* or the *Project Information Officer* (PIO) as described by Tyréns.[193] Such roles, evolving from new business models, carry specific responsibilities that never existed before BIM and are closely tied to project and design management domains. Their remit often includes policing new requirements to ensure information and process standards are applied in project team participants' work.

2.2 Project Management & Design Management

Effective project management is an important aspect of the Architects' and Design Managers' professional domain and should be supported by a BIM standardisation needs and support systems model for adoption.

Project Management theory suggested in the PMBOK Guide by PMI[194] consists of a broadly applicable and accepted set of guiding principles and, according to Koskela & Howell,[195] are those most commonly applied in practice. However, Koskela and Howell[196] also acknowledge that these principles are becoming increasingly obsolete and that the application of modern project management methods such as *Last Planner* and *Scrum* are on the rise and radically deviate from the conventional doctrine of project management. Modern project management frameworks such as Scrum,[197] which may include agile and sprint methodologies, are popular within IT and production industries.[198] However, theoretically aspects of Scrum may have application in supporting Design Information Managers (*BIM Managers*) in developing their digital deliverables for specific information exchanges or *soft landings*.[199] Activity *burndown*[200] is applied on an experimental level in connection with the

[193] http://www.tyrens.se/Global/Tjanster/BIM/pio_web.pdf
[194] PMI (2008), *A Guide to Project Management Body of Knowledge* (4th Ed. ed.). PA, USA: PMI, Inc.
[195] Koskela, L. & Howell, G. (2002), *The underlying theory of project management is obsolete*, in: The PMI Research Conference, June 2002, Seattle, Washington.
[196] Koskela, L. & Howell, G. (2002), *The theory of project management: Explanation to novel methods*. In Proceedings 10th Annual Conference on Lean Construction, IGLC-10 (Vol. 6, No. 8).
[197] Scrum = A project management framework within which people can address complex adaptive problems, while productively and creatively delivering products (and services) of the highest possible value.
[198] Schwaber, K. & Sutherland, J. (2013), *The Scrum Guide – The Definitive Guide to Scrum: The Rules of the Game*. Accessible: https://www.scrum.org/Portals/0/Documents/Scrum%20Guides/Scrum_Guide.pdf
[199] Soft landings: process (& information exchange) to align design and construction with operational asset management and purpose as now required by the UK Government. http://www.bimtaskgroup.org/gsl-faqs/

study executed in Paper #4 being model population progression during design phases leveraging *Level of Development* (LOD).

Design management in the AEC sector is a rapidly evolving discipline[201] and is a discipline that resides within both design consultant and contracting domains. Like project management, it assumes a wide range of scopes, interpretations, applications and understandings.[202] In a BIM context it can be analogous to Design *Information* Management where the aim is to leverage the digital asset (the model) to create value for multiple stakeholders. The theory suggests development in information standardisation requirements and supporting procedures and protocols are needed to support the role.[203,204]

2.3 The need of improvement & Current Industry Initiatives

Today the construction industry in Sweden represents 8% of GDP, equivalent to 250 billion Swedish Kronor.[205] BIM Alliance Sweden[206] representatives determine that several billion Swedish Kronor can be saved in the Swedish construction sector, representing nearly 30%.[207]

According to McGraw Hill Construction's SmartMarket Report, 70% of BIM users say more clearly defined BIM deliverables between parties is highly to very highly important to increasing the value of BIM within the sector.[208] Beyond the issue of interoperability (that has compromised both productivity and the value of the building design and construct information since the advent of CAD), sorting out objectives around information exchange, deliverables and collaboration remains both a theoretical and practical challenge. It is claimed for example that one has to enter the same data 7 times through the design and construction process.[209] Ultimately the information that may be available and accessible through a facilities *operate* phase may be either irrelevant or inaccurate. BIM Alliance Sweden representatives point out:

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[200] A Scrum Burndown displays the *remaining effort for a given period of time.*
[201] Emmitt, S. (2010) Design Management in Architecture, Engineering and Construction: Origins and Trends, *Gestão & Tecnologia de Projetos*, Vol. 5, nº 3, November 2010.
[202] Ibid.
[203] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport, Stockholm, Sweden.*
[204] Race, S. (2012), *BIM Demystified*, London: RIBA Publishing.
[205] Statistics Sweden & Isaksson, F (2011) *The Swedish Construction Sector and a Short term Economic Outlook*, The Swedish Construction Federation, Stockholm.
[206] BIM Alliance Sweden – Sweden's main branch organisation supporting the application and development of BIM. Accessible: http://www.bimalliance.se/
[207] Anderson, R. (2010) VVS-Forum #2, February 2010, Stockholm, also see: www.OpenBIM.se
[208] McGraw Hill Construction (2008) SmartMarket Report: *BIM – The Business Value of BIM: Getting Building Information Modelling to the Bottom Line*, New York: McGraw Hill Construction.
[209] Edgar, J-O. (2008), *Brist på samordning hotar BIM*, Byggindustrin, Jan 2008.

> *"There is neither a central directive nor common guidelines [in Sweden] which leads us to sub-optimized and unnecessary costs for [construction] energy and the environment and poor competition development."* [210]

With a background of a theoretical promise of much to gain together with a fog of practical uncertainties and difficulties, the integration of BIM into the design, construct, operate process today presents an opportunity to deliver on improving important aspects of construction industry practices.

The construction industry is seen by many as a problem sector[211] as the British *Egan Report* (1998)[212] and the Swedish *Skärpning Gubbar!* (2002)[213] testify. Follow-up reports, *Construction Excellence, 10 years since Egan* (2008)[214] and *Sega gubbar?* (2009)[215] moreover suggest that not much has improved since then. However, one can pick out a number of resent high-profile construction projects that have been resounding success stories. Öresundsbron 2005, and Malmö City Tunnel 2010, for example, were both technical and economic success stories where the crucial factors, time and budget, were maintained or bettered.

The construction sector has had a tendency to harbour certain paradoxes but one thing is clear, the use and integration of ICT in the AEC sector together with the volume and value of data is destined to rise. Corporate frustration arises when one compares or attempts to benchmark the construction industry with, for example, the auto industry or mobile phone industry that, as such, have managed to achieve so much more with the use of similar technologies. It is conjectured that the scope for improvement through BIM adoption and realisation of promised benefits may lie in standardisation needs and support systems that may in turn usher AEC players to leverage the available technology and intelligent data.

2.3.1 buildingSMART Alliance Initiatives

The scope and diversity of building industry standards development efforts around the world are vast. Multiple initiatives by numerous organisations are underway, synonymous of the fact that there are many challenges that need to be addressed. Here it is important to

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[210] Lindström, M. & Jongeling, R (2012) *Nationellt Initiativ för Digital Information - För ett bättre samhällsbyggande*, OpenBIM Presentation.

[211] Landin, A. & Lind, H. (2011) Hur står det egentligen till med den svenska byggsektorn? – Perspeciv från forskarvärlden, Kalmar: Lenanders Grafiska.

[212] The Construction Task Force (1998) The report of the construction task force, Rethinking construction (The Egan Report), Department of Trade & Industry, London.

[213] Byggkommissionen (2002) *Skärpning Gubbar!,Om konkurrensen, kvaliteten och kompetensen i byggsektorn*, SOU 2002:115, Fritzes offentliga publikationer, Stockholm, Sweden.

[214] G4C (2008) *Construction Excellence, 10 years since Egan*, Department of Trade & Industry, London.

[215] Statskontoret (2009) Sega gubbar? En uppföljning av Byggkommissionens betänkande "Skärpning gubbar!", Statskontoret, rapport 2009:6.

consider this work in the context of the bigger picture and specifically it's relation to the ongoing efforts and long-term goals of the buildingSMART alliance.

The buildingSMART alliance (previously known as the IAI[216]) has the broad mission to serve as a forum for the coordination of the work of standards development groups and a large number of international research and development projects. It is a neutral international organisation that supports open BIM through the DCO lifecycle.[217] They develop and maintain international standards and technical solutions relating to process and product.

Among the foundational standardisation efforts of the buildingSMART alliance and its worldwide counterparts are the *Information Delivery Manuals* (IDMs) and *Model View Definitions* (MVDs). These are examples of the sector's collective recognition that better information is needed to support the development of better tools now emerging to deliver construction projects.[218] Technologies such as IDM and MVD are intended to help identify exactly what that information is by defining, for example, a model definition view for automated code checking and the information that must be included to generate that view. This is work is ongoing and as such is still a long way off being available for all DCO participants; as is the full capabilities of the *Industry Foundation Classes* (IFC)[219].

One of the aims of this study is to contribute towards the development of IDM's and MVD's by helping DCO players articulate their information needs through the DCO process. However, whilst buildingSMART is largely concerned with technical solutions, this work attempts to present a number of small scale practical interventions that DCO participants can perform to address a number of key challenges.

This study must be viewed in the context of industry initiatives such as that of buildingSMART and whilst much of the integrated technical solutions heralded have still to reach maturity and full mainstream implementation, there is much wisdom to be gained from ideas behind buildingSMART's initiatives which claim to be market-driven.

This study postulates that, notwithstanding the possible technical solutions for construction information management on the horizon, rather than waiting or relying on external agents to sort out internal information management issues, AEC organisations must focus on what they can do, both individually and collectively to embrace BIM. This may include reaching a

[216] International Alliance for Interoperability
[217] http://buildingsmart.com
[218] Smith, D and Tardif, M. (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, John Wiley & Sons.
[219] There has been significant resistance by a number of mainstream software AEC vendors to fully embrace the IFC data standards and resolve the matter of interoperability, for amongst other reasons, to assert and maintain market domination. This has manifested in half-hearted implementations, leading to a dilution of trust for IFC as an exchange format amongst users. However, to date, utilization is increasing by virtue of the need for open standards and improving functionality.

rational consensus for standardised *administrative* and *strategic* BIM protocols. Whilst the long term vision of buildingSMART is an effort in the right direction, immediate operational challenges still loom large. These are the challenges embraced here, and focus on *here and now* solutions whilst aligning with buildingSMART's long term goals.

2.3.2 BIM Alliance Sweden Initiatives

BIM Alliance Sweden is Sweden's branch organisation responsible for promoting the adoption of BIM in the Swedish AEC industry and for coordinating sector and academic research and development relating to BIM and open standards. Originally known as OpenBIM, the organisation merged with buildingSMART Sweden and Föreningen för Förvaltnings Information (FFI) in 2013. BIM Alliance Sweden and its partners recognise that digital structured information implicit in BIM is an extremely important application and development area in the construction sector. Their mission is to work with industry and academia to increase use of BIM and work towards their vision to create a seamless flow of information in the design – construct – operate process.[220]

Selected objectives of BIM Alliance Sweden include:

1) **Standardisation of frequently occurring processes and / or interfaces between them.**
2) **More effective and internationally-based data structures, classifications, concepts, etc.**
3) **Development of standard contract agreement so that issues such as liability for information ownership, access rights etc. are adapted to work.**
4) Increased information security for standard and vendor-independent interface for communication.
5) **Processes for greater participation from stakeholders and customers.**
6) **Tools that stimulates job satisfaction, creativity and knowledge and enable intelligent cooperation between different specialists.**
7) **Better support for "building right from the beginning", an improved process that eliminates or greatly reduces the cost rework.**
8) **Ability to more easily than with today's technology do simulations and investigate options, to ensure that the best solution was chosen, the different decisions.**
9) Industry-wide metrics that provide an opportunity to see the changes and compare themselves with others (for example, regarding life cycle costs).
10) **Tools and methods that provide better means to:**
    a) **Meet user requirements**
    b) Create good architecture
    c) Create good living environments and urban planning
    d) Comply with financial and technical requirements.

[220] http://www.bimalliance.se/om_bim_alliance/vision_och_mal

Those general objectives highlighted align with the specific objectives of this research and thereby seek to contribute towards realisation of BIM Alliance Sweden's strategic vision.

2.4 Push & Pull of BIM Implementation

Encouraging improvements in the efficiency of the construction industry has been the topic of many high-profile reports.[221] The UK Government is one that has applied many performance changing measures through amongst other things, regulation and standards. High on the UK Government's agenda, as public sector client, is a four year strategy for BIM implementation in the construction industry that *'will change the dynamics and behaviours of the construction supply chain, unlock new, more efficient and collaborative ways of working'.*[222] Their ambition is '*to become the world leaders in BIM',*[223] and they are applying a classical *push* and *pull* strategy on implementation. On the one hand (pull) the Government client has mandated delivery of Level 2 BIM by 2016, giving the industry the time to understand requirements and upskill accordingly, and on the other (*push*), it is letting the industry decide how to delivery whilst supporting them with applicable standards, guidelines and protocols to allow them to move forward in a consistent way without distorting the market[224] (Figure 9).

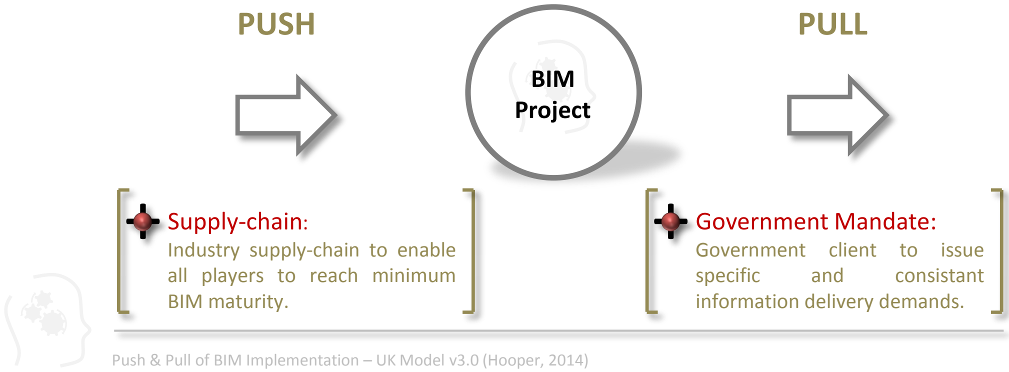

Figure 9: Push & Pull of BIM Implementation

It is postulated here that the UK provides an exemplar model for BIM adoption through its comprehensive strategy which supports the development of standards around specific data drops and information exchanges enabling leverage of the digital asset. In Sweden there is strong evidence of *push* through construction industry initiatives coordinated by BIM Alliance Sweden, and investment and leadership demonstrated by the construction giants (NCC,

[221] G4C (2008), *Construction Excellence, 10 years since Egan*, Department of Trade & Industry, London.
[222] Francis Maud, Minister for the Cabinet Office. Accessible: http://www.bimtaskgroup.org/
[223] Ibid.
[224] BIS (2011) BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper, London.

Skanska, Peab & JM) together with significant resources deployed by the larger consultant organisations (Tyréns, White, Tengbom & FOJAB). On the pull side however, hitherto there has been a rather lacklustre demand from the State and requirements are only now being developed.[225] Furthermore, Samuelson[226] notes that within design consultant organisations the initiative behind BIM adoption appears largely to be bottom-up in orientation, where individuals or groups who are involved in the creation of design material for construction have developed an interest in using smart tools and follow the general development of working methods, software tools and standards. Amongst contractors, however, the lead is coming from management level.

2.4.1 Government Initiatives around the World

The UK, Norway, Denmark, Sweden, Finland, Netherlands, Australia, Singapore, Hong Kong, South Korea, Canada and the US all have some form Government initiative to advance the adoption of BIM in construction (Figure 10). The Government standpoint is that of the construction client and property owner – a large public sector commissioner with a vast stock of facilities needing to be designed, constructed and maintained over facility life times.

In recent years a strong trend has emerged amongst Governments around the world to press the construction industry into BIM adoption by policy. Convinced by the benefits to them as construction clients and the industry itself in terms of productivity and communications efficiency gains, Governments are investing considerable sums in developing not just a BIM vision, but comprehensive requirements and standards to ease delivery. The theory suggests engagement from all levels (bottom-up / top-down); together with a suitable balance of push and pull incentives and common standards are essential to support a full and comprehensive BIM adoption.

[225] Appelgren, R. (2011) *Staten måste ställa krav på BIM*, Byggindustrin, Oct 2011.
[226] Samuelson, O. (2010), *IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium,* Hanken School of Economics, Helsinki.

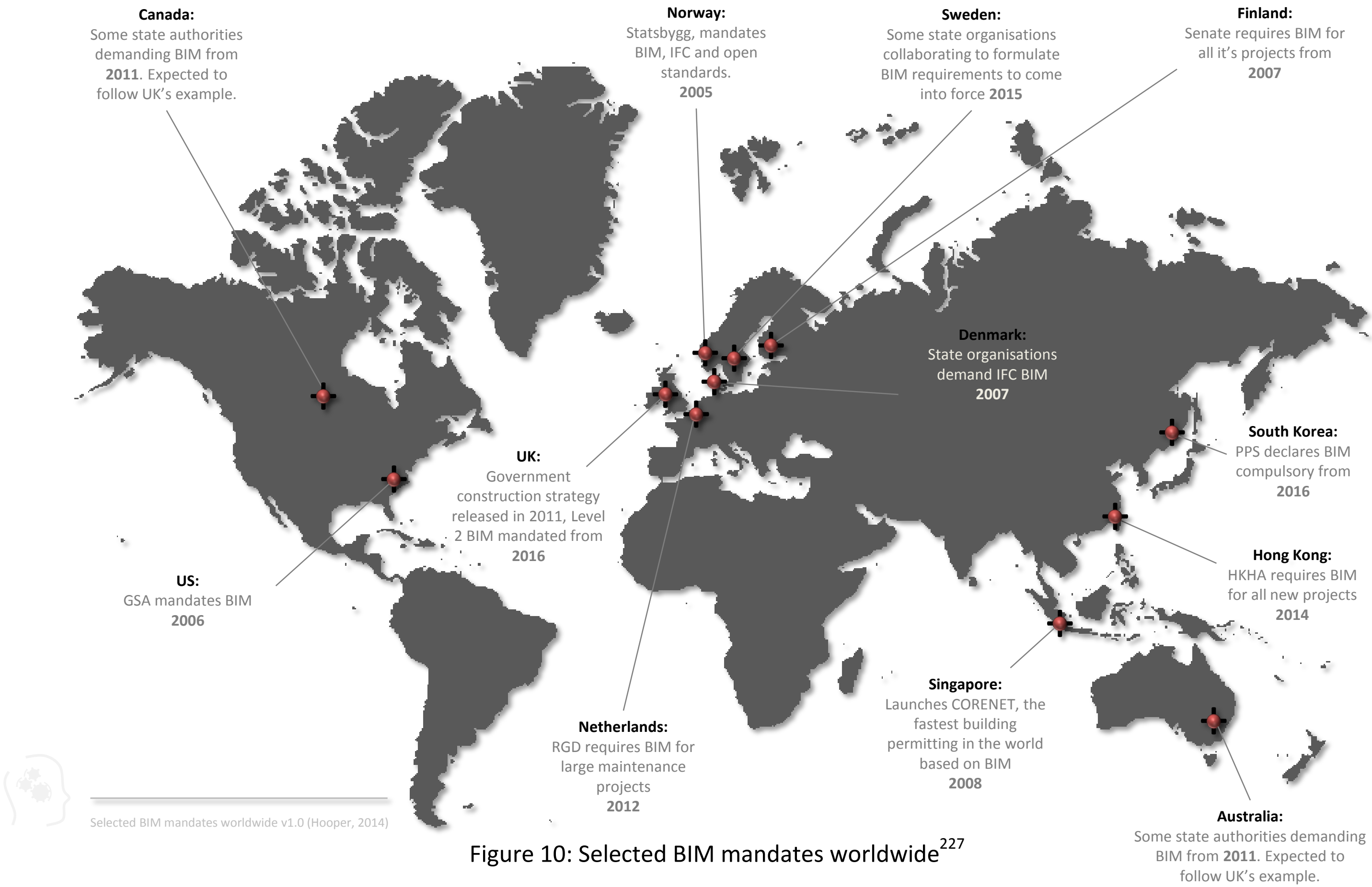

Figure 10: Selected BIM mandates worldwide[227]

[227] Information adapted from: http://geospatial.blogs.com/geospatial/2013/07/widespread-adoption-of-bim-by-national-governments.html

2.4.2 Policy Stages and Level of Adoption in Europe

Sweden lies behind its Nordic neighbours and the UK when it comes to BIM policy development and supporting contact documentation including applicable delivery standards (Figure 11). In order not to continue to loose competitiveness in international markets it is essential that BIM is adopted and implemented consistently. This involves identifying and standardising those BIM concepts and processes that are key to avoiding divergence in methodology.

That's not to say that standards don't exist and players are just making their way blindly. There are a number of organisations in Sweden that are leading world and have produced a number of exemplar projects using BIM technology and appropriate methodologies. But there are also a lot *just making rules up as they go along a*nd still some who think BIM is just 3D visualisation on steroids. Players need help to get the best out of BIM, not just to leverage small scale organisational benefits but more importantly to enable teams to do the best for the project. Standards are required beyond office boundaries and must be applied consistently to entire projects through not just design or construction, but the complete lifecycle to FM, refit and decommissioning.

Finland and the UK are amongst the early birds in developing both BIM policy and standards to support adoption. Further the UK has come from nowhere. The UK Government BIM mandate together with updates and extensions to British Standards (BS1192)[228,229] the RIBA plan of work[230] and new digital services from the NBS[231] has launched BIM adoption into the mainstream and organisations are well equipped to meet demand. The Fins, with their smaller more agile construction industry have their COBIM 2012 requirements[232] based on the Senate Properties Guidelines and have emerged as the unlikely world leader.[233]

So where is Sweden? And where does it want to be? After a call for state support,[234] initially five state organisations; Akademiska Hus, Specialfastigheter, Riksdagsförvaltningen, Fortifikationsverket & Statens Fastighetsverksomhet, pledged to start working together to formulate common BIM Requirements in October 2012. Since then, the Swedish Transport Authority (Trafikverket), one of Sweden's largest public sector construction clients

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[228] BSI (2013), *PAS 1192-2:2013 - Specification for information management of the capital delivery phase of construction projects using building information modelling*, British Standards Institution, London: BSI.

[229] BSI (2014). *BS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling*, British Standards Institution, London: BSI.

[230] RIBA (2013b), *RIBA Plan of Work*, RIBA Publications, London.

[231] http://www.nationalbimlibrary.com/

[232] COBIM (2012), *Common BIM Requirements*, V.1.0, Finland: COBIM Project.

[233] WSP & Kairos Future (2011), *Ten truths about BIM – The most significant opportunity to transform the design and construction industry*, WSP & Kairos Future, Stockholm, Sweden.

[234] Appelgren, R. (2011) *Staten måste ställa krav på BIM*, Byggindustrin, Oct 2011.

responsible to infrastructure projects[235], has joined them in developing requirements in collaboration with industry experts that will be applicable on their projects from 2015. The aim is to save cost and leverage the digital asset for operation and maintenance.[236] The intention is that other public sector clients will follow suit. However a full Government mandate and a comprehensive set of branch standards to support these requirements is wanting.

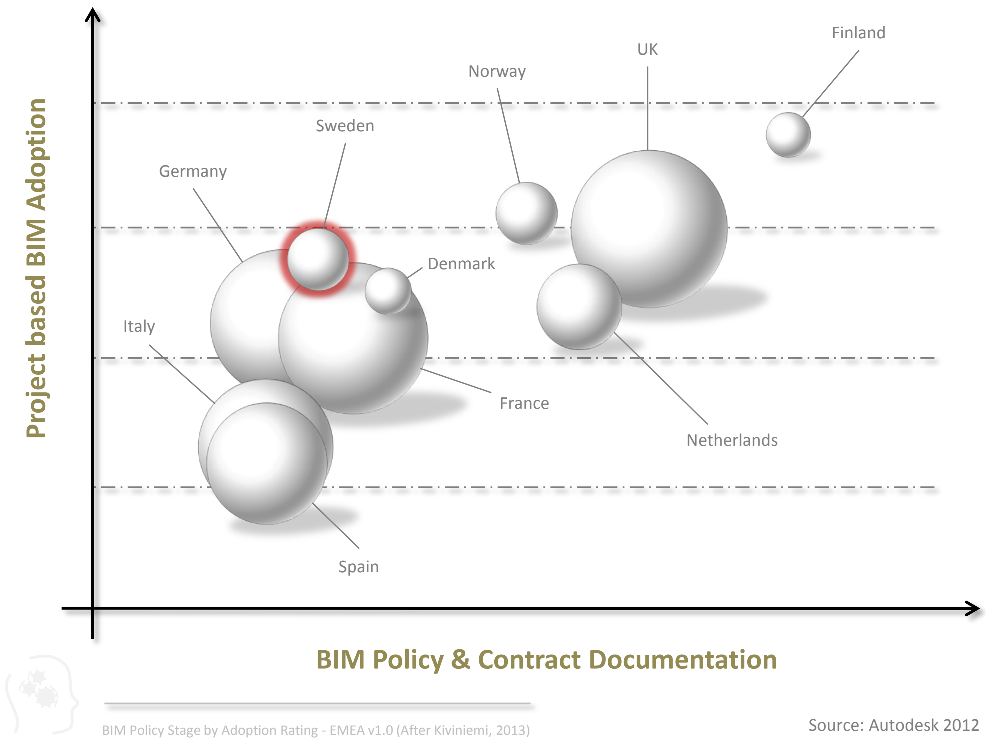

Figure 11: BIM Policy Stage by Adoption Rating (After Kiviniemi, 2013)[237]

Since the start of this research much as moved on in terms of BIM policy and adoption. Organisations have accepted the pain of the climb from a traditionally stubborn industry (mediocrity), through a developed understanding of the tactical value of BIM (difficulties), towards potential for success with some state organisations now demanding BIM (Figure 12). Sweden is under pressure to raise its game, and with incremental mandates now

[235] Including: roads, railways and bridges.

[236] BIM Alliance Sweden (2014), Info Blad: *Gemensamma kravnivåer på BIM hos statliga aktörer.* Available at: http://www.bimalliance.se/~/media/OpenBIM/Files/Infoblad/Gemensamma_kravnivaer_pa_BIM_hos_statliga_aktorer.ashx

[237] Kiviniemi, A. (2013) *Public Clients as the Driver for BIM Adoption – Why and how the UK Government wants to change the construction industry*, Presentation to the OpenBIM Conference, Stockholm, April 2013.

materialising, we should start building and optimising BIM implementation routines and associated standards with some urgency. Judging by benefits reaped by other industries, the rewards of adopting a process improvement framework implied by BIM may be too great to ignore or postpone.

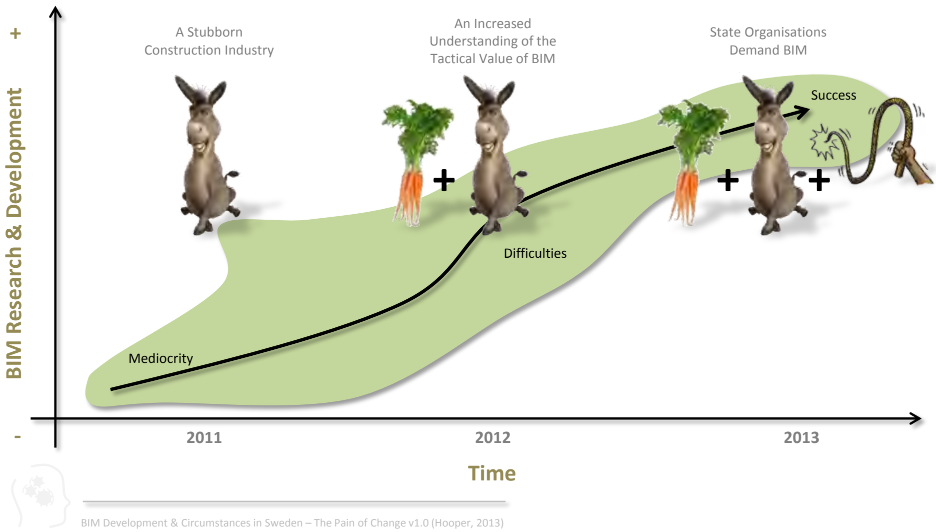

Figure 12: BIM Development & Circumstances in Sweden – The Pain of Change

2.5 BIM Standardisation Needs

2.5.1 Standards

Standards are critical for information organisation and flow in construction.[238] The topic of standards is wide and often not given the prominence it deserves.[239] It can be applied to all international, regional and national normative documents, such as standards, technical reports, standardised profiles, technical specifications, technical regulations, guides and codes of practice.[240] It is widely accepted that adoption of standards in IT leads to creating, using and maintaining information in a far more effective way – and is a necessary prerequisite to collaborative BIM.[241]

[238] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport,* Stockholm, Sweden.
[239] Race, S. (2012), *BIM Demystified*, London: RIBA Publishing.
[240] ISO (2005), *International Classification for Standards*, 6th Ed., Switzerland: ISO
[241] Race, S. (2012), *BIM Demystified*, London: RIBA Publishing.

According to Ekholm et al[242] standards in IT can be categorised into *Data Model*, *Concept* and *Process* standards (Figure 5) and an outline of existing standards are presented in Tables 2, 3 & 4. However, there are many standards relevant to BIM, not just those that aim to address the single building model.[243] Examples include the UK's BS 1192:2007[244] and its extensions PAS 1192-2[245] and PAS 1192-3[246] linked up with the new RIBA Plan of Work[247], Responsibility Matrix (CIC)[248], and the National BIM Library[249] tools and resources with standardised content. But international implementations need to be tailored for local cultures and conditions,[250] and equivalent national branch standards applicable in the Swedish AEC sector are missing or lacking official endorsement. Instead diverse corporate standards are emerging coupled with ad hoc quick-fix solutions.[251] These shortcomings have resulted in widespread call for a systematic review of branch standardisation needs related to the use of BIM in practice.[252,253,254,255]

2.5.2 Levels of Standardisation & Effect on Competition and Innovation

Standards are published and can be applied at 3 different levels being: *International Standards*, *National Standards* (including sector / branch standards), and *Corporate Standards* (potentially incorporating company secrets). Similarly the level of compulsion to adhere to them can vary from *must do* to *recommendations.*

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242 BIM Alliance Sweden (2011), Info Blad: *Gemensamma standarder krävs inom BIM-området*. Available: http://www.bimalliance.se/~/media/OpenBIM/Files/Infoblad/Gemensamma_standarder_kravs_inom_BIM-omradet.ashx

243 Howard, R. & Björk, B-C. (2008), *Building Information Modelling – Experts views on standardisation and industry deployment*, Advanced Engineering Informatics, 22 (2008) 271-280.

244 BSI (2007), *BS 1192:2007 - Collaborative production of architectural, engineering and construction information - code of practice*, British Standards Institution, London: BSI.

245 BSI (2013), *PAS 1192-2:2013 - Specification for information management of the capital delivery phase of construction projects using building information modelling*, British Standards Institution, London: BSI.

246 BSI (2014). *BS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling*, British Standards Institution, London: BSI.

247 RIBA (2013b), *RIBA Plan of Work*, RIBA Publications, London.

248 CIC (2013), *Building Information Model (BIM) Protocol*, Construction Industry Council, London.

249 http://www.nationalbimlibrary.com/

250 Howard, R. & Björk, B-C. (2008), *Building Information Modelling – Experts views on standardisation and industry deployment*, Advanced Engineering Informatics, 22 (2008) 271-280.

251 Jongeling, R., Lindström, M., Samuelson, O. (2013), *BIM Special – Dags att fokusera på standardiseringen*, Byggindustrin 30/2013.

252 Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport,* Stockholm, Sweden.

253 Jongeling, R., Lindström, M., Samuelson, O. (2013), *BIM Special – Dags att fokusera på standardiseringen*, Byggindustrin 30/2013.

254 BIM Alliance Sweden (2011), Info Blad: *Gemensamma standarder krävs inom BIM-området*. Available: http://www.bimalliance.se/~/media/OpenBIM/Files/Infoblad/Gemensamma_standarder_kravs_inom_BIM-omradet.ashx

255 Hindersson, P. (2013), *BIM-Standard Behövs*, Byggindustrin 6/13. Available: http://byggindustrin.se/artikel/nyhet/%C2%94bim-standard-beh%C3%B6vs%C2%94-18767

A traditional perception is that standardisation hinders innovation and competition.[256] However, there is also evidence to support that standardisation, if defined and applied under particular conditions, for example, openness of the standardisation process and broad stakeholder participation, actually promotes innovation.[257] There are pros and cons to standardisation. Linderoth[258,259] warns us that we should not get locked into insisting on so-called *best-practice*, which might in the long run turn out to be the worst practice. Implying that those who stick to today's best practices are likely to be tomorrow's losers. Rather, players should feel the way forward with caution and be flexible. Standards can contribute to *lock-ins* into particular technologies that may become inferior over time.[260] Therefore their positioning and scope must be controlled by suitable framework conditions.[261]

Standards have different purposes and / or aspects. Swann and Lambert[262] highlight standards can be informative (eg. codified knowledge) whilst others constraining (eg. health and safety), typically a set of standards contains a mix of both information and constraints. They observe that those firms which use standards as an information source for innovation and which are constrained in their innovation activities by regulations are very innovative. Obviously, those firms are efficient in squeezing information from standards and successful in overcoming these constraints by regulations.[263]

CIFS (2011)[264] argues that we need standard solutions in order to be innovative. Further remarking that in a time where we strive for the unique and the remarkable, the term '*standard solution*' implies something grey and boring. Like the word '*routine*', we mostly use it negatively. However, we could not manage without either routines or standard solutions. Without them, we would have to start over each time and our projects would never get off the ground. We need the familiar and well tested. In the context of BIM there is good reason to support standard solutions for without them, we would be unable to create new things and be innovative.

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[256] Swann G. M. P., Lambert, R. (2010), Why do Standards Enable and Constrain Innovation?, 15th EURAS Annual Standardisation Conference "Service Standardization" , University of Lausanne, Switzerland, Jul 1 2010.
[257] Blind, K. (2013), *The Impact of Standardization and Standards on Innovation*, Nesta Working Paper 13/15.
[258] Linderoth, H. (2013). *Ledarskap avgör BIM's Framtid*, Byggindustrin, Issue 13/2013, Stockholm. [Leadership determines BIM's Future] http://byggindustrin.se/artikel/debatt/ledarskapet-avg%C3%B6r-bims-framtid-18901
[259] Jongeling, R., Lindström, M., Samuelson, O. (2013), BIM Special – Huvudet på spiken, Henrik!, Byggindustrin 16/2013.
[260] Blind, K. (2013), *The Impact of Standardization and Standards on Innovation*, Nesta Working Paper 13/15.
[261] Ibid.
[262] Swann G. M. P., Lambert, R. (2010), Why do Standards Enable and Constrain Innovation?, 15th EURAS Annual Standardisation Conference "Service Standardization" , University of Lausanne, Switzerland, Jul 1 2010.
[263] Ibid.
[264] CIFS (2011), *Scenario*: March 2011, Copenhagen Institute for Future Studies, Copenhagen, pp41.

2.5.3 Digital Delivery Specification

Definitions of digital information deliverables for specific BIM-Uses still remain something of puzzle in practice today. Too much guess-work still exists and as such BIM information deliveries could be better organised and potentially standardised. *Construction Documents 90* (Bygghandlingar 90)[265] outlines the concept of *Leveransspecifikationer* (Digital Delivery Specifications) but it remains a somewhat abstract idea and concrete examples are lacking. This guide recommends the use of delivery specifications to accompany exchanges in digital information at all stages of the design, construct and operate process and has some parallels with buildingSMART's process standard *Information Delivery Manual* (IDM).

The Swedish organisation Föreningen för Förvaltningsinformation (FFI) (now part of BIM Alliance Sweden) has developed a form of *Leveransspecifikationer* specifically for enabling standard delivery of information for FM purposes. The result is a plug-in tool that can extract model content (from presumably an as-built record model) in the form of drawings, models, calculations etc in fi2xml format. A limiting feature of this development is that it is not designed as a collaboration tool to enable BIM information content authors (Architects and Engineers) to align information content requirements against planned BIM-Uses.

Ekholm highlights that existing IDM's are few and are not yet in practical use.[266] It is therefore suggested that the concept and application of *Digital Delivery Specification* needs developed to address here and now problems with information exchange and model authoring to help align information delivery expectations and to offer the control, confidence and simplicity necessary for a more effective information exchange process to be realized.

2.5.3 Classification

Classification is about the need to *put the right information in the right place*. Construction classification is one of the most fundamental and important standards in the AEC sector. It is particularly important in a BIM context where the model is to be used for its intelligence such as automated code checking or quantity take-off. If objects are miss-classified or unclassified, they will be useless to downstream users and uses. Classification systems enable organisation of construction project information into views, for example, building parts, activities or production results. Standardisation of information, such as its classification, is essential to proper leverage of information within a BIM project.[267] The information contained in models must be universally understandable and accessible; otherwise it is useful

[265] SI, Swedish Standards Institute (2008*), Bygghandlingar 90: byggsektorns rekommendationer för redovisning av byggprojekt. D. 8, Digitala leveranser för bygg och förvaltning*, Stockholm : SIS Förlag AB.
[266] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport,* Stockholm, Sweden, pp.19.
[267] Weygant, R. (2011), *BIM Content Development: Standards, strategies and best practices*, John Wiley & Sons: New Jersey.

only to the individuals who populated the model with that information. A standard taxonomy of construction and design terms allows information to be exchanged with the knowledge that it will be understood by others.

The international standard for building classification is manifested in SS-ISO 12006-2. This standard is reflected in the Swedish BSAB 96 building classification system as well as a number of other more internationally well-known systems like OmniClass.[268] Since the advent of BIM, formats are being developed that lend themselves to use within BIM modelling platforms. OmniClass for example, has a series of formats and standardised tables that allow information captured within a model to be organised to its simplest level and cross-referenced in a variety of ways. Certain difficulties have been voiced regarding the use of BSAB classifications in BIM projects in Sweden, which has resulted in discreet auxiliary methods of identifying objects (tagging) critical for automated cost estimation.[269]

Application or assignment of BSAB building parts codes in a BIM environment, for example, is problematic. However, recent findings suggest that the Swedish BSAB construction classification does have the capacity to sustain information flow from design through to operations if supported and extended by a PLM system (Product Lifecycle Management).[270,271] Still, significant overspend on construction is shown to be attributed to misinterpretations and misunderstandings associated with deficiencies in construction classification and its application.[272] An overhaul of the Swedish BSAB 96 building classification system is recommended to better support information organisation and structure in a BIM environment. Proposed amendments include supplementation of BSAB codes, additional tables and definitions which may enable a common language to be uniformly adopted.[273]

2.5.4 Interoperability

No single computer application can support all the tasks associated with building design, production and FM.[274] For this reason applications must be able to import and export data (ideally seamlessly) to allow data about a building to be used intelligently downstream. Interoperability depicts the need to pass data between applications, allowing multiple types of experts and applications to contribute to the work and flow of design, construction and

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[268] OmniClass Construction Classification System (OCCS)
[269] OpenBIM (2011), *OpenBIM effektiviserar bygg- och förvaltningsprocesserna*, OpenBIM Seminarium, Stockholm.
[270] BIM Alliance Sweden (2013), Infoblad: Bättre informationsflöde I BIM med BSAB-systemet. Available: http://www.bimalliance.se/~/media/OpenBIM/Files/Infoblad/Battre_informationsflode_i_BIM_med_BSAB-systemet.ashx
[271] Hindersson, P. (2013), *Bra BIM kräver fritt flöde av information*, Byggindustrin, 14/2013. Available:
[272] Dahlberg, H. et al. (2013), Slutrapport Fokus I – BIM med BSAB, Kvalitetssäkrad informationshantering i bygg- och förvaltningsprocessen. Available: http://byggtjanst.se/globalassets/aktuellt/fokus-i/slutrapport-fokus-i-bim-med-bsab.pdf
[273] Ibid
[274] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2008), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, London: John Wiley & Sons.

operations digital information. Poor interoperability continues to be an enormous burden to the industry.[275,276] However, data model standards have improved thanks to the work led by the ISO-STEP international standards effort. Today, one of the main building product data models are the Industry Foundation Classes (IFC) which can handle data for building planning, design, construction through to FM. IFC can represent geometry, relations, processes and material, performance, fabrication and other properties needed for design and construction.

Functioning interoperability imposes a new level of modelling rigor that organisations still need to get to grips with. Objects require to be modelled with the correct tools, labelled in the correct and consistent manner, display correct and appropriate properties and have the correct relationship to other objects.[277] In practice this demands a whole new level of attention to detail, standards, classification and model development methodology when authoring and leveraging data from the digital model.

There are many ongoing debates over the use and reliability of IFC in which the competence level of users and incomplete software implementation are significant hindering factors. In attempt to circumnavigate interoperability issues and at least temporarily side-step the frustration of non-interoperability (Figure 13), clients have been known to insist on the use of particular software platforms to enable consistent use of native formats. Whilst a high level of interoperability is desirable and indeed high priority to enable teams to foster a culture of information stewardship, it remains a technical problem that AEC players cannot solve themselves.

[275] Gallaher, M., O'Connor, A., Dettbarn, J., and Gilday, L., (2004), *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*, NIST GCR 04-867, Gaithersburg, MD.

[276] Bynum, P., Issa, R. & Olbina, S. (2013) Building Information Modeling in Support of Sustainable Design and Construction, *Journal of Construction Engineering and Management,* Vol. 139, pp24-24, ASCE.

[277] Björk, B-C., (2008), Interoperability in Practice: Geometric Data Exchange Using the IFC Standard, ITcon Vol.13 (2008).

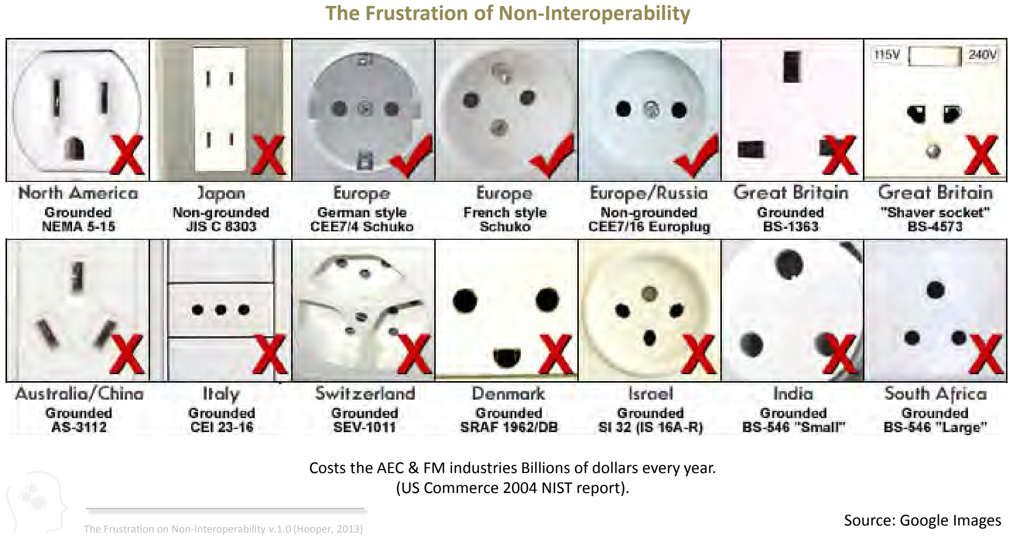

Figure 13: The Frustration of Non-Interoperability

2.6 BIM as Socio-Technical System

The notion of the socio-technical system was created in the context of labour studies by the Tavistock Institute in London at the end of the 1950's.[278] It was established to stress the reciprocal interrelationship between humans and machines and to foster the program of shaping both the technical and the social conditions of work, in such a way that efficiency and humanity would not contradict each other.[279] The idea of socio-technical systems was designed to cope with the theoretical and practical problems of working conditions in industry.

A report commissioned by WSP[280] and carried out by Kairos Future[281] proposes that BIM is a typical example of socio-technical system. It is a *system* because it could be described as a unified entity consisting of many interacting parts, some physical, and some soft, and *socio-technical* because it has social components, complementing the technical core (Figure 14).[282]

[278] Emery, F. E. & Trist, E.L. (1960), *Socio-technical Systems*, Management Sciences Models and Techniques, vol. 2. London.
[279] Ropohl, G. (1999), Philosophy of Socio-Technical Systems, *Society for Philosophy and Technology*, Vol.3, Issue 3.
[280] WSP is a global construction consultancy firm: http://www.wspgroup.com/
[281] WSP & Kairos Future (2011), *Ten truths about BIM – The most significant opportunity to transform the design and construction industry*, WSP & Kairos Future, Stockholm, Sweden.
[282] Ibid.

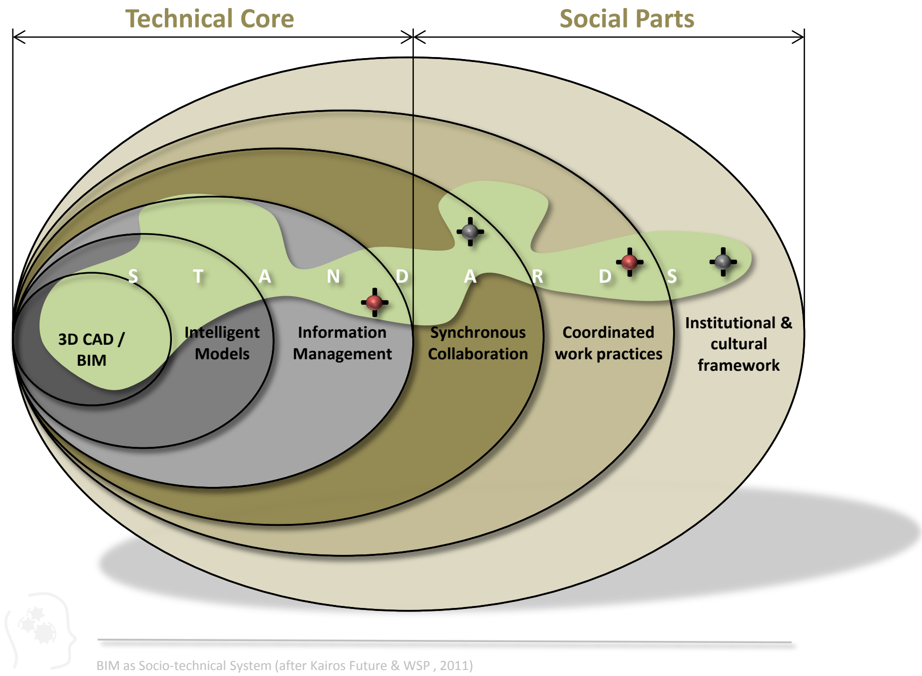

Figure 14: BIM as a Socio-technical System (after Kairos Future & WSP, 2011)

The new social and cultural institutions implied with BIM implementation are both interesting and important areas to consider, and viewing it as a socio-technical system may offer clues as to how adoption can be integrated within AEC society efficiently. Standards, as in other socio-technical systems, will come to have significant bearing on the behavioural aspects of the new working practices associated with BIM and ultimately on the success levels of implementations.

Certain observations and predictions can be made about socio-technical systems as they tend to develop along similar paths.[283] 1) Those with an under-developed view of BIM will focus on software and on its most obvious feature: 3D modelling. Soon this develops into an appreciation of intelligent models and information management it makes possible. However a social-technical gap exists. 2) Once society moves beyond the software and realise there is a lot more to BIM than its technical core, working practices take shape expanding possibilities towards collaborative working supported by standards. 3) Industry acceptance of the new system (technical and social parts) enables realisation of promised benefits through practice evolution. The new system implies dismantling the old, it is therefore the responsibility of innovators to point out the deficiencies of the existing.[284]

[283] Whitworth, B. (2006), *Socio-Technical Systems*, Encyclopedia of human computer interaction.
[284] WSP & Kairos Future (2011), *Ten truths about BIM – The most significant opportunity to transform the design and construction industry*, WSP & Kairos Future, Stockholm, Sweden.

On methodology:

"We must revisit the idea that science is a methodology and not an ontology." (Deepak Chopra)[285]

3.0 Research Methodology

This chapter details the methodological decisions made and later implemented. A description of the practical process and overall design of the research are presented together with a scientific rationale. It covers approach – the manner in which the problem (cognitive and practical) is tackled, and the strategy adopted to collect evidence and extract findings. A particular research design has been developed for this study which is not just social research or technological research, it is both. It concerns people and technology.

3.1 Research Project Workflow

This research project has been an exploration into the advancement of BIM adoption, standardisation needs and support systems, with a focus on the design management domain. During the course of the project, knowledge has been built up and the detailed plans for how and what studies to conduct has been finalised as the project progressed. Consequently the research strategy and specific methods deployed have been decided based on the continuous build-up of results and knowledge about BIM standardisation needs and support systems. Nevertheless, looking at each part of the research, the general workflow applied to each study aligns demonstratively with the conventional research workflow described by Robson,[286] being organised under formal steps: plan, do and reflect (Figure 15).

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[285] Deepak Chopra (b.1946), American Philosopher

[286] Robson, C. (2002), *Real world research: A resource for social scientists and practitioner-researchers*, 2nd edition, Oxford: Blackwell Publishers.

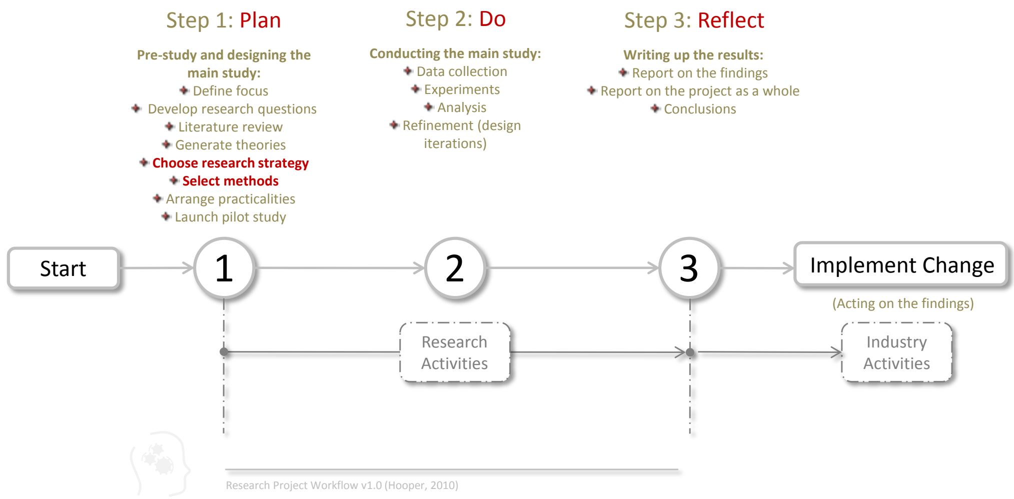

Figure 15: Research Project Workflow (after Robson, 2002)

3.2 Research Approach

All research aims to add to the existing body of knowledge and, depending on the nature of the phenomenon and adopted philosophy, different strategies are appropriate. In this section we consider the options and define the adopted position.

In the research world there are many different ways of perceiving both the research itself and the reality that shall be described or investigated. This has resulted in a number of research methodology guidelines, some of which either partly or wholly oppose each other. For this reason it has been important to consider the problem of selecting the most appropriate research approach from different angles to enable the possibility of describing a plausible picture. The choice of approach should endeavour to lead the research project to the desired result where the probability of obtaining a relevant result is greatest. Saunders[287] describes different approaches of research through 6 levels that can be divided into rings - like an onion – which one can scale off to reveal the core: the actual research. The layers reduce in abstraction level and become more concrete towards the core: philosophy, approach, strategy, application, perspective, data collection & analysis. Figure 16 encapsulates these elements and indicates the chosen route to the core. The methodological decisions within each layer made are subsequently described.

[287] Saunders, M., Lewis, P., Thornhill, A. (2009), *Research methods for business students*, 5th ed., Harlow: Pearson Education Ltd.

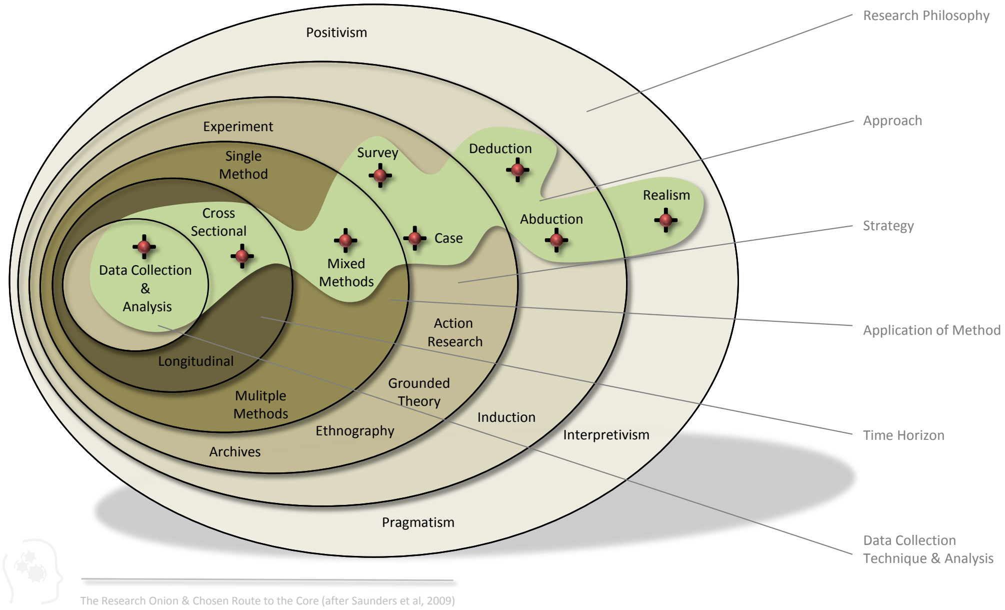

Figure 16: The Research Onion & Chosen Route to the Core (After Saunders et al, 2009)

3.2.1 Philosophy

Research *philosophy* relates to the development of knowledge and the nature of that knowledge. Saunders[288] describes four research philosophies: *positivism*, *realism*, *interpretivism* and *pragmatism*. Here we briefly describe each possibility in turn and postulate a philosophical stand point based on the nature of the study and contextual circumstances.

Positivism views the world through an objective lens. It is based in natural science and has a functionalistic perspective, concerned with material things that exist independently of human cognition. The positivist attempts to find general claims to predict and control outcomes.[289] The subjective view of the world correlates to the interpretivist. Proponents claim the world to be socially constructed, where each phenomenon is unique and knowledge is created from interaction amongst individuals. A third way of viewing the world embraces an objective and subjective reality, which is represented by a realistic perspective. Pragmatism considers all views and adopts a varied ontology, epistemology and axiology best suited to the task in hand.

[288] Saunders, M., Lewis, P., Thornhill, A. (2009), Research methods for business students, 5th ed., Harlow: Pearson Education Ltd.
[289] Guba, E.G. & Lincoln, Y.S. (1994), *Competing paradigms in qualitative research*, In: Denzin, K. & Lincoln, Y.S (eds.) Handbook of Qualitative Research, Thousand Oaks, California: Sage.

Figure 17 illustrates different views of the world (ontology), the nature of knowledge (epistemology), and the role of values in research (axiology) and their relative positions. Interpretivists believe the impact of context and individual's values on research results to be significant, whereas positivists do not.

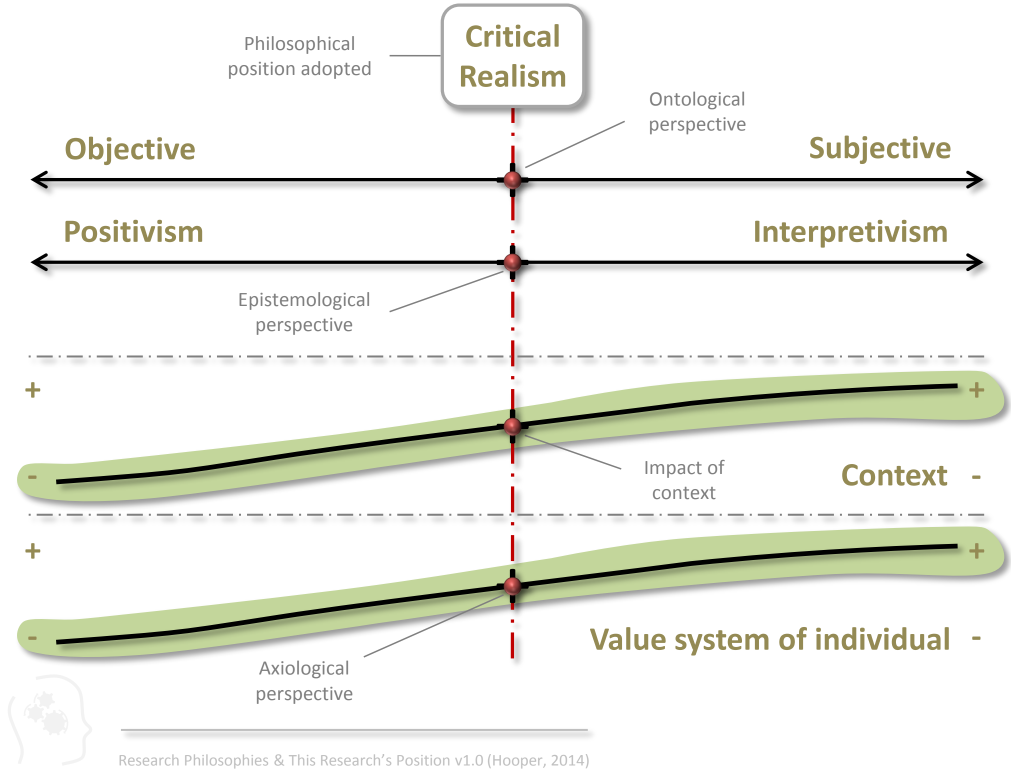

Figure 17: Research Philosophies & This Research's Position

Since the purpose of this work is to contribute towards the existing body of knowledge that may inform the shaping of the standardisation of the construction industry's production information practice processes and organisation, the general philosophy adopted is realistic. Furthermore, realism is seen as particularly appropriate for research in practice and value-based professions[290] such as Architecture and Engineering in the construction industry. Realism's ontology and epistemology lies in the middle ground (Figure 16) and of the various forms of realistic perspective, *critical* appears the preferable for the purposes of this study.

[290] Robson, C. (2002), *Real world research: A resource for social scientists and practitioner-researchers*, 2nd edition, Oxford: Blackwell Publishers.

Critical realism as used by Bhaskar,[291] provides not only a third way between positivism and interpretivism, it also help fulfil the emancipatory potential of social research.[292]

Overall, the philosophical disposition adopted can best be described as critically realistic with aspects of pragmatism. Critically realistic because it is important to not loose objectivity and strive towards generalizability. Pragmatic because it is important to maintain focus on the research questions and purpose and utilise methods and strategies that best contribute to the answer.

Regarding axiology (the researcher's view of the role of values in research), *realism* acknowledges that the researcher may be influenced by world views, cultural experiences and upbringing. Assuming a realistic line on this philosophical aspect allows for certain influences of the researcher's experience as Architect and design consultant information manager to be acknowledged, it acknowledges the researcher's *self.*[293]

3.2.2 Approach

The approach that is selected for the specific research project often is connected to the question of research philosophy. A popular approach is to start from existing theory then formulate hypothesis to test and verify. This suggests a *deductive* approach. A deductive approach implies the research happens in sequence: theory – data collection – analysis. Alternatively an *inductive* approach occurs through a sequence of data collection – analysis – theory. The goal here is theory building and data is collected merely with an understanding of the studied phenomena. Analysis is done through seeking patterns within the collected data and developing, for example, categorisations that can form a base for a new theory.[294] Deduction tests a theory whilst induction builds a theory.

Since the goal here is to build on existing knowledge by testing propositions / hypothesis based on theory that may point towards answering the research questions it can be concluded that the logical approach be deductive in nature. Notwithstanding, aspects of *abductive* reasoning is also applied to allow for exploration and leverage of both theoretical and empirical data as the work progressed (Figure 18).

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[291] Bhaskar, R. (2008), *A realist theory of science*, Oxon: Routledge.

[292] Robson, C. (2002), *Real world research: A resource for social scientists and practitioner-researchers*, 2nd edition, Oxford: Blackwell Publishers.

[293] Hooper (the researcher) is a British Architect with 10 years practice experience, currently undertaking research on BIM standardisation needs and support systems with a focus on the Swedish construction industry and the design (information) management domain.

[294] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.

3.2.3 Strategy

The next layers in Saunder's research onion deals with the matter of selecting a suitable research strategy or strategies and their possibility to be combined. There is a broad range of scientific methods available including *action research, grounded theory, ethnography & archives*. They are closely related to the type (quantitative / qualitative) of data sought to shed light on the problem, and have strict demands on the way the data is collected and can be used. Grounded theory for example, requires that the researcher must abandon a certain amount of existing knowledge on the matter and start from the ground. Glaser and Strauss[295] go so far to suggest that if adopted, one can never return to a research area that one earlier studied. Such a criterion demands a certain degree of knowledge waste and as such not suitable for this research project.

Experiment, *survey* and *case* approaches may all be suitable methods here and indeed can be mixed to form a triangulation of data. However, *experiment* with its origins in natural sciences, is most often adopted in connection with research in the physical sciences and are largely limited to the measurement and recording of actual behaviour in laboratory. They generally do not include the systematic use of survey or verbal information.[296] *Survey,* whilst ideal for collecting quantitative statistical data, would not function well in addressing research questions 1-4, however may be suitable for dealing with research question 5. Finally, there is the *case* method. The *case* study approach works best when the research project involves an investigation into an issue in depth and seeks to provide an explanation that can cope with the complexity and subtlety of real life situations.[297] It lends itself to the study of processes and relationships within a particular setting and facilitates the use of multiple methods of data collection necessary to underpin the results.

With a *case* approach one can study in depth an occurrence, activity, process and / or individual – ideal for research work within the field of IT in the construction industry which is concerned with people, technology and processes. Furthermore, since the construction industry from an AEC perspective is project-based, the *case* method lends itself to both discovery led and theory lead research based on investigation of case projects. Against the background of possible strategies, it is therefore deemed most appropriate to adopt a *case* study approach to tackle the main research questions central to this study. The data required to shed light on these questions is largely qualitative and a case strategy enables the collection of such data. The *case* method has been chosen for its capacity to find

[295] Glaser, B.G. & Strauss, A.L. (1967) *The Discovery of Grounded Theory: Strategies for Qualitative Research,* New Jersey: Transaction Publishers.
[296] Yin, R. K. (2003), *Case Study Research: Design and Methods* (Applied Social Research Methods), Third Edition, London: Sage Publications.
[297] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.

explanations to the complex circumstances that prevail between the study's objects and their connection: building information modelling, strategic planning, information exchange, etc. This single method together with the utilization of a variety of data collection sources has provided the backbone to address research questions 1-4. Further, Easton[298] argues that critical realism is an ideal match for case studies since events, entities, structures and mechanisms act as a guide for how one relates to and understands the world.

For the final paper however, which sought to capture population views on the value and contribution of ongoing BIM standardisation initiatives and research efforts, a quantitative method using a survey questionnaire was chosen. This allowed for the collection of data that enabled a presentation of a broad picture of the current views on BIM standardisation and research efforts using a sample of known national academic and industry experts in the field. The purpose here was to seek to legitimise current work which may be better supported by survey and secondly to triangulate findings from the case studies and so validate them in different contexts.

3.3 Research Design

The research design has been flexible from the start to enable a framework of reference to emerge, refinement of research questions and focus to surface, and interim results to build upon one another. This research was initiated from a tentative research funding project description[299] which led to an analysis of industry needs[300] and broad literature review. The initial literature review highlighted gaps and facilitated formulation of the preliminary research questions which were developed and refined through the research project, taking consideration to incremental findings. Case studies were used in papers 1,2 & 4, to *explore* (find out what is happening; to seek new insights; to ask questions and assess phenomena in a new light)[301] and investigate respective research questions. These papers present successive propositions which are tackled using particular units of analysis and research rationale. Paper 3 seeks explanations and uses documents and focus group interviews as empirical evidence. In the 5th paper a survey was used to help validate previous findings and improve the understanding of BIM standardisation needs. The overall design assumes a cyclical form where each stage or cycle includes literature review and empirical data collection, conducted through workshop-interviews, semi-structured interviews, observations, documents, and in the 5th paper, a questionnaire (Figure 18).

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[298] Easton, G. (2010) Critical realism in case study research, *Industrial Marketing Management*, Vol.39, Issue 1, pp.118-128.

[299] Ekholm, A. (2009), *Information systematic, BIM lab and pilot implementations – Project Description, PhD Funding Application to SBUF & Formas*, Lund University, Sweden.

[300] See Note #1: An Analysis of Industry Needs, pp.132

[301] Robson, C. (2002), *Real world research: A resource for social scientists and practitioner-researchers*, 2nd edition, Oxford: Blackwell Publishers.

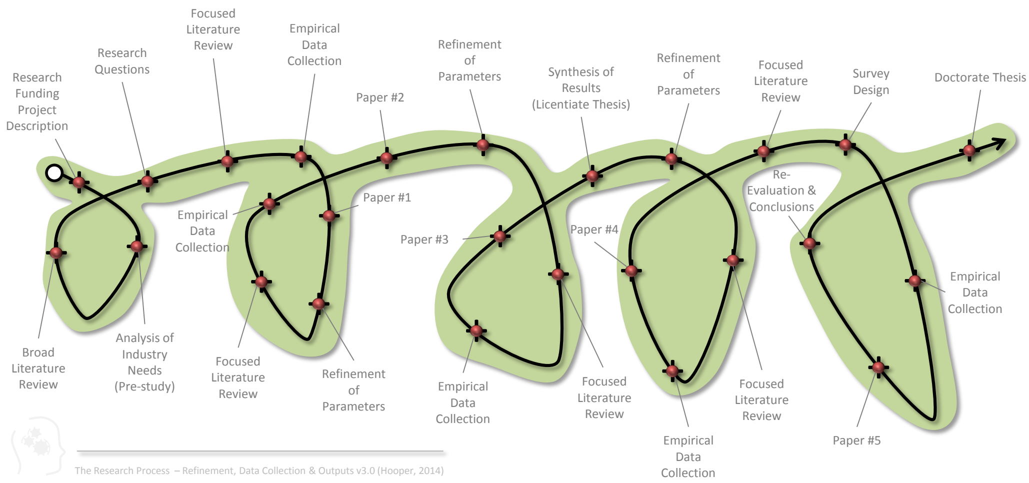

Figure 18: The Research Process – Refinement, Data Collection & Outputs

3.4 Literature Search Strategy

Before launching into the process of collecting relevant literature, for example scientific articles, on the subject or field of reference, it is recognised good scientific practice to consider and implement a project-specific scientific information management plan from the outset. Figure 19 sets out the process adopted here including steps and activities.

Adopting such a process on the one hand demonstrates good scholarly discipline, scientific rigor and can serve to support research results built on findings from others; and on the other, makes the process of keeping track, accessing and referring to other research and literature sources both manageable and convenient, and furthermore helps avoid re-work.

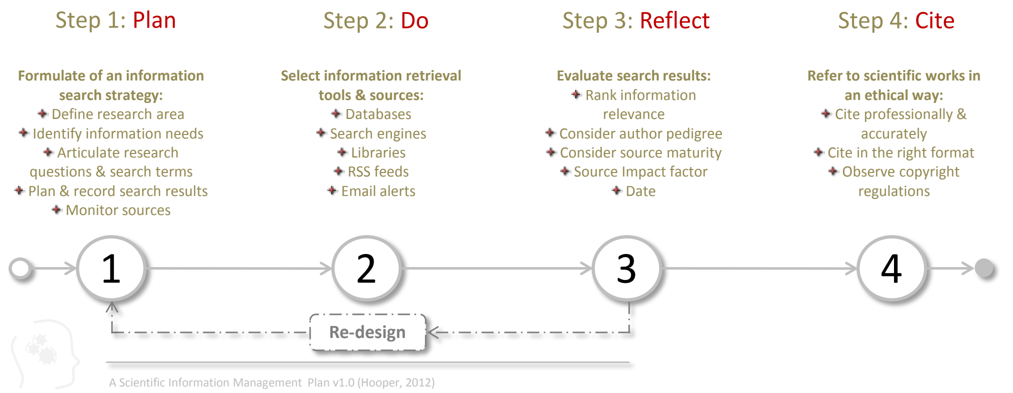

Figure 19: Scientific Information Management Plan

3.4.1 Step #1: Formulation of an information search strategy

To establish an information search strategy, as opposed to randomly searching, one must first outline information needs, often derived through a distilled definition of the research area. A clear purpose behind the information search is also important together with an idea of expected results. To enable a search strategy to be set in motion, tentative research questions (later refined into those found in Chapter 1, Introduction) were drafted and condensed into expressions, then reduced to keywords (search terms). Similar keyword searches where applied to a variety of databases, search engines and library search tools and include:

- "BIM"
- "Building Information Modelling"
- "Building Information Modelling" AND "Standards"
- "Building Information Modelling" AND "Planning"
- "Building Information Modelling" AND "Contracts"
- "Building Information Modelling" AND "Level of Development"

3.4.2 Step #2: Selection of information retrieval tools & sources

Since the research area carrying the acronym *BIM* is relatively new, it was deemed reasonable to assume that most relevant information pertaining to the field will have been produced within the last 10 years. Nevertheless, the number of research outcomes is rapidly increasing, and keeping up-to-date with the forefront of the research field is challenging.

BIM has connections and implications for a broad range of disciplines in different, but adjoining fields including: Architecture, Construction, Civil Engineering, Information and Communications Technology (ITC). For this reason, it has been deemed necessary to apply a literature search strategy utilising retrieval tools that cover some or all of these fields. Selected information retrieval tools used here include:

Databases:[302]

- Avery Index to Architectural Periodicals (covering Architecture)
- Civil Engineering Database (covering Civil Engineering)
- Compendex (covering Technology)
- ICONDA (covering Construction)
- SciVerse Hub (covering all sciences generally)
- Scopus (covering all sciences generally)
- Web of Knowledge (covering all sciences generally)

[302] All accessible through: http://www.lub.lu.se/

Libraries:

- Lunds Unversitets Bibliotek[303]
    - Summon[304]
    - Lovisa[305]
    - E-journals & E-books
    - Lubito[306]

Other / Web Search Engines:

- Google Scholar (covering everything)

Once specific searches were set up, RSS feeds and email alerts were employed to notify the researcher of the latest articles. Similarly, e-newsletter subscriptions[307] and reference to expert discussions on industry discussion forums,[308] where used. Throughout the searches all references where added to a reference management tool.[309]

3.4.3 Step #3: Evaluation search results

The use of scientific research databases in particular allowed for smart filtering and systematic evaluation of articles, in terms of ranking relevance, author pedigree and source impact factor. Initial searches using a sample of sources produced the results shown in Table 3. Searches started out broad and included *pearl picking*[310] then narrowed down to bring in particular themes of interest and filtering criteria.

[303] http://www.lub.lu.se/
[304] http://lu.summon.serialssolutions.com/sv-SE/
[305] http://lovisa.lub.lu.se
[306] http://lubito.ub.lu.se
[307] Including: AECBytes, BIM Alliance, ENR, Byggindustrin.
[308] BIM Experts, Linked-In Discussion Forum. Accessible: https://www.linkedin.com/groups?mostRecent=&gid=98421&trk=my_groups-tile-flipgrp
[309] Endnote was used in this research project. Accessible: http://endnote.com/
[310] One scans the reference list of particularly important papers to gain awareness of other important papers or information sources.

Search Terms (Keywords)	ICONDA	Compendex	Scopus
"BIM"	73	1402	4027
"Building Information Modelling"	141	31355	5362
"Building Information Modeling"	73	31355	5362
"Building Information Modelling" AND "Level of Detail"	1	565	153
"Building Information Modelling" AND "Collaboration"	11	1468	349
"Building Information Modelling" AND "Contracts"	4	320	124

Scientific Information Management – Search Results v1.0 (Hooper, 2012)

Table 6: Initial search results[311]

3.4.4 Step #4: Referring to other scientific works in an ethical way

Not all, but most reference material was stored digitally[312] together with analytical notes and commentary, all indexed in a reference database as a kind of literature BIM. A deductive approach was adopted in reviewing the literature, in that the literature aided reference to applicable theories, some of which are tested.[313] More on approach is covered in the next chapter. All efforts have been made to cite in an ethical way, using footnotes and the Harvard method of referencing.

3.5 Existing Research in the Field – Organisation & Categorisation

As part of the literature search process, early on it was found necessary to organise the retrieved literature into key categories to enable a structured review model to emerge. Figure 20 presents the chosen categories, scientific papers taking precedence over shades of grey literature.

[311] Limited to publication years: 2000-Current.
[312] In pdf format with notes, all linked to Endnote reference database.
[313] Saunders, M., Lewis, P., Thornhill, A. (2009), Research methods for business students, 5th ed., Harlow: Pearson Education Ltd.

Figure 20: A BIM Literature Review Database – Key Categories

The literature studied includes scientific articles, existing national and international standards and guidelines, BIM related reports such as those published by buildingSMART,[314] BSI,[315] Government bodies and state clients,[316] industry journals,[317] and text books.

Within the scientific papers category, further categories emerged as noteworthy key development areas (Figure 21). Most of today's research in BIM can be assigned to one or more of subcategories: *adoption*; *buildingSMART*; *new roles and responsibilities*; *contracts, procedures & collaboration*; *business benefits*; *applications*; *integrated digital design soultions* (IDDS); or *BIM server* related. Literature retrieved and reviewed were organised accordingly. No attempt has been made to map out the entire current status of BIM in the construction industry, however, utility of particular articles enables insight into what has been done, trends, and identify shortcomings and opportunities for contribution.

[314] http://www.buildingsmart.org/ & http://www.buildingsmart.com/
[315] Such as British Standards & BSI (2010), *Constructing the Business Case – Building Information Modelling*, London: BSI.
[316] Such as: The UK Government & The Swedish Transport Authority (Trafikverket)
[317] Such as: RIBA Journal & Byggindustrin.

The following sub-sections present a series of themed reviews connected to current research developments and impacting on the research under study.

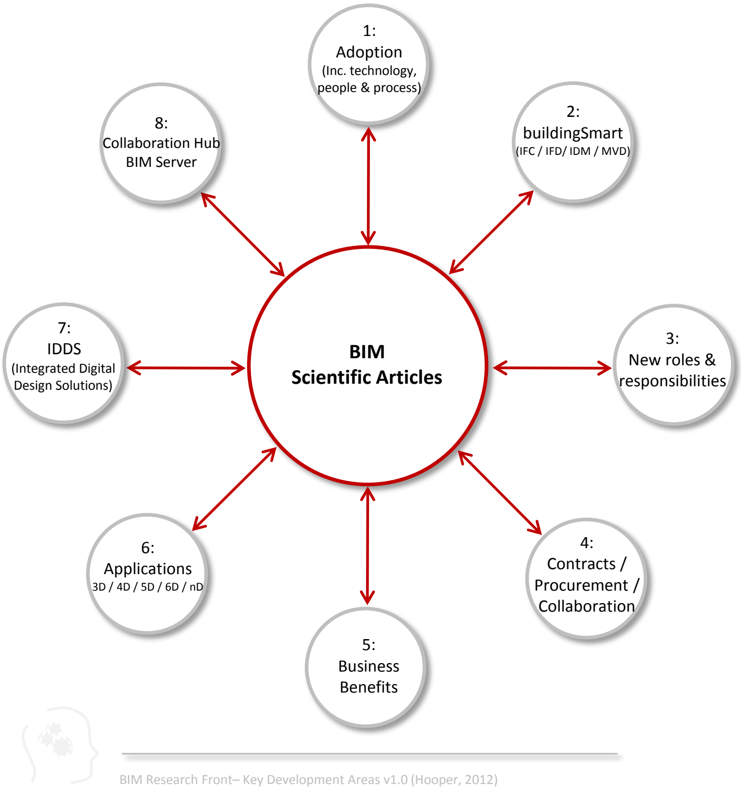

Figure 21: The Research Front – Key Development Areas

3.6 Methods of Empirical Data Collection

3.6.1 Qualitative and Quantitative Data

The main areas revealed as being in need of further investigation suggest a qualitative examination of evidence. This research therefore adopts primarily a qualitative case study strategy which partners well with a realistic philosophy and culminates in a quantitative survey strategy (with some qualitative aspects). Overall, strictly speaking, a mixed method model is hence present which partners suitably with the pragmatic and allows for both *exploratory* investigations and *confirmatory* explorations. Such an approach is supported by a case study strategy which encourages mixed methods in order to capture the complex reality under scrutiny and allows for good use of triangulation.[318]

The decision to use predominately a case study strategy was a strategic decision that relates to the scale and scope of the investigation and leaves the data collection methods open to suit the particular enquiry. As such the strength of the case approach is that it allows for the use of a variety of methods depending on the circumstances and specific needs of the situation.[319]

This research adopts a qualitative case strategy with deductive reasoning in order to add to the existing body of knowledge. Qualitative empirical data is collected from a variety of relevant case materials and sources and the cases where in all instances selected on the basis of them being relevant to the practical problems being researched. One of the most difficult hurdles in research is negotiating research assess.[320] Resultantly accessibility and availability of information were case selection factors. However, a number of established industry contacts were usefully probed and in each instance led to fruitful research collaborations. The qualitative data is lastly augmented with quantitative material which serves to either support or offer counter-arguments to the main findings or observations. This may be viewed to offer a necessary degree of objectivity where interpretation of observations is used.

3.6.2 Interviews

Interviews are generally used in research to gather data on matters that simply cannot be observed or gleaned from documents. There are a variety of types of interview and it is important to select the right kind for the purpose and to seek corroboration of data received by reference to alternate sources. Here a combination of open-ended workshop-interviews and semi-structured interviews were used. Each interview had an interview guideline designed for each study with introduction presentations and questions built upon literature review. Interviews were open and semi-structured to allow the possibility of capturing aspects about which the interviewer might not be aware, and leading questions were avoided. Flexibility allowed for follow-up questions such as: why do you think this occurs? What is the value of this process? Why is that a problem or benefit? What do you think are the consequences of that situation? This encouraged interviewee reflection, a vital attribute of critical realism according to Bhaskar.[321]

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[318] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.
[319] Ibid.
[320] Saunders, M., Lewis, P., Thornhill, A. (2009), *Research methods for business students*, 5th ed., Harlow: Pearson Education Ltd, pp.150.
[321] Bhaskar, R. (2008), *A realist theory of science*, Oxon: Routledge.

Notes where taken for each individual, group and workshop interview, which were later rationalised into: 1) completed BIM PEPG[322] templates, statements and inferred findings (Paper #1); 2) statements and observed patterns (Papers #2&3); 3) statements and a current practice case process map (Paper #4). Draft papers where sent back to interviewees for validation.

The selection of interviewees was based on criteria such as their level of experience and understanding current issues in BIM adoption and utilisation. All interviewees were in some capacity involved in BIM projects and consequently possessed on-the-job knowledge and reference experience that could be drawn from. Where applicable, experiences where pulled directly from the referenced case projects, allowing contextualisation.

3.6.3 Observations

Participant observations are used by researchers to infiltrate situations, sometimes as an undercover operation, to understand the culture and process of the groups being investigated.[323] They can be used to corroborate or deepen the understanding of respondents' accounts or situations.

For the study exploring digital deliveries through specification (Paper #2), workshop observations (together with workshop-interviews) were used to understand model progression and coordination on the ground. Observation in design team meetings was employed to gain insight into current practice methodology relating to digital model information exchange for the purpose of achieving *3D Design Coordination*.[324] Direct observations are a key source of qualitative information in case studies, they stand in contrast to interviews which base their data on what informants reveal and to documents where the researcher is one step away from the action. Field notes were taken to form a permanent record of the data,

3.6.4 Documents

Like observations, document reviews can be used to confirm or deepen the understanding of a situation and can provide a third leg for triangulation. Document review here provided the basis for the inventory and review of existing BIM standards and guidelines (Paper #1), the study investigating BIM related process obstacles pertaining to contracts and behaviours (Paper #3) and the context surrounding the concept and application of *Level of Development*

[322] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

[323] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.

[324] One of many so called 'BIM-Uses' explained in Paper #2.

(Paper #4). The aim was to understand the frame of reference in which respondents (the subjects) and phenomena (the objects) under study operate. Governmental and institutional publications such as BIM related standards, guidelines and existing contract documents were analysed contextually. Together with interviews, the purpose was to understand the impact of existing sector standards documents, their application, and whether there are any deficiencies set against a foreground of actor experience and understanding of standards adoption.

3.6.6 Questionnaires

Questionnaires are useful for collecting facts and opinions from populations in many locations and when a standardised data set is desirable. To nuance the emergent results inferred in papers 1-4, a final study (Paper #5) was executed to help validate the research and position it amongst the ongoing national BIM standardisation work.[325] A concise web-based questionnaire was prepared incorporating a mix of both open and closed questions to collect primarily quantitative data with some qualitative aspects. Ordinal data was sought to rank the significance of particular research themes and standardisation efforts. The aim was to identify levels of support for earlier research work across disciplines. Descriptive text was collected to add context and allow a deeper understand of the views.

The questionnaire used in paper 5 is included as Appendix 3.

3.7 Data Analysis

3.7.1 Deductive Analysis

The sources of qualitative data gathered include interviews, observations, documents, and questionnaires. The raw data takes the form of field notes, interview transcripts, texts and case project models and model outputs such as schedules and images. Transcribed interviews were abstracted into summary statements transforming the data into emerging patterns where evidence converged or was corroborated by multiple respondents or triangulated sources. Where appropriate, to provide a structure to aid data analysis and presentation of results, converging datasets are interpreted into key issues (Paper #2) categories and themes (Paper #3), and process-orientated events (Paper #4). Unitising the data enables its organisation and postulation of meaning which is then compared with the literature.

Quantitative data is collected for the final study (Paper #5) which allows for the simple presentation of descriptive statistics offering the research a succinct and precise way of

[325] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov*, SBUF Final Report No. 12690, Stockholm, Sweden. [BIM Standardisation Needs]

displaying the evidence, describing the profile of the findings, and exploring correlations and associations between the parts. In a sense the data *speaks for itself*.[326] Descriptive texts were codified and reduced into restricted categories of meanings and organised into groups, for example, by discipline occupations that enable presentation of discipline trends or tendencies. In all, the deduced findings derive from the consequences of the assumed.

3.7.2 Abductive Analysis

Abductive reasoning, in other words, *inference to the best explanation,* is applied in some instances (Paper #3 & #4). This kind of reasoning can be used to develop scientific propositions, which in turn can be tested by additional reasoning or data. Analysis sought to reduce, display and verify the data with the purpose to develop concepts and arrive at some generalised statements.

3.8 Quality of Research

3.8.1 Validity

This research mainly assumes a case strategy supported by survey and therefore acknowledges Yin's[327] criteria for testing research quality in terms of *construct*, *internal* and *external* validity. Construct validity deals with establishing robust measures for the concepts being studied, for example, through respondent validity. To increase construct validity Yin suggests use of multiple sources of evidence that may encourage convergent lines of inquiry.[328] Here multiple sources were tapped and in particular, observations in coordination / design team meetings enabled collection of not just data on what people say they think and do, but on what they actually think and do. Descombe[329] advocates that interview data should always be corroborated with other sources of information on the topic and in this respect *triangulation* was widely practiced.

Triangulation, being the corroboration of facts from a variety of different views or sources,[330] has been exercised here to support the reliability of the research in so far that: 1) aspects of the qualitative and quantitative data are compared and enable corroboration of results; 2) comparisons using similar methods, for example interviews, provide a check on the accuracy

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[326] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.
[327] Yin, R. K. (2003), *Case Study Research: Design and Methods* (Applied Social Research Methods), Third Edition, London: Sage Publications.
[328] Yin, R. K. (2003), *Case Study Research: Design and Methods* (Applied Social Research Methods), Third Edition, London: Sage Publications.
[329] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press, pp.201.
[330] Ibid.

of findings; 3) use of contrasting sources of information, (interviews, workshops, documents, questionnaires) aid accurate measurement and a more complete picture to emerge.

Internal validity refers to how well the data collected corresponds to reality and primarily applies to explanatory studies. Paper #3 sought to explain plausible connections between BIM inertia, contracts and behaviours. In this study patterns are established using converging evidence and feedback was sought to validate inferences. Further, interviewees were chosen from a list of available *key players* in the field – precisely those specialists, experts and highly experienced actors whose testimony carries the greatest credibility.

External validity concerns the ability to generalise beyond the immediate study. However, it is acknowledged that it's notoriously difficult to generalize from case studies.[331] One measure to compensate for this weakness is to select cases that can be deemed typical or representative in their class. Further, there is a need to identify what is generalizable from each case and what is specific or contextual; as such, the level of generalisation of a case is determined by the strength of the description of the context. These aspects are explained in each individual study, but still most of the knowledge produced in this research is context-dependent.

The survey, introduced in the final study, increases the generalisation of the findings, and seeks to render results more broadly applicable, and accepted as the truth. What is lacking however is further and thorough scientific validation of the new theoretical propositions and frameworks, such as those emerging from papers 2 and 4. In this research project no verification cases were performed and as such this is noted as a relevant further research need.

3.8.2 Reliability

Reliability refers to the ability to replicate findings and measures are required to ensure that the data collected and later interpreted accurately reflect events themselves. One important aspect of qualitative research is the acknowledgement of *self*. This is also an underlying feature of the adopted critical realistic research philosophy. Here, it is recognised that the researcher's self is a crucial measurement device. The researcher's social background, values, identity and beliefs will all have an impact of the nature of the data collected and interpretation of it. This implies replication is problematic if not impossible. Notwithstanding, Robson[332] argues that one may nonetheless be at liberty to capitalise on original studies where there are relatively strong findings giving support to a particular theory suggesting the operation of certain mechanisms in the contexts of the study. In contrast, with the execution

[331] Merriam, B. (2006), *Fallstudien som forskningsmetod*, Studentitteratur, Lund.
[332] Robson, C. (2002), *Real world research: A resource for social scientists and practitioner-researchers*, 2nd edition, Oxford: Blackwell Publishers, pp.42.

of the quantitative research, the self is removed and the point is to produce numerical data that are wholly objective in the sense that they exist independently of the researcher.[333] The survey reported through paper#5 is highly suited to replication.

3.8.3 Limitation to the methods employed

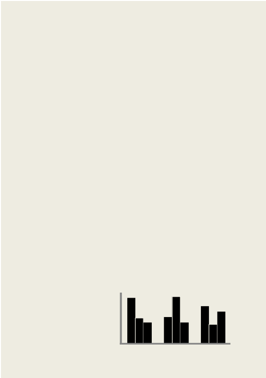
Certain weaknesses in this research need to be acknowledged, some which are generic, some which are specific to this project. Firstly, it is acknowledged that it is difficult to generalize from case studies where one lacks verification cases to support initial findings. Some validation tests were carried out through document review, observations and asking similar questions to a broad range of people. However, within the scope of the project, reliability may have been strengthened if broader case evidence was sought. Further, it may have been preferable to extend the theoretical framework presented in paper #4 into practical application and real world testing had circumstances allowed.

Secondly, researchers always have reservations about the authenticity, accuracy or honesty of answers – perhaps most of all with survey data. In this respect it has been difficult to corroborate the data which acknowledges that responses represent views at a snap-shot-in-time. Further, it has been problematic to compare results with other studies as there are few that are similar.

In hindsight the methods employed may have been implemented more robustly if draft transcripts derived from interviews and workshops were passed back to the participants for verification prior to writing up the research. This step was missed, however draft papers were sent to participants for comment prior to publication. A further limitation was that the survey data was gathered anonymously. The researcher took the view that in declaring respondent confidentiality at the outset, confidence and the number of completed questionnaires may increase. In retrospection, it may have been pertinent to identify respondents so that a cross analysis could be made between the group of respondents directly involved in Swedish BIM Standardisation efforts and the wider population of industry and academic representatives who took part.

[333] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press, pp.250.

On Results:



"However beautiful the strategy, you should occasionally look at the results." (Winston Churchill)[334]

4.0 Findings

This chapter presents a summary of the main findings that are presented in full in the 5 appended papers. The results, emerging from the case materials examined and empirical evidence collected, are presented as extended abstracts and provide a set of preliminary responses to the objectives of this research.

4.1 Presentation of Papers and Objectives

The findings presented here aim to provide an initial response to the objectives of this research effort. Accordingly, Table 7 returns to these objectives and assigns paper extended abstracts.

See Note #5 in the appendix section for a detailed account of the main author contributions in each paper.

[334] Winston Churchill (1874-1965), British Orator, Author and Prime Minister during World War II.

Extended Abstract	Research Objectives
Paper #1	Review existing BIM guides and standards to identify gaps, test and evaluate the industry's appetite for utilisation of a project-based strategic BIM implementation plan based on buildingSMART Alliances' Building Information Modelling Execution Planning Guide (PEPG).
Paper #2	Establish a process model for defining BIM information content for specific BIM deliveries, extending the concept of Digital Delivery Specification.
Paper #3	Examine the connections between the legal and commercial environment of construction contracts and the resulting procedures and behaviours that may be seen to hinder BIM collaboration and the expedient usage of data rich models downstream.
Paper #4	Uncover mechanisms facilitating and constraining utilisation of Level of Development (LOD) to support information stewardship and explore the plausibility of automated model progression scheduling.
Paper #5	Identify which BIM standardisation initiatives are of interest and to whom, assess the extent to which standardisation needs are aligned with research efforts and legitimise current research efforts.

Papers & Research Objectives v1.0 (Hooper, 2014)

Table 7: Relationship between Papers & Research Objectives

4.2 Extended Abstract of Paper #1

Review existing BIM guides and standards to identify gaps, test and evaluate the industry's appetite for utilisation of a project-based strategic BIM implementation plan based on buildingSMART Alliances' Building Information Modelling Project Execution Planning Guide[335] *(PEPG).*

The theory behind BIM provides an exciting integrated solution for project information management, however in this new paradigm further effort is required to define the planned scope of BIM adoption on a project and communicate associated information deliveries. Responses to even the basic who?- what?- when?- how?- questions relating to object and property definitions have hitherto been problematic to pin down.

The pilot study revealed that decisions about how BIM (tools and methodology) could be used on a construction project are ad hoc. A lack of guidance exists and common methods of systematically and collectively agreeing BIM priorities, goals, information exchanges in an open form where wanting. In other words BIM planning was inadequate.

Case participants understood the value of efforts to standardise BIM planning routines and control information exchanges to avoid misalignment of delivery expectations and re-work but few practiced it. The difficulties found in practice include: 1) scope for key player

[335] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

participation (procurement related); 2) time demanding at early stages (fee related); and 3) propensity to reach desired levels of information definition across disciplines (process related). These issues are taken up in papers #2 and #3. To help manage these issues Architects and Engineers relied heavily on experience-based intuition rather than formalised methods such as those found in the PEPG[336] and as found in the literature. This calls for a need to re-evaluate and / or further develop existing guidelines and methods which facilitate the flexibility to accommodate experience-based learning.

Utility of the PEPG[337] in the absence of suitable equivalent local planning and execution guidelines revealed some interesting insights which may positively impact practitioners. Execution helped improve clarity of purpose. It proved to be a valuable method of determining important prerequisites for effective BIM implementation; and a platform for recording information needs set against specific BIM-Uses, allowing consultants to focus on authoring the construction information needed in a systematic way. Further, it enabled team members to formally articulate in a common environment responses to the age-old who?- what?- when?- how?- questions related to information exchange.

The process and components involved in the PEPG are closely tied to the development of the *Information Delivery Manual* (IDM) and *Model View Definition* (MVD) wherein exactly which information is to be exchange in each exchange scenario, and which parts of the IFC specification are used, is specified. In this respect, by encouraging organisations to take part in planning for information exchange, and articulate exchange parameters in a coherent and pedagogical way, it amplifies awareness of requirements and provides participants a prelude to IDM, a key part of building SMART's folio of standards currently still under development.

A fuller overview of existing BIM guidelines, their content, scope and positioning is presented in *BIM Anatomy - An investigation into implementation prerequisites*,[338] and reveals significant gaps in BIM guidelines and strategic planning support applicable in Sweden. The gaps cultivate a constellation of fragmented approaches where internal BIM-Manuals are relied on to nurture narrow internal efficiencies rather than the collaborative possibilities that BIM promises. The question of the need for national BIM standards and guidelines is re-visited in Paper #5.

The conclusion of this preliminary study naturally leads to a deeper investigation on information deliveries and standardisation needs relating to the activity of proactive BIM planning and the idea of individual and consecutive *BIM-Uses*.

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[336] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.
[337] Ibid.
[338] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151

4.3 Extended Abstract of Paper #2

Establish a process model for defining BIM information content for specific BIM deliveries, extending the concept of Digital Delivery Specification.

In order for design consultant teams to work towards common goals, be it delivery of a fully coordinated set of construction documents, or any other specific pre-specified BIM-Use, consultant organisations must understand each other's information needs. However, defining the content and status of BIM information needs and / or deliveries remains both a practical and theoretical problem. This study examines two case projects with a view to firstly understanding the issues involved and secondly test a propositional *BIM-Info Delivery Protocol* (IDP) designed to authenticate the concept of *Digital Delivery Specification* presented but not substantiated in BH90.[339]

The study takes a critical view of buildingSMART's information exchange standardisation efforts and explores a back-to-basics approach to information exchange based on minimum information needs for 2 key primary specific BIM-Uses: *3d Design Coordination* and *Early Energy Appraisal*.

The findings demonstrate that aligning design consultant BIM information delivery expectations are problematic. Frustrations are common and much time is wasted on re-work – specifically extra effort required to clean up digital model deliveries to meet intended requirements. Too much guesswork and imprecision exists in information exchange creating uncertainty and wasted opportunities to leverage the model. The main deliverable from the study is the *BIM-Info Delivery Protocol* (IDP) which functions as a tool to align consultant BIM-Info delivery expectations and represents a tangible solution to assist consultant disciplines manage workflow, BIM information authorship and exchanges. The constituent parameters of a *Digital Delivery Specification* are articulated being: *BIM Use, Project Stage, Info Exchange* (number), *Delivery Date, Classification of Building Objects*, *Responsible Party* for the information, *LOD,*[340] *Information Author, Information Receiver, Format* of data.

Conclusions for the case application of the IDP indicate potential for the removal of guesswork in information exchange. To add maximum value to the project, the timing and content of BIM authorship is critical. By articulating planned BIM-Uses, the necessary BIM-Info needed to carry out these Uses together with target BIM-Delivery dates; project teams can more readily focus on the strategic task in hand and help each other to deliver the intended result in a more efficient manner.

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[339] SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

[340] LOD: Level of Detail, Level of Development, Level of Definition. See Note #4, pp.135 for definitions and appended Paper #4.

4.4 Extended Abstract of Paper #3

Examine the connections between the legal and commercial environment of construction contracts and the resulting procedures and behaviours that may be seen to hinder BIM collaboration and the expedient usage of data rich models downstream.

Whilst BIM promises significant improvements in construction quality and efficiency, current contractual models do not encourage its use; indeed actively inhibit the collaboration at its core. To help bring BIM into the mainstream, it is claimed we need to re-craft existing contractual relationships to facilitate collaborative decision making and to equitably allocate responsibility among construction participants. This study looks at the case of Sweden and aims to identify and appraise observed hindrances to BIM collaboration and digital information stewardship. Methods employed include a critical review of existing contract forms, synthesized with focus group interviews (FGIs) with representatives from diverse AEC disciplines.

The document review revealed certain deficiencies in existing applicable contract documentation in supporting BIM collaboration and digital information stewardship in Sweden. Reference to the AIA's E202[341] and Integrated project Delivery (IPD) as delivery method points toward new opportunities to remove uncertainty, more effectively leverage the data model(s), and craft greater team-working around the model. Trends in barriers to utilisation of intelligent model data suggest further mechanisms to avert procedural, circumstantial and behavioural difficulties are needed.

Interview responses revealed commonality in experiences and points of view. The analysis and respondent feedback suggest a clear link between procedural, circumstantial, behavioural issues and inertia-making effects on BIM projects and that specific propositional BIM collaboration supporting mechanisms may have a positive impact on BIM project outcomes. For example, clarity on responsibility for accuracy where multi-party input is required can eliminate blame-games when errors occur, and LOD and status marking of objects targets mitigation of downstream data misuse and specificity of deliverables.

The findings indicate that most industry representatives perceive similar patterns of existing barriers to BIM collaboration, data use and stewardship, however are hesitant to place the fault directly on contracts themselves, rather on a combination of circumstances and behaviours associated with traditional mindsets and the commercial environment. The repeat occurrence of particular behaviours and associated effects provides strong evidence to show that teams require support on BIM projects to better manage decisions, production and usage of data, and deliver a more integrated approach to project execution. Traditional

[341] AIA (2008), *AIA Document E202-2008: Building Information Modeling Protocol Exhibit*, AIA and AIA California Council, California, USA.

project structures and contracts can create discrete and often competing agendas and associated behaviours. Respondents highlight the need for five unambiguous supporting mechanisms, which if standardised, may offer a means to avoid communicative setbacks, frustration, and wasted opportunities on BIM projects.

4.5 Extended Abstract of Paper #4

Uncover mechanisms facilitating and constraining utilisation of Level of Development (LOD) to support information stewardship and explore the plausibility of automated model progression scheduling.

Level of Development (LOD)[342] is a key parameter for describing digital content in a BIM context. It is seen an important vehicle for specifying information exchange throughout a facilities lifecycle. However, hitherto there has been little research examining how, beyond the theoretical concept, LOD can be applied and smartly utilised in practice. This study seeks to unravel the concept and reveals new insights into its application from a design management perspective.

The literature review found that application of LOD on BIM projects has hitherto been both inconsistent and weak due primarily to three re-occurring issues, namely: 1) a lack of consistent understanding and utilisation of LOD in practice; 2) scepticism over its usefulness; and 3) difficulty in integrating LOD & MPS into a BIM-like work flow, vis-á-vis a dissatisfaction with the management of it outside the BIM in high maintenance stand-alone documents. Particular LOD errors are highlighted and described as a set of phenomena including: *we can't see the wood for the trees*, and *using objects that may cover all eventualities.* The hypothesis that LOD can be so much more useful if integrated into a BIM-like workflow is confirmed through case investigation. A novel method of automatically comparing planned model progression with the current state of the model is exhibited leveraging LOD in a way that renders the process of model development more efficient, and improves output quality.

The research found fresh insights into LOD, concept and application and contributes with: 1) a literature and case review of LOD in practice; and 2) a plausible novel method of employing LOD that may reduce or remove the known labour-intensive activities associated with MPS and help design authors focus on creating critical path information. The proposed framework is also expected to improve the construction industry's potential for reuse of knowledge across stakeholders and intelligent processes in a way that is readily transferable. This is seen as crucial in promoting the industry's productivity performance. Advancement of the understanding of the concept and application of LOD and its usefulness has significant implications for design information management research.

[342] Note reference here to Level of Development, instead of Level of Detail. See Note #4, pp.135 for explanation.

4.6 Extended Abstract of Paper #5

Identify which BIM standardisation initiatives are of interest and to whom, assess the extent to which standardisation needs are aligned with research efforts and legitimise current research efforts.

Nations around the world are feverishly developing new standards relating to BIM in the construction industry which may enable teams to leverage greater value from BIM adoption through design, construction and operations phases. This study reflects on ongoing standardisation initiatives in Sweden and considers where current research efforts fit in. There is limited research presenting stakeholder perceptions on current BIM standardisation efforts whether driven by industry representatives or the research community. To address this gap, through a national survey, this study investigates the impact and correlation of particular process-orientated standardisation initiatives and related research efforts within the field of BIM. The aim is to determine the level of importance of common themes and establish their legitimacy. BIM experts are asked to rank individual standardisation projects and research themes and offer comment on their relevance in a context of national BIM initiatives. In doing so views are captured on the value and contribution of ongoing BIM standardisation initiatives, and position current research efforts within the landscape of other national strategic BIM programmes.

The results indicate broad underlying support of the ongoing BIM standardisation efforts happening in Sweden. Some scepticism over standardised *BIM-Planning* protocols such as those to be found in the US emerged, but strong support for *national BIM guidelines* and associated *state-driven vision*. In addition, respondents highlight a number of alternative standardisation needs that are either missing or low priority on the national BIM standardisation agenda, including *requirements management* and measures to overcome *barriers to BIM*. Difficulties exist in translating standards from theory into practice and more local case examples are needed. These findings are significant; they tell us which standardisation efforts are important and help us to understand what aspects are essential to support stakeholders in achieving common BIM goals. They indicate emerging trends upon which further studies can build and contribute to literature on state-of-the-art BIM standardisation.

This research contributes to the existing body of knowledge with a comprehensive survey reporting a snap-shot in time of the views of 67 diverse industry representatives on BIM Standardisation efforts in Sweden. The findings of this study provide useful information for the AEC industry, practitioners and researchers alike, on the positioning and perceived level of importance of ongoing standardisation efforts relating to BIM. This is valuable because it enables us to objectively understand their usefulness. The results tell us that greater knowledge is required in *Digital Delivery Specification, Contractual Support* and *Concept &*

Application of LOD whilst confirming, at a general level, that most disciplines attach a significant level of importance to all *10 BIM Standardisation Projects* – and in particular *National BIM Guidelines*, *Classification* and *BIM Concepts for Digital Information Management* (such as LOD). The data also implies that a new determination is required to align industry and research community efforts to deliver BIM Standards starting with a cross disciplinary effort to deliver *Nation BIM Guidelines* in a form that reflects the AEC industry's needs and expectations.

4.7 Summary of Main Findings

A summary of the combined main findings can be understood as a *BIM Standardisation Needs & Support Systems Model to support adoption*. The constituent parts are investigated as individual studies and the results are verified through case studies including case projects and experimental cases. The concluding survey supports prioritisation of BIM standardisation efforts.

The parts can however be brought together at a general level to form a platform to support BIM adoption making use of the results from each study. The cumulative result is an important research outcome. The model (Figure 22) aims at enhancing BIM project outcomes through transparency and control of selected strategic BIM decisions relating to project goals, BIM-Uses, information exchanges etc. The model, supported by Wallbank,[343] and Hodder[344] at a theoretical level, suggest a number of primary step *push* requisites including:

- A BIM-Plan
- Digital Delivery Specification (in man and machine-readable format)
- BIM-Project contractual supporting mechanisms
- LOD utilisation and a method of exploiting it to ensure expedient model progression

Whilst these provisions can be applied at an organisational level, the theory suggests such measures are most beneficially employed project wide and can be viewed as a critical component of the push towards level 3 BIM adoption[345]. Further, this research supports the argument that enhanced engagement at national and sector level to *pull* the industry towards level 3 BIM is required through:

- Creation and maintenance of applicable national BIM Standards including:
    - National BIM Guidelines
    - Development of building classification for BIM
    - Format standards and application

[343] RIBA (2011a), *A Model Procedure*, RIBA Journal: August 2011, RIBA Publications, London.
[344] RIBA (2014), *Working together with extra BIM*, RIBA Journal: December 2014, RIBA Publications, London.
[345] BIS (2011) BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper, London.

- Concepts for digital information management in standard forms of agreement.

- State mandate for BIM and associated BIM requirements on public projects.

Some of these later initiatives are already in motion in Sweden[346] and are essential to build a progressive and competitive BIM maturity capability in the industry. What is interesting is the interaction, scope and positioning of push and pull elements, how they can be integrated into design management practice, and how they may transfer from tentative concepts to recommendations towards branch standards. The question of local market-readiness has not been tested, however organisations are already benefiting from BIM standardisation efforts and are further standardisation is in demand.[347,348] Here, adoption of model components aims to increase efficiency and transparency, improve communication, understanding of the project, and relationships and avoid the set-backs and frustration present where standards and support mechanisms are missing. The research offers concretisation of 4 strategic BIM development areas which, if standardised across the branch may offer a vehicle of the realisation of the promised but often illusive BIM benefits.

[346] Such as Trafikverkets BIM Requirements initiative with industry experts in 2014.

[347] Jongeling, R., Lindström, M., Samuelson, O. (2013), *BIM Special – Dags att fokusera på standardiseringen*, Byggindustrin 30/2013.

[348] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov, SBUF ID: 12690 Slutrapport,* Stockholm, Sweden.

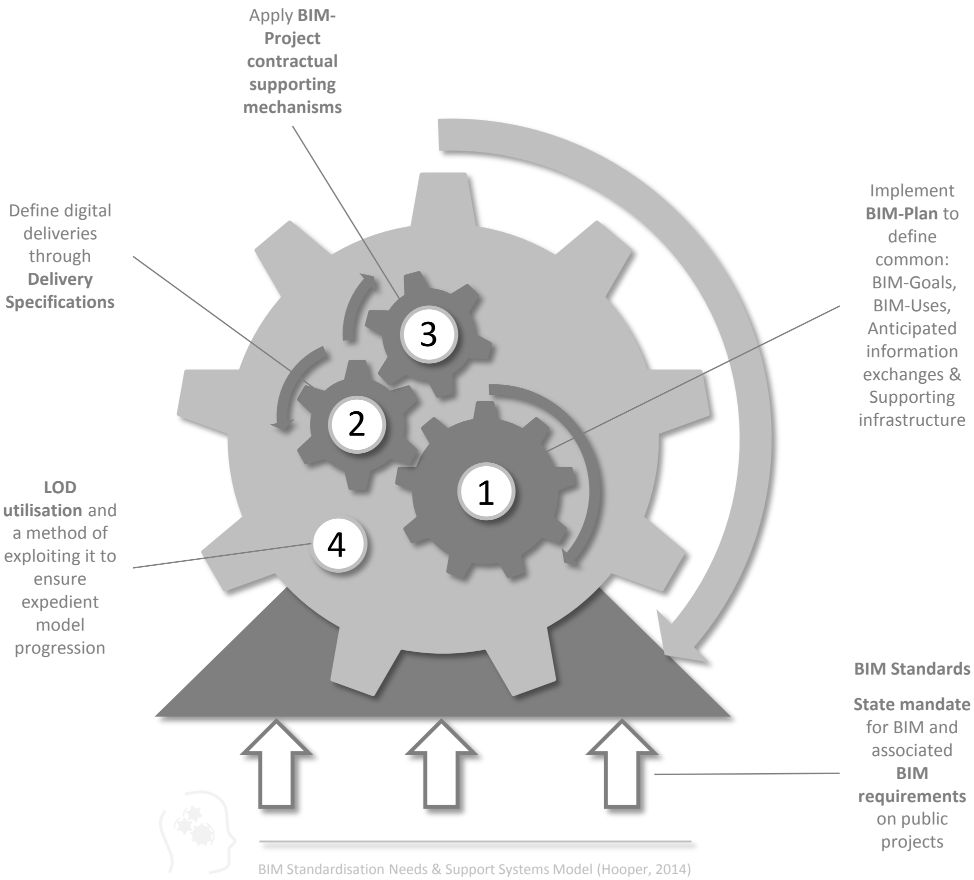

Figure 22: BIM Standardisation Needs & Support Systems Model

On summing-up:

"We have the duty of formulating, of summarizing, and of communicating our conclusions, in intelligible form, in recognition of the right of other free minds to utilize them in making their own decisions." (Ronald Fisher)[349]

6.0 Discussions & Conclusions

This chapter presents a discussion on the findings and scrutinises what they might mean. The findings are discussed and analysed with reference to the theory, ideas and problems that have been noted earlier. The 5 research questions are revisited and examined with our new knowledge. The consequences of the research results and their application are then considered together with reflections, contribution to the field and suggestions for further research.

6.1 BIM Standardisation Needs & Support Systems

In spite of increasing demand for adoption of BIM throughout the AEC industry and the desire from clients and society for teams to upskill and deliver, there are still significant difficulties in realising the higher potential of BIM's utility. Knowledge about how to better align information management process and expectations on information deliveries through the design, construct and operate phases of construction projects is a central concern for the industry and its clients; yet, standards and support systems are lacking.[350,351]

[349] Ronald Fisher (1890-1962), English Mathematician

[350] Ekholm, A. (2009), *Information systematic, BIM lab and pilot implementations – Project Description*, PhD Funding Application to SBUF & Formas, Lund University, Sweden.

Many AEC organisations including clients, through lack of existing branch standards and support systems for BIM deployment, are developing their own requirements and / or internal standards and process to move ahead in earnest, whilst others have not moved past BIM as technology. It is recognised that one will only get so far with little, stand-alone BIM and never be able to achieve the level 3 collaborative BIM which calls for commonality and convergence.

Consequently, this research has focused on unravelling a selection of important interconnected BIM standardisation and support system themes that to date have remained both practically and theoretically problematic within industrial and academic circles and may support national and international development efforts in the field. The research called for an answer to *how can particular standardisation efforts and support systems support an increasingly integrated BIM adoption,* which is tackled through the 5 research questions recapitulated here and specific investigations into: *BIM-Planning*, *Digital Delivery Specification*, *BIM Process Obstacle*, *LOD Concept & Application*, and efforts to *validate and legitimise national standardisation efforts*.

According to theory, standards and consistent methodology is required to advance from isolated BIM utility to collaborative BIM working. However, BIM standards development is still immature and even agreement on best practice elusive. Nevertheless, convergence on selected common requirements that may make the application of BIM more fruitful and easier for all to contribute and realise wins, appears appealing. The research conducted through case and survey inquiries provide some promising results in response to the objectives and the empirical part of the research supports the mains findings that reveal the value and impact of progressive digital information management adoption requisites. The belief is therefore that the findings presented in the results chapter, underpinned by more profound theorisation and justification in the appended papers, respond to the research questions in a consistent and rigorous way.

6.2 Research Questions Re-Visited

The 5 research questions that this research project seeks to answer are repeated below. The questions are answered in order under respective headings with support from the results and discussions in the previous chapters.

[351] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov*, SBUF ID: 12690, Slutrapport, Stockholm, Sweden.

6.2.1 Research Question #1 (on Standards & Information Exchange)

What development / standards / guidelines are needed to support the implementation of BIM in connection with construction projects in Sweden with a specific focus on information exchange and delivery specifications?

The findings from Paper #1 together with the outcome of the review of guidelines presented in *A Review of BIM-Guidelines - Content Scope & Positioning* published in *BIM Anatomy - An investigation into implementation prerequisites,*[352] come to bear on research question #1 in so much that they identify what is missing in the way of guidelines and what could be done to address deficiencies in terms of content, scope and positioning.

It is established that to support meaningful information exchange and the downstream usability of design team authored data, some form of strategic planning is required. The BIM PEPG[353] is tested to determine its suitability to complement the existing administrative guidelines in Sweden (BH90).[354] The results suggest that the deployment of a strategic execution plan, like the BIM PEPG,[355] offers teams the necessary strategic insight to implement BIM intelligently, support information exchanges and enable teams to leverage the technology more effectively.

A significant difficulty exists however in fully implementing a strategic execution plan from the outset. Typically not all of the project team can participate – due amongst other things to timing of appointments and scope of work – meaning optimum value cannot be brought to project at the critical early stages. This issue is taken up through research question #3 and in the context of contractual hindrances to BIM collaboration.

The results from the pilot study and associated case indicate that authored design data can be created, utilised, shared and bring added value to the project, in a way that is often neglected in traditional practice. Proper BIM planning appears to have good practical application that may offer organisations opportunity to improve project outcomes through contribution to collaborative processes deemed to be at the core of BIM use.

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[352] Hooper, M. (2012), *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden.

[353] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

[354] SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

[355] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

Where strategic BIM Planning is carried out, teams have the possibility to deploy resources smartly and with overall project goals agreed, members can focus on the creation, utilisation and sharing of data necessary to achieve those objectives.

Hitherto, branch requirements and / or standards for BIM strategic planning are wanting and the scope of existing guidelines for digital information management contained in BH90 limited. Findings suggest BIM-Planning, as an activity to ensure BIM goals and information exchange requirements are articulated and aligned, should be an adoption requisite and recommend development of applicable guidelines accordingly.

6.2.2 Research Question #2 (on Digital Delivery Specification)

How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis? Could a standard exchange matrix be established for various BIM-Uses at various project stages that would help align information delivery expectations?

Findings revealed in Paper #2 provide an insight into responding to research question #2 through a proposal for a standard method of producing an information delivery specification for supporting information exchanges associated with specific BIM-Uses. The process involves 3 key stages being: 1) establish BIM-Uses*;* 2) establish BIM-Info content; 3) create BIM-Delivery Schedule. The developed specification suggests 8 key parameters are required to articulate digital information content. The resultant protocol attempts to address the need for DCO players to better align information requirements and helps structure information production (model authoring) into a logical sequence that negates re-work and lost opportunities to leverage the data. If standardised and brought to mainstream use together with the other measures mentioned, it could contribute to practice communications and avoid the risks associated with divergent approaches.

The employment of emerging concepts like *level of development*, *model author* and the utilisation of suitable building parts classification are viewed as central to communicating digital content and the underlying theory of buildingSMART's standardisation efforts have offered instruments to develop simple, user-friendly communication-support mechanisms.

It is highlighted that it can be rather laborious work filling in a delivery specification. However, once done can be re-used or fine-tuned to suit the next project. Another development might be to generate the digital delivery specification directly from the model – This is investigated in paper #4. Authors can then easily check that their model contains the correct objects and properties to enable, for example a particular simulation to be carried out, without proceeding in error. In this sense the delivery specification can function as an early warning system to aid and guide design authors to generating the right information for the right purpose – whether it is for a specific information exchange or to carry out a specific BIM-Use, for example, cost control at scheme design stage.

It is clear that with so many possible uses, users and application for digital construction information through the DCO process, the individual user of the information (or organisation) may be best placed to make demands for information requirements. It is here that the delivery specification has particular strategic application. Downstream users of the digital construction information, for example Facility Managers, can use a standardised delivery specification to communicate to design authors (upstream) their information requirements. This way key information can be authored early (if deemed to add value) and re-work, duplication of effort, and waste can be avoided.

A first step in this process is for DCO players to understand what parameters are important and secondly to become aware of what objects and properties should be authored, when, ie; establish a logical information order with cognisance to a strategic BIM Plan. This is a learning process, and only through lengthy application can patterns be recognised that may lead to further standardisation. The Information Delivery Protocol (IDP) can be seen as a viable contribution to the development of smart authoring, and standardisation of process. It takes forward the general key ideas behind Information Delivery Manuals (IDM) and Model View Definitions (MVD) and may offer practitioners scope to start operating with such exchange methodologies.

6.2.3 Research Question #3 (on Process Obstacles)

What is the connection between traditional contracting and BIM inertia and what are the necessary components that may facilitate more effective early BIM collaboration?

Results from the third study provide material to respond to this question. The study investigates contractual and behavioural challenges to BIM collaboration and digital information stewardship. It highlights a number of discrete phenomena viewed as detrimental on BIM projects and validates the need for tailored BIM collaboration supporting mechanisms to underpin the value and downstream utility of authored digital information about facilities. To the above research question, we can now say, first that traditional project structures and contracts can create discrete and often competing agendas and associated behaviours. Lack of contractual provisions that support technology, people and process, can be said to be particularly problematic when working in a BIM mode where a new set of procedural, circumstantial or behavioural issues can emerge if left unchecked. Difficulties can be traced through commercial and legal pressures to protective behaviours which can compromise collaborative efforts and ultimately project outcomes.

Currently consultants share digital information at their own risk,[356] and furthermore management of digital information is characterised by agreement-less ad-hoc file sharing where the status of digital content, its reliability and the ways in which it is permitted to use the data, is neglected.[357] In the worst case this can lead to disputes between parties and a tendency to renege on responsibility for its accuracy or that the digital information has been managed in such a way that the responsibility for its content and accuracy becomes impossible to subsequently clarify.

To address this aspect, borrowing from the AIA's E202, the study revealed a general consensus for a set of BIM collaboration supporting mechanisms designed to aid stewardship of intelligent model data through projects phases and ownerships. They include: 1) A BIM Plan; 2) BIM Delivery Schedule; 3) Level of Development Schedule at each project stage; 4) Object Author Matrix; 5) BIM Authorised Uses Schedule. If ratified, such support mechanisms could be developed into a branch standard as a BIM-Addendum to contract. This work offers extended insight into the connections between specific behaviours, traceable circumstances and BIM project outcomes, and a knowledge of a local consensus behind the need for, and focus of, a number if BIM collaboration support mechanisms.

6.2.4 Research Question #4 (on LOD concept & application)

Can we better facilitate adoption of LOD and associated responsibility matrices by improving their integration into BIM workflow and is there a way of automatically verifying model content against intended use and programme that could be standardised?

The fourth study enables a response to the fourth research question with its investigation into the concept and application of LOD. Results indicate that there is much frustration and misunderstanding around the concept and application of LOD particularly in practice which has led to industry experts questioning its usefulness and its suitability as BIM content descriptor. Further, today the MPS[358] with specified LOD participant outputs or exchanges exists as stand-alone documents - not very BIM. A thorough literature review is assembled to establish a fuller understanding of the concept of LOD and 4 fundamental LOD errors are highlighted.

To answer the research question, a digital test-bed project was established to examine the plausibility of a corresponding testable hypothesis that: *if there is a way of automatically comparing planned model progression with the current state of the model, MPS can be better*

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[356] Edgar, J-O. (2011), *Entreprenörer bygger på egen risk*, Byggindustrin, Nov 2011.

[357] SFUB (2012), *Avtal behövs även för de digitala leveranserna*, Available: http://vpp.sbuf.se/Public/Documents/InfoSheets/PublishedInfoSheet/8289b8c7-2aa5-432c-a918-d3b6328f2aab/SBUF_1102.pdf

[358] Model Progression Specification. See: Vico (2012), *Model Progression Specification*, Vico Software. Accessible: http://www.vicosoftware.com/modelprogression-specification/tabid/85227/Default.aspx

integrated in to BIM work flow, LOD can be more useful, and mundane tasks can be eliminated. The hypothesis is confirmed through the development of a new LOD utilisation framework that presents a novel method of exploiting LOD to support the information production process through utilisation of standardised model rules enabling automatic checking of model progress against planned model development.

The main contribution is insight into how LOD can be applied expediently and awareness of the need to structure digital content to facilitate real-time cross-checking with scheduled deliverables. This knowledge is important in order to enable BIM information authors to align information deliveries or data-drops with the expectations of downstream users.

6.2.5 Research Question #5 (on BIM Standardisation efforts validation)

Which BIM standardisation initiatives are of most interest and to whom and to what extent are these standardisation needs aligned with existing research efforts?

The fifth study seeks to unlock answers to the fifth research question. Here we sought to ascertain the value and contribution of resent BIM research efforts and position them within a landscape of other national strategic BIM development and standardisation initiatives. The survey employed allowed for concise and accurate reporting of the present state of opinion on the current BIM standardisation efforts within academic and industry spheres. Respondents highlight different aspects of BIM standardisation needs. The general conclusion that stands out most clearly is that there is not just one way to organise and prioritise standardisation efforts, not even within the same industry. More than anything, the study highlights diversity. Looking at particular trends we can observe, Clients and Developers found improvements in *Communication* but were less convinced about overall improvement in *Project Results* so far. Looking forward, they thought *National Guidelines* were essential and expressed strong support for *BIM Requirements* on public projects. Architects, for instance place higher importance on front-end standardisation activities such as *BIM-Planning*, *Digital Delivery Specification* and *Classification* whilst less on downstream pursuits. They called for a state organ to drive BIM standardisation and *National Guidelines*. Contractors observed improvements in *Communication* but where more neutral on *Project Results*. They found *Productivity* increases and indicated support for research in standardised *Contractual Support*. They were not so interested in standardised *BIM Concepts*. Academic Experts observed improvements across the board since BIM with greater neutrality on *Productivity*. They recommend effort on *National Guidelines* and *Classification* whilst also placing providence in *Digital Delivery Specifications* and standardisation of *BIM Concepts*.

The diverse rolls found in construction and stakeholder's individual propensity to benefit from BIM standardisation efforts is significant. Some have specific objectives and goals and need standards to support the means to these goals. Others create and maintain their own standards and compel others to comply. Nevertheless, a general level of support for the ongoing BIM standardisation efforts was observed and evidence of positive alignment of themes within research. However, the data implies that a new determination is required to align industry and research community efforts to deliver BIM Standards starting with a cross disciplinary effort to deliver *Nation BIM Guidelines* in a form that reflects the AEC industry's needs and expectations.

6.3 Consequences and Possibilities

Examining DCO business processes to determine how we can improve communication and coordination of digital information is not so different than a team coach developing and implementing new plays. The goal is not to complicate our work with endless introspection and analysis. Instead, the aim is to examine and implement options that allow us to achieve peak performance and effectively move the ball toward the goal: designing, building and operating a facility more efficiently and truly meeting the needs of our clients.

The results of this work presented builds on existing knowledge by testing propositions based on theory that enable deductive responses to the research questions and fulfil the research objectives. Whilst the resolution of the research questions also seeks a practical application in contributing towards unlocking the difficulties in moving from BIM *organisational optimization* (Level 2) towards BIM *project optimization* (Level 3) (see Figure 6) in the field.[359] Overall they aim to go some way to identifying and binding together the prerequisite process standards and decisions support mechanisms required for improved BIM-project delivery.

On returning to our underlying enquiry of *how can particular standardisation efforts and support systems support an increasingly integrated BIM adoption?* We can formulate that standardisation work is essential to advance with BIM, however there are risks in standardising too much too soon. Standardisation priorities are emphasised in the results and support mechanisms, if standardised could be deployed in a more consistent way thereby avoiding divergences in approach in the field. In particular, further standardisation efforts are needed in the production of national guidelines which in turn point to best practices and other standards, international and national branch standards. A mature BIM adoption hangs on 3 hooks: communication, interoperability and standards.

6.3.1 General Observations

A general observation over this study that was particularly telling is the propensity for organisations to muddle through on the back of their own initiatives and good will amongst

[359] Notional levels of BIM implementation maturity range from 0-3. See: BIS (2011) *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London. Also implied in: WSP (2011), *Lilla Boken om BIM – Så förändras en bransch*, WSP, Stockholm, Sweden.

team members. There have been many attempts to bring about BIM implementation standards through various CAD or IT Manuals, with little attempt to identify what is central and what is peripheral. Further, there is the tendency to start well but when nobody is looking, revert to old practices. This is why more than internal initiative may be needed to steer a sector toward a consistent BIM approach – an element of compulsion centred round a national consensus of best practice and standards may not be a bad thing. However, there has hitherto been a tendency to do nothing and wait and see, whilst others overtake.

This thesis mainly refers to conditions relating to the *Swedish* DCO sector or context. It does this because the conditions and circumstances under study relate to phenomenon experienced in Sweden. That is not to say similar conditions do not exist elsewhere, but it is fair to say that the circumstances Sweden finds itself in are rather different from its Nordic neighbours – particularly when it comes to the development of BIM policy and standards. Here there is work to be done.

When it comes to BIM, the UK has adopted a rather heavy handed top-down approach to adoption and has spent considerable resources developing policy and standards to compel and support the industry to deliver. Sweden hitherto has taken a rather less demanding approach being decidedly soft on policy and weak on standards. However, Sweden is keen to benefit from experiences elsewhere and the ongoing work on developing state BIM requirements is positive, and represents a step in the right direction.

6.3.2 Application of Results

This research effort is first and foremost an academic work which primarily endeavours to extend the existing body of knowledge in the field. However, the results, if used with caution may be of interest and even tentative application in the field if developed into suitable working tools. The results remain conceptual, however one thing is clear: application of a standard BIM Planning protocol – such as the PEPG - is recommended as is adoption of delivery specification and contractual support – such as the AIA's E302. Given time, local versions of these branch standard documents may emerge and it is projected that the results of this thesis may be of relevance in shaping forthcoming BIM policy and standards. Notwithstanding, it is expected that this work will offer strategic insight into improvement areas.

The belief is that an improved understanding of *BIM-Planning*, *Digital Delivery Specification*, *BIM Process Obstacles, Concept & Application of LOD*, together with associated standardisation needs can improve the management of digital information and strive to enable a more integrated approach through enhanced cross-discipline collaboration. However, they need to be applied correctly and in a way which does not conflict with other requirements. As with any new methodology or process, willingness, education and time are essential. In this respect it is suggested that an incremental application of the processes be deployed with full project team buy-in as an initial goal.

A crucial next step is the development of national BIM guidelines and formalised national vision for BIM in Sweden. Such guidelines should point towards known best practices and applicable standards and where standards are missing or not localised, provisions should be made to close gaps. The research findings indicate that consistency is critical, and trends suggest, some form of national vision, based on open standards appears to be the logical approach emerging elsewhere.

6.3.3 Practical Benefits & Barriers

Architects and technical consultants have been quick on the uptake of BIM technology since it is readily recognised to support their existing activities better than 2D CAD. The possibility to carry out automated 3D collision control, amongst other things, has accelerated consultants use. However model-based design requires standards otherwise the communication and coordination problems witnessed set in.

BIM technology in itself cannot contribute to solving the individual, organisations, or sectors problems; in fact it can be said to create a whole new set of problems. Collectively results from the 5 studies into standardisations needs and support systems seek to offer some practical benefits by helping organisations overcome implementation difficulties and thereby enable common BIM benefits to be realised – the belief is that this starts with clarity of purpose and good information stewardship.

One of the barriers to practical uptake of the suggested process improvements is the time it takes to create and maintain a culture of collaboration; enabling a suitably functioning socio-technical system to exist. Individuals and organisations are impatient and want to experience personal benefits quickly, when perhaps the focus should be on the success of the project.

According to Samuelson,[360] in Sweden the drive for BIM adoption is being led by a small number of technical enthusiasts, and only to a lesser extent by client demand (as is the case elsewhere). With this in mind it is difficult to imagine convergence of approach and the production of common implementation standards emerging without some form of standards body taking the initiative and the element of compulsion to comply. Furthermore, a fragmented sector, with individual organisations looking after their own interests, serves as no vehicle for an easy transition towards a more integrated approach across the sector. For this reason, the push and pull of BIM implementation in Sweden may need to change its dynamic.

[360] Samuelson, O. (2010), *IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium*, Hanken School of Economics, Helsinki.

With reference to successes in other countries, where BIM is mandated, standards are in place, and clients are driving BIM implementation, organisations are forced to think outside their own boundaries and place the project in the centre. In Sweden the state is less convinced of the necessity to mandate BIM, and perhaps for good reason has till recently largely stayed out of the BIM debate. There is an argument that the construction industry should be left to its own devices and market demand will dictate the need for and success of innovative interventions. However, this stand point may leave the Swedish DCO split, lacking in expertise, and struggling to catch up with its Nordic neighbours with regards implementation maturity level. BIM and associated integrated activities offers an opportunity to mend something of the fragmented nature of the construction industry.

6.4 Validation of Results and Generalisation

Since this research is largely based on *qualitative data* from *case studies* it can be notoriously difficult to generalise from results and, in line with a critical realistic perspective, it is acknowledged and accepted that there is no absolute proof that the data is right. Instead reassurances are offered to confirm good practices were adopted. Verification of qualitative research is important to establish and support its credibility.[361] To support the credibility of this research, where possible, *triangulation* was employed by referencing contrasting data sources to bolster confidence the data are on the right lines. Further, a level of *respondent validation* was exercised by returning to the participants with the data and findings as a means of checking the validity of the findings. The survey performed in the fifth study, moreover sought to strengthen the credibility of results by firstly drawing on objective quantitative data and secondly contextualising the current research within the ongoing national BIM standardisations work.

It is always risky to attempt to generalise from results based on selected cases and for this reason it is wise to exercise caution. To say the cases were typical provides only a certain comfort when it comes to generalisation. However, the detailed descriptions of the cases provided in the appended papers gives a deeper understanding of the case contexts and thereby scope to generalise from the results. One size does not necessarily fit all but the results (suggested processes and decision support mechanisms) are intended to incorporate sufficient flexibility to have universal application.

[361] Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press, pp.296.

6.5 Contribution to the Field

6.5.1 Scientific & Practical Contribution

When discussing contribution, it is normal to ask what we can learn from this research. What is its impact in the field? To answer this, the five identified areas in need of further investigation stated in chapter 1 are re-visited. The first identified area concerns the need for knowledge on national guidelines and potential to standardise routines for BIM projects to support information exchange. This research contributes with an investigation and appraisal of existing standards and guides and tests the new buildingSMART PEPG[362] on a residential case project. The results were promising and suggests 1) there is a lack of existing applicable BIM strategic planning guidance in Sweden; 2) a pedagogical approach to planning for information exchange appears advantageous toward achieving planned BIM goals; 3) completed process map templates for BIM-Uses where fed back to buildingSMART PEPG authors for further development. The research contributes through the review and testing of the new BIM execution plan which enabled insight gathering on its application and potential to fill gaps in existing strategic BIM guidance in Sweden to support information exchange.

The second area concerns the need for methods of exchanging digital information in a consistent and accountable way. This study contributes with a process model of how to develop a digital delivery specification and provides a worked example generated from a BIM use-case. The essential parameters are identified and shortcomings with existing construction classification to support BIM use / information exchange noted. The research contributes with a concretisation of the concept of *delivery specification* suggested within BH90[363] but not substantiated and practical method of defining and controlling information deliveries to support specific BIM-Uses. The findings contribute to the body of knowledge on digital delivery specification and information exchange and can be viewed as a contribution to buildingSMARTs IDM / MVD standardisation efforts.

The third area concerns the need to improve understanding of the impact of contracts and behaviours on BIM projects and project outcomes, and postulates collaboration support mechanisms are needed to support improved information stewardship. This research contributes with a comprehensive view of those behaviours that hinder collaboration and can lead to inertia on BIM projects and a proposal to address such issues through a set of decision-making and collaboration support mechanisms. The contribution of the research is an improved understanding of BIM inertia, extended insight into the connections between

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[362] Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

[363] SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

specific behaviours, traceable circumstances and BIM project outcomes, and a knowledge of a local consensus behind the need for, and focus of, a number of BIM collaboration support mechanisms; in other words identification of barriers and enablers for effective information stewardship across project disciplines and phases.

The fourth area concerns the need for an understanding of new BIM concepts since the application of those concepts play an important role in standardisation work. Specifically, this study focuses in on the need to improve understanding and application of *Level of Development* (LOD) in a BIM context to support digital information production and delivery. This research contributes with a literature and case review of LOD in practice and second, a novel method of employing LOD that may reduce or remove the known labour-intensive activities associated with MPS and help design authors focus on creating critical path information. The contribution to knowledge is insight into how LOD can be applied expediently and awareness of the need to structure digital content to facilitate real-time cross-checking with scheduled deliverables. This knowledge is important in order to enable BIM information authors to align information deliveries or data-drops with the expectations of downstream users.

The fifth area concerns the need for national BIM standardisation initiatives to be validated and aligned with BIM research. The research contributes with a comprehensive survey presenting a snap-shot in time of the views of 67 diverse industry representatives on BIM Standardisation efforts in Sweden. The findings of this study provide useful information for the AEC industry, practitioners and researchers alike, on the positioning and perceived level of importance of ongoing standardisation efforts relating to BIM. This is valuable because it enables us to objectively understand their usefulness. The findings are important; they tell us that greater knowledge is required in *Digital Delivery Specification*, *Contractual Support* and *Concept & Application of LOD* whilst confirming, at a general level, that most disciplines attach a significant level of importance to all *10 BIM Standardisation Projects* – and in particular *National BIM Guidelines*, *Classification* and *BIM Concepts for Digital Information Management* (such as LOD).

Collectively, the individual contributions against each study aim to push forward the forefront of the research field (Figure 23) and offer a new front extending knowledge on 5 fronts. The novelty of *activity burndown* using LOD, conceptual explored in Paper #4 presents an exciting new island of knowledge ripe for further exploration and extension.

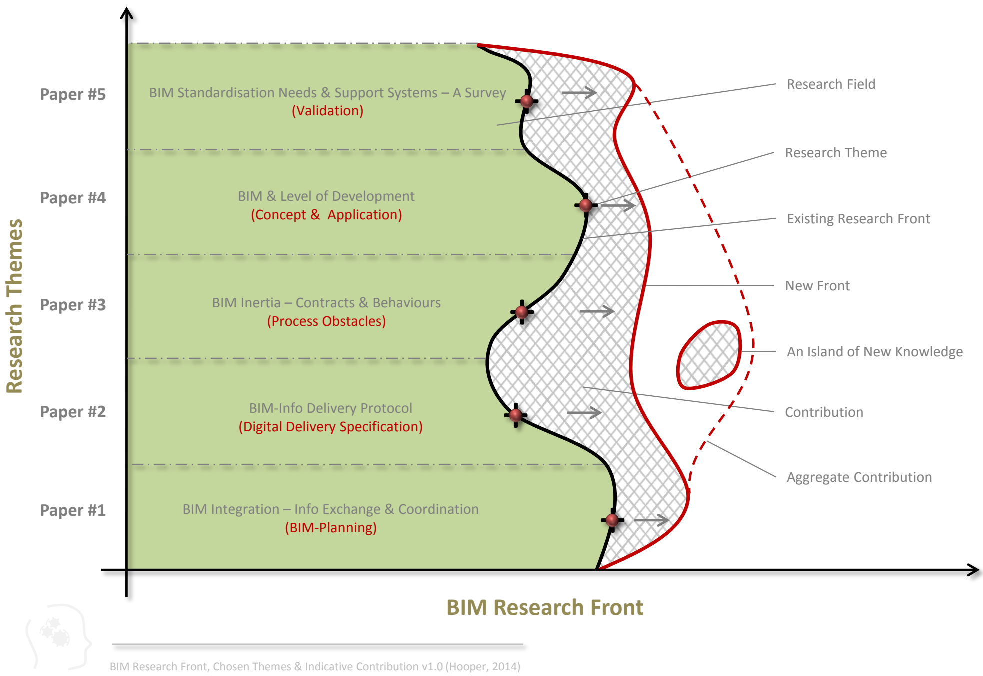

Figure 23: The BIM Research Front, Chosen Themes & Indicative Contribution

6.5.2 Positioning of Contribution

In consideration to the positioning of this research effort in relation to that in the field, reference can be made to Succar's[364] BIM iceberg that depicts those visible BIM deliverables and requirements and those hidden. This research contributes to those *below sea level* BIM requirements research including that relating to standards, workflow, model quality (& progression), and collaboration (Figure 24). Succar suggest that to the inexperienced, BIM is similar to an iceberg, only a small number of BIM requirements and deliverables are seen while most remain hidden below the surface.[365]

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[364] Succar, B. (2011), *BIM ThinkSpace : Episode 16: Understanding BIM Wash*. Available at: http://www.bimthinkspace.com/2011/06/episode-16-understanding-bim-wash.html

[365] Ibid.

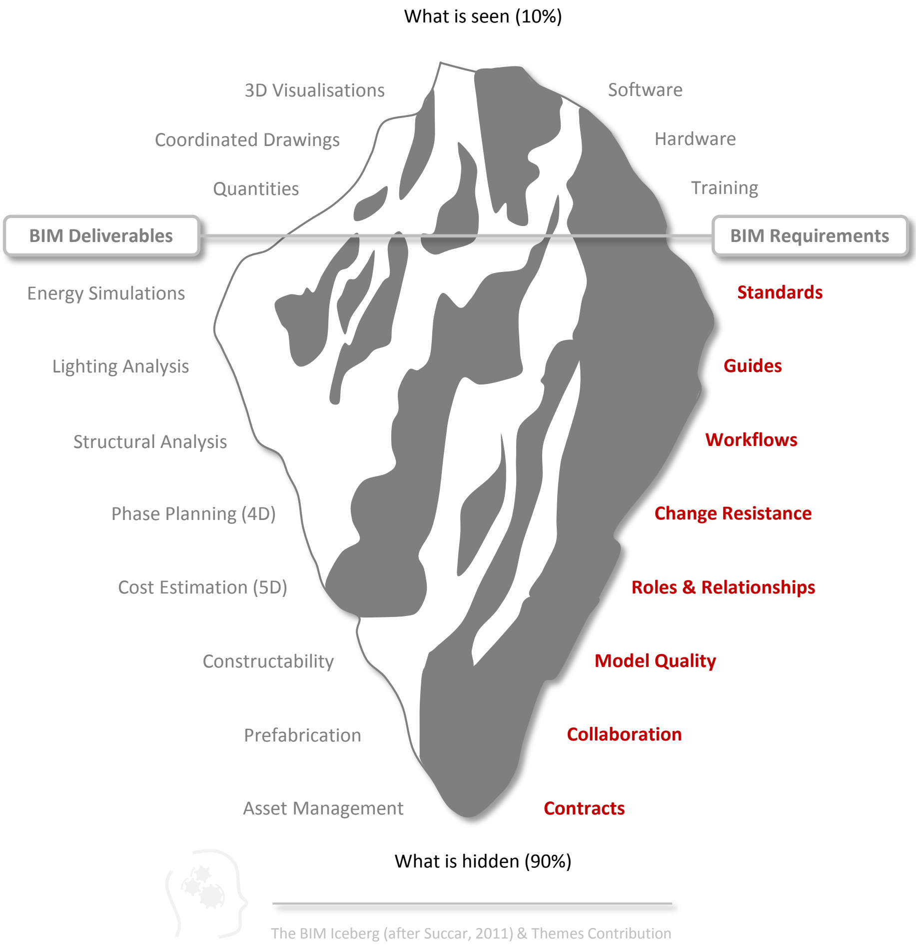

Figure 24: The BIM Iceberg (after Succar, 2011) & Themes Contribution

6.6 Suggestions for Further Research

On carrying out this research further gaps or opportunities for auxiliary or further research emerged which for the time being have been pushed to edge in order to reach some form of closure on the main themes.

Examples include:

1) In relation to study #1: the PEPG could be more widely tested to include different project types, and include all project team members. This would provide scope for refinement and further confirmation of formal BIM Planning as essential support to BIM adoption. The question of what planning aspects may be necessary to standardise to secure a consistent approach, remains open.

2) In relation to study 3: the practical application of the new Swedish *Avtal för Digitala Leveranser* [Agreement for Digital Deliveries] should be appraised through, for example, case investigations and user interview feedback to establish if it is making a difference with digital information stewardship and downstream utility from a contractual and behavioural perspective.
3) In relation to study 4: the conceptual framework for automated model progression scheduling remains theoretical. Further refinement and pilot application / test implementation could be an interesting development opportunity.

Notwithstanding the above research strengthening suggestions, a promising new avenue for further research lies in the need to further investigate and refine *BIM Requirements*. Formal state BIM Requirements are due to be published soon on the back of the standardisation work carrying out by Ekholm et al,[366] The Swedish Transport Authority[367] and other state client organisations. An interesting and logical extension of this work would be to investigate how the forthcoming requirements are formulated, assess the impact of these requirements and how the industry is expected to adapt in order to deliver them. More knowledge is needed in how to upskill the workforce to meet state BIM demands.

6.7 Close

Successful implementation, hidden in the forest like a shy deer, is to be reached not by avoiding disappointment and set-back, but by recognising its role as a natural, inevitable step on the way to reaching anything good. Why? Because no organisation or set of organisations are able to produce a great work without experience, nor achieve a worldly position immediately, nor fall on superior results at the first attempt. In the interval between initial failure and subsequent success, in the gap between how we wish one day to perform and how we perform at present, must come pain, anxiety, envy and even humiliation. However, we must not be tempted to withdraw from challenges that might have been overcome if only we had been prepared for the perseverance demanded by almost everything valuable.[368]

The author extends a final thank you to all involved this is work; from those in academia who contributed with views and reviews, to those from industry who contributed with knowledge from their own experiences; thereby assuring the academic and practical relevance of the project to the trade.

[366] Ekholm, A., Blom, H., Eckerberg, K., Löwnertz, K., & Tarandi, V. (2013), *BIM – Standardiseringsbehov*, SBUF ID: 12690, Slutrapport, Stockholm, Sweden.
[367] Trafikverket: http://www.trafikverket.se/
[368] De Botton, A. (2000*), The Consolations of Philosophy,* London: Penguin.

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Publications

Appended Papers

Paper #1:

- Hooper, M. & Ekholm, A., (2010), A Pilot Project - Toward BIM integration - An analysis of design information exchange & coordination*, Proceedings of the 27th Annual CIB W78 International Conference - Applications of IT in the AEC Industry*, Cairo, Egypt. 15-17 November 2010. http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=1766917&fileOId=1766923

Paper #2:

- Hooper, M. & Ekholm, A., (2012), A BIM-Info Delivery Protocol, *Australasian Journal of Construction Economics and Building, Special Issue on BIM*, AJCEB vol. 12, no. 4, Sydney, Australia. http://epress.lib.uts.edu.au/journals/index.php/AJCEB/article/view/3031

Paper #3:

- Hooper, M. & Widén, K. (2014), BIM Inertia – Contracts & Behaviours, Book Chapter in: Issa, R.R.A. and Olbina, S. (Eds.), *Building Information Modeling: Applications and practices in the AEC Industry,* ASCE Press, in production.

Paper #4:

- Hooper, M. (2014), Automated model progression scheduling using Level of Development (LOD), *Construction Innovation*.

Paper #5:

- Hooper, M. (2014), BIM Standardisation Efforts - The Case of Sweden, *IT in Construction*.

Other Publications

- Hooper, M., Ekholm, A., (2011) A Definition of Model Information Content for Strategic BIM Implementation*, Proceedings of the CIB W078-W102: 2011 Joint International Conference,* Sophia Antipolis, France, 26-28 October 2011.
  http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2201243&fileOId=2201251
  (Nominated for the Charles Eastman Award)

- Hooper, M. (2012), *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden.

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- Hooper, M. (2012), *A Review of BIM-Guidelines - Content Scope & Positioning,* LTH, Lund, Sweden.

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- Hooper, M. (2013), *BIM for FM - Much to win in the operational phase*, LTH, Lund, Sweden.
  (Contribution to: Atkin, B. (2014), *Total Facilities*)

Appendix 1: Notes

Note #1: An Analysis of Industry Needs

In order to ensure the research remained focused on addressing real world problems, an industry workshop (BIM-Info Start Meeting) was held at LTH with the purpose, amongst others, of formulating a strategic research focus. Representatives from all corners of the Swedish AEC industry were present to discuss matters of the development of BIM from a number of user perspectives.

The workshop culminated with a summary survey to gather industry thoughts on the BIM-related challenges industry members felt they faced together with where their development aspirations lay. From this material it was possible to establish the essence of industry needs, identify and categorise priorities relating to a desired development of BIM in Sweden and confirm that the work is important, *timely* and *right*.

Data gathered enabled a summary analysis to be performed that revealed similar concerns. Representatives recommended research was needed (to aid industry development) in the following areas:

> *"Definitions for information deliveries, development of national standards, connection to classification system, user perspective, development of exemplar projects as case studies, information exchange standardisation between primary actors, best practice guidelines, AEC collaboration*."[369]

By identifying the overlaps between the research project objectives and industry priorities, research questions can further be brought into focus. Here, contact and discussions with practitioners has provided an alternative perspective revealing, at least in part, what is important and what is not. Further it facilitated a robust path (Figure 25) towards developing shaper, more insightful research questions.

[369] These key short statements emerged from the BIM-Info start meeting held on 4 December 2009 following a GAP analysis of participant views on Sweden's DCO BIM development focus.

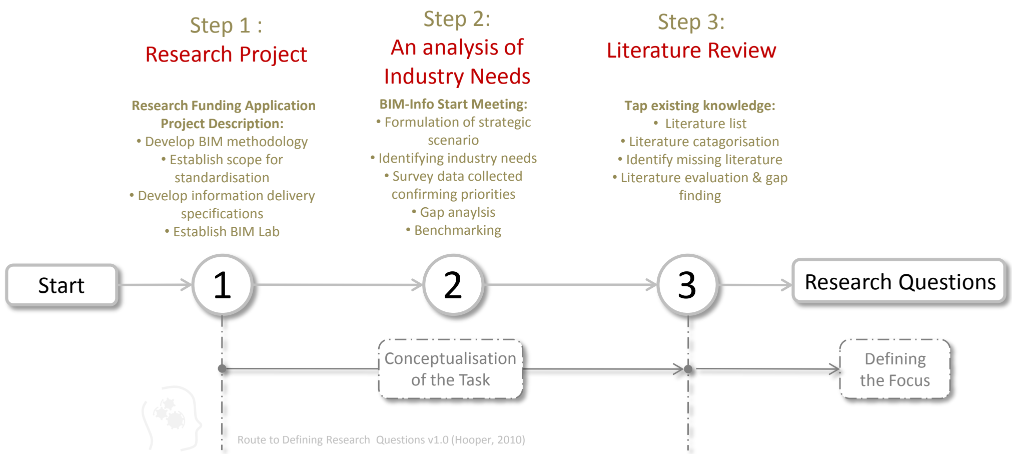

Figure 25: Route to Defining the Research Questions & Focus

Note #2: BIM in Lund – A Discussion Seminar on BIM Research and Educational Needs

Following the defence seminar of the research project licentiate thesis: *BIM Anatomy - An investigation into implementation prerequisites*[370] a discussion seminar on BIM research and educational needs was held in Lund.[371] The idea behind the seminar was 2 fold: 1) that the opportunity should be taken to pick the brains of the BIM community to identify and reach consensus on the suitable extension and development of the research work to date; 2) a review of existing and future BIM educational requirements was needed to ensure resources are in place to teach architectural and engineering students in BIM applied to respective disciplines and as a collaboration platform.

Two statements emerged which informed and supported the 2nd phase of the research project represented through this doctoral thesis and education design:

- "Of highest priority is to reach a national consensus and uniform industry acceptance is Level of Development and an understanding of model content."[372]

- "[Architectural and Engineering students] can operate the tools of the trade but have no idea about the process around the use of BIM in practice."[373]

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[370] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151
[371] BIM i Lund Workshop, August 2012, Lund.
[372] Nina Borgström, White arkitekter AB. BIM i Lund Workshop, August 2012, Lund.
[373] Gunilla Qvarnström, Projtools AB. BIM i Lund Workshop, August 2012, Lund.

Note #3: BIM Anatomy II: Standardisation Needs & Support Systems

The title adopted for this thesis summarises the content. Here a short explanation to the decisions made regarding title selection is presented through asking 2 pertinent questions:

Why 'BIM Anatomy'?
BIM: as in Building Information Modelling / Management being the core research field.
Anatomy: as in the study of the structure of living things and their parts. Here used more loosely to encapsulate the notion of man and *living* information management, it's structure and parts (see Figure 27).
II: as in part 2, the sequel to the initial work presented as *BIM Anatomy - An investigation into implementation prerequisites.*[374]

Why 'Standardisation needs & Support systems?
Standardisation needs: as in requirements for normalisation deemed necessary in order to enable specific collaboration routines to take place to release BIM benefits.
Support systems: as in those mechanisms, schemes and organisations that can be deemed to encourage the furtherance of phenomena under study in advantageous ways.

To augment, a graphic explanation is offered through the aid of the illustration presented in Figure 27, introducing notions of structural parts of a living machine, including: BIM-Mindset, BIM-Drivers, and BIM-Lifecycle Perspective. The unifying project logo (Figure 26) used throughout the thesis and associated presentations is designed to remind the BIM community that adoption builds on the 3 essential interlocking fields of *policy*, *process* and *technology*.[375]

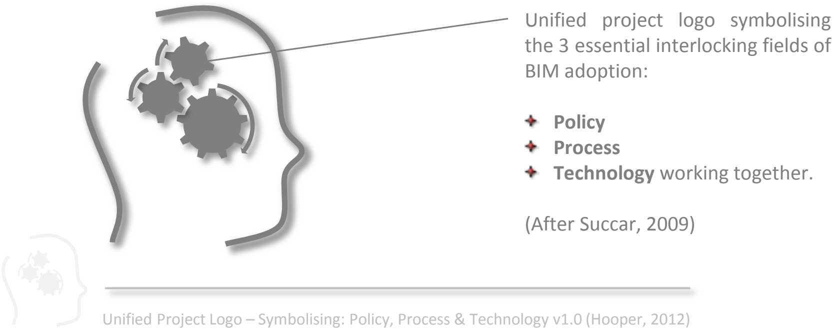


Figure 26: Unified Project Logo – Symbolising: *Policy*, *Process* & *Technology*

[374] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151
[375] Succar, B (2009), Building Information Modelling: A Research and Delivery Foundation for Industry Stakeholders, *Automation in Construction*, Vol. 18, pp. 357-375.

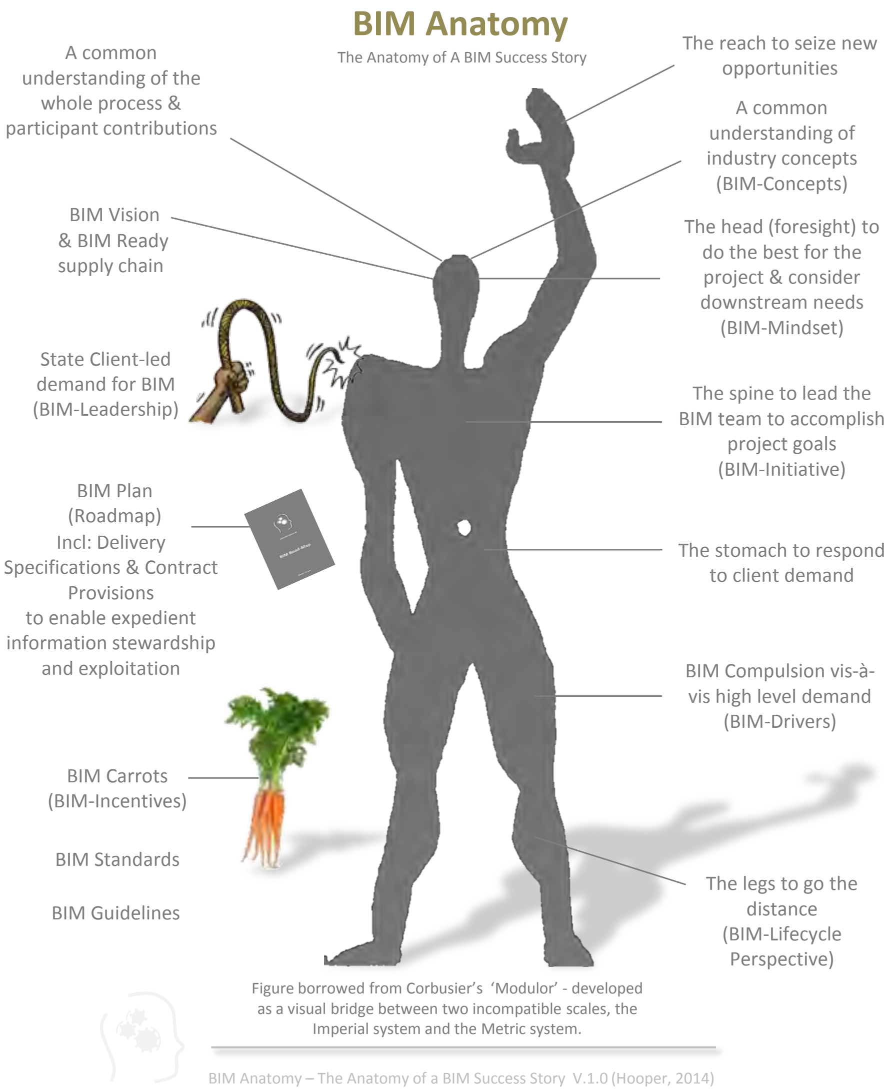


Figure 27: BIM Anatomy – The Anatomy of a BIM Success Story

Note #4: Level of Detail v. Level of Development

In this research both Level of *Detail* and Level of *Development* are referred to. At first glance this may be seen as a lack of consistency of terminology – a grave scientific oversight. But the reasoning is as follows. The AIA's E202[376] published in 2008 defines LOD as Level of Detail and expands on the meaning of various levels (Paper #2&3). Subsequently, in 2013 the AIA

[376] AIA (2008), *AIA Document E202-2008: Building Information Modeling Protocol Exhibit*, AIA and AIA California Council, California, USA.

decided to redefine LOD to mean Level of *Development*. Consequentially Paper #4&5 adopts the most resent terminology and definitions and instead refers to AIA's E203[377] and LOD Specification[378] both published in 2013.

Therefore, the initial referral to LOD as Level of Detail (Paper #2&3) and later referral to LOD as Level of Development (Paper #4&5) is a reflection on the AIA's decision to make this change. The AIA's LOD definitions and BIM Forum's LOD Specification[379] are assumed to be the most important, since they were the first, are the most developed and nations around the world have chosen to adopt them in preference to inventing their own. The UK, Canada, Australia and Norway are examples.

This development is an example of external progress that has emerged during the course of this research project and not intended to confuse or be an error, however, does warrant this expanded explanation.

Note #5: Main Author Contributions in Papers 1-5

Below is a note describing the main author's contribution to the appended papers and background to their status.

Paper #1: *A Pilot Project - Toward BIM integration - An analysis of design information exchange & coordination* - captures results from a pilot test of a BIM implementation plan. The main author together with the second author attended the workshops, the main author wrote the paper with the second author supervising, offering commentary and improvement suggestions. This paper was included in the Licentiate Thesis[380] and is appended here.

Paper #2: *A BIM-Info Delivery Protocol*, is an upgraded journal paper, developed from the conference paper entitled *A Definition of Model Information Content for Strategic BIM Implementation*. The main author attended the workshops, collected the data and wrote the paper. The second author supervised, commented and offered improvement suggestions. This paper was included in the Licentiate Thesis[381] and is appended here.

[377] AIA (2013a), *Digital Practice Documents: E203-2012, Building Information Modeling and Digital Data Exhibit; G201-2012 Project Digital Data Protocol Form; and G202-2012 Building Information Modeling Protocol Form*. AIA, California, USA.
[378] BIM Forum (2013), *Level of Development Specification*, BIM Forum. Accessible: www.bimforum.org/lod
[379] Ibid.
[380] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151
[381] Ibid.

Paper #3: *BIM Inertia – Contracts & Behaviours* emerged from a re-write of a draft manuscript included in the Licentiate Thesis[382] entitled *Contractual Hindrances to BIM Collaboration.* The main author designed and executed the research, collected the data and wrote the paper. The second author supervised the re-write as a book chapter, commented on the paper and offered improvement suggestions prior to submission. This paper is a new contribution and is appended here.

Paper #4: *Automated Model Progression using Level of Development (LOD),* a deep investigation into the concept and application was entirely executed and written by the main and sole author. This paper is a new contribution and is appended here.

Paper #5: *BIM Standardisation Efforts – The Case of Sweden,* a survey to legitimise the work was entirely executed and written by the main and sole author. Comments and improvement suggestions where offer from BIM Alliance Sweden in particular Rogier Jongeling and Olle Samuelson. This paper is a new contribution and is appended here.

[382] Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, LTH, Lund, Sweden. Accessible: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=2972126&fileOId=2972151

Appendix 2: Project Plan as Executed

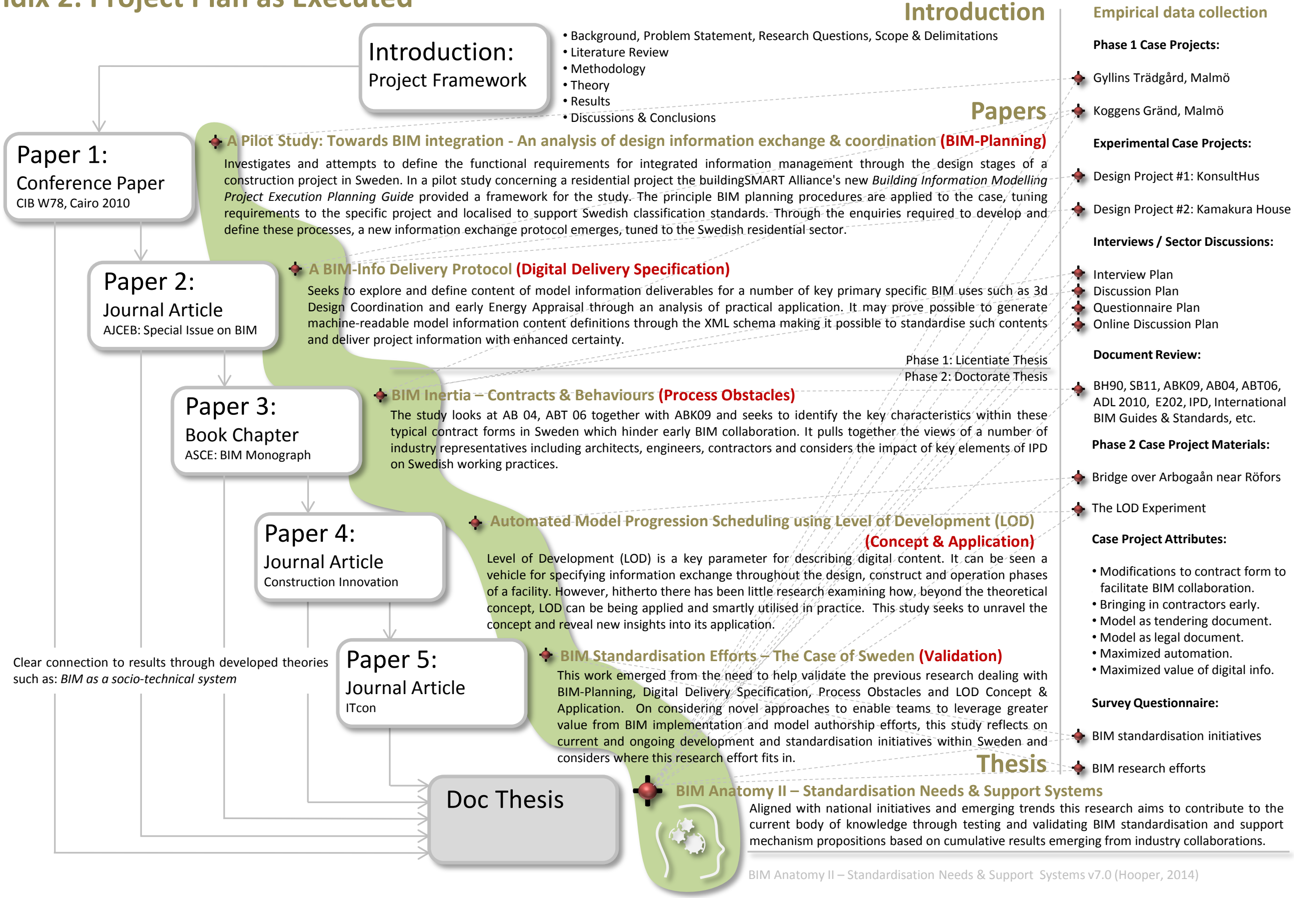


Figure 28: Project Plan as Executed

Appendix 3: Questionnaire used in Paper #5

Introduction

Grateful if you can spare a couple of minutes to fill out this short survey measuring alignment of BIM Standardisation Needs and Research Initiatives:
https://www.surveymonkey.com/s/6TKPMV2

Great if you can respond within a week.

The aim is to determine the level of importance of a number of BIM related themes including: *National BIM Guidelines, Delivery Specification with property set accountability*, and *Concepts for digital info management in Standard Agreements*. You as participant are asked to rank research themes and offer comment on their relevance in a context of national initiatives. In doing so, we hope to ascertain the value and contribution of such research initiatives and position them within a landscape of other national strategic BIM development and standardisation efforts.

The results will be published in a scientific paper, anonymity will be preserved.

5 Survey Questions

Please indicate your discipline: (eg: Construction Client (Public or Private), Owner, Architect, Engineer, Contractor, Supplier, Facilities Manager, Software Supplier, Academic Expert.)

Please indicate levels 1-5

Q1: What has improved since the introduction of BIM and by how much?

Categories: Communication; accuracy; project planning; project result; other.

Q2: Which of the following BIM benefits have you witnessed / experienced in your work and how much?

Categories: Improved decision support; quality of output, productivity, confidence in completeness of scope, other.

Q3: BIM Alliance Sweden through an SBUF project is coordinating local BIM standardisation efforts. Which initiatives are important & how much?

Categories:

- National BIM Guidelines
- Development of Classification

- Co-ordination of information structure BIM & GIS
- Delivery Specification with property set accountability
- Application interface to a common information source
- Format standards & their application
- Development & combination of IFC & LandXML
- Development & Application of BCF
- Concepts for digital information management in Standard Forms of Agreements (Inc. LOD)
- Public Procurement with requirements for BIM deliverables
- Other

Q4: What do you / the industry need help with & how much?

Categories: BIM-Planning, Digital Delivery Specification, Contract & Behavioural Process Obstacles, Concept & Application of LOD, other.

Q5: What is lacking or misaligned in research and national initiatives to support BIM Standardisation efforts?

Comments:

Thank you very much for completing this survey questionnaire.

Distribution of Respondents

- Construction Client (Public or Private)
- Commissioner
- Owner
- Architect
- Engineer
- Contractor
- Supplier
- Facilities Manager
- Software Supplier
- Academic Expert

Paper #1:

A Pilot Project - Toward BIM Integration - An Analysis of Design Information Exchange & Coordination

Type: Conference Paper

Status: Published in 2010
Proceedings of the 27th Annual CIB W78 International Conference - Applications of IT in the AEC Industry, Cairo, Egypt.

Authors: Hooper, M. and Ekholm, A.

A PILOT STUDY: TOWARDS BIM INTEGRATION - AN ANALYSIS OF DESIGN INFORMATION EXCHANGE & COORDINATION

Submission No: 36
Martin Hooper, PhD Student, martin.hooper@caad.lth.se
Anders Ekholm, Professor, anders.ekholm@caad.lth.se
Design Methodology, Department of Construction Sciences, Lund University, Faculty of Engineering, Lund, Sweden

ABSTRACT

Construction projects are costing too much and taking too long as a consequence of unnecessary omissions and errors in project documentation and sub-optimal coordination of design information between consultant disciplines. The theory behind BIM provides an exciting integrated solution for project information management, however in this new process further effort is required to define the content of information deliveries and a number of basic who?- what?- when?- how?- questions relating to object and property definitions need to be resolved.

This study investigates and attempts to define the functional requirements for integrated information management through the design stages of a construction project focusing on architectural practice requirements within the residential sector in Sweden. In a pilot study concerning a residential construction project in Sweden the buildingSMART Alliance's new *Building Information Modelling Project Execution Planning Guide* was applied. The principle BIM planning procedures are applied to the case, tuning requirements to the specific project and localised to support Swedish classification standards. Through the enquiries required to develop and define these processes, a new information exchange protocol emerges, tuned to the Swedish residential sector.

Keywords: BIM, information exchange, design coordination.

1 INTRODUCTION

1.1 Background

In recent years there has been an international explosion of interest in the development of BIM in the construction sector. Actors are gradually developing the skills and personnel to implement BIM and are starting to leverage some of the benefits of working with intelligent 3D objects in a virtual building design environment (Eastman et al 2008).

One reason for an increase in this adoption is that traditionally much project information and development relies substantially on human input and subsequent multiple manual checks and cross-referencing operations which, on complicated projects, inevitably leads to errors or missing information leading to extra cost and waste (Cohen 2010).

Construction projects are becoming increasingly complicated in nature, requiring more specialist discipline input resulting in a much greater volume of technical information which in turn requires to be coordinated and kept up-to-date and relevant through the life cycle of a project. In such contexts conventional project filing systems and information work-flows are becoming un-manageable and there appears to be a need for user friendly practice guidelines to supplement existing standards which if adequately tested, could form a key part of an Information Delivery Manual (IDM) or even a National BIM Standard.

In Scandinavia, where building is generally more expensive than in central and southern regions of Europe (Statistics Sweden, 2009), there is a concern expressed throughout the industry that building productivity must be increased. In conjunction with the new processes implied by BIM for design delivery, construction and facilities management, an industry-informed information exchange protocol should be able to contribute toward providing better value.

BIM, amongst other things, seeks to streamline processes, present construction information in an accessible and common way, minimise the possibility of missing or clashing information and ensure optimised project coordination. The real value of BIM to any organisation be it a design firm, construction firm or building owner, is in leveraging the structured information contained in a building information model to create value (Jernigan 2008).

To implement BIM and tap into leveraging efficiency benefits an organisation must first consider a critical evaluation of its core competencies and business objectives, followed by strategic deployment of appropriate technology to take the guesswork out of business decisions and shift the organisation's output from traditional routine, low-value-added tasks and services toward high-value-added tasks and services (Smith 2009).

For design firms, this means investing in tools and implementing business processes that are essential to increasing efficiency, productivity, profit, and value. There is a need for a new focus on providing sustained value to clients, eliminating or reducing inefficiencies in the process and eliminating repetitive and mundane tasks.

1.2 Problem statement and research questions

The theory behind BIM provides an exciting integrated solution for project information management, however, in this new process a number of key questions need to be resolved: Who is involved? What models are required and why? When are the models needed? What should the models contain? How are the models exchanged? Who manages the process?

Whilst some of these matters may be obvious in a traditional method or design methodology, new processes with new responsibilities are emerging which need to be defined in order to facilitate optimised design co-ordination and integrate BIM into working practices. The research question investigated in this study is how the new process requirements may be handled in a systematic way.

1.3 Purpose and objectives

This study aims to assist in and promote the adoption of BIM technologies in the Swedish architectural, engineering, construction & facilities management (AEC&FM) industry, and try to avoid the uncertainty and disparate approaches that created inefficiencies with the implementation of 2D CAD over the past three decades (Jernigan 2008).

Many business aspects are affected through full and effective BIM implementation. By viewing the implementation process and the act of exchanging information as a role of information stewardship (Smith 2009), the study aims to test and reveal the results of mechanisms facilitating and constraining BIM integration through an analysis of identified BIM uses, designed implementation processes and developed information exchanges.

This objective is pursued by: 1) a study of a residential construction project with a major architectural practice in Sweden; 2) a series of workshops with design consultant participants involved in the development and use of BIM in connection with the studied project; 3) an analysis of empirical data collected by the application of the buildingSMART Alliance's new Building Information Modelling Project Execution Planning Guide (hereafter referred to as the BIM guide) (Anumba et al 2009).

One of the first steps in any research process is to assess the potential for improvement in order to tune the study focus towards a defined purpose in which a valuable contribution towards to development in the field can be realized. The purpose of this initial pilot project is amongst others: to measure and evaluate how far BIM has come in practice; to identify issues of information exchange; to record current practice methodologies; to explore possibilities for improved efficiency and error mitigation; to create an example of set-up guidelines for residential projects; and to develop a proposal for an information delivery matrix.

1.4 Focus and delimitations

This project focuses on information delivery through the design phase of residential projects with the aim of moving towards an optimised system of design material delivery for this type of project. It is intended that further studies will facilitate analysis beyond design stage and out-with the residential sector, however this provides a sound starting point.

The instances of information exchange here centre attention on those commonly understood to be those carried out through the design phase.

2.0 METHODOLOGY

As a starting point an extensive literature review was carried out with particular attention drawn to the various BIM Manual / BIM Guideline documents now emerging around the world through organisations such as the buildingSMART Alliance. Information is not lacking, however, practical experience in moving forward with BIM beyond office boundaries in Sweden still is in its infancy.

Following an investigation of existing literature and other published guidelines, the BIM Guide provided a suitable supporting platform to launch a study focused on shaping an overview of the use and benefits of BIM on a typical residential construction project and exercising a method of reaching a common agreement with regards to information exchange and extent of implementation.

2.1 Case study design

The case study is preferred in examining contemporary events and when relevant behaviours cannot be manipulated. Two important sources of evidence are: direct observation and systematic interviewing. The case study's strength is its ability to deal with a full variety of evidence - documents, interviews, and observation - beyond what might be available through other research approaches (Yin 2003).

Through its natural setting, the case study provides an ideal practical real-life context and a suitable grounded platform to consider and test strategic decisions with regard to information exchanges thereby creating an opportunity to introduce a move towards BIM implementation in practice.

A pilot project has been launched, establishing a collaboration between academic experts at Lund University and industry through White Architects. The purpose is to initiate a strategic study centring on the question of BIM implementation in construction, and specifically information exchange, with an aim to solve some of the structural and organisational issues associated with this new working method in Sweden.

Common goals are to establish a documentable and transferable method of overcoming difficulties in implementing BIM focusing on practical solutions to advance information exchange.

The known attributes of this case project fit well with the opportunities to break new ground in BIM implementation. The project's simplicity, reality, and that it is at an early stage of development present an opportunity to make a fresh start and facilitate optimal leverage of results. Its relevance to the generic problems outlined in the problem statement and transformed into research questions are direct and represent real practical issues to be solved. The study provides a basis for a deeper understanding of specific practice-related issues in their natural setting.

Since new build housing represents a significant market within the construction industry - not least in Sweden - this case study project may be deemed typical as an instance to study. The case being typical, it is likely that the findings can be generalised and therefore applied elsewhere.

2.2 Data collection and case description

The collection of empirical material has been assembled to firstly facilitate a deeper understanding of the context in which BIM is being adopted and used and secondly articulate the current status of BIM implementation in the organisation under study.

To meet these objectives a series of workshops where carried out in connecting with the Gyllins Trädgård project together with the project architect and BIM experts within White Architects organisation. The project is live and provides a real-world setting for the study, facilitating a grounded source of valid data collection.

Through the enquiries required to develop and define the BIM implementation processes described in the BIM guide, valuable data has been collected, organised and analysed. The guide's planning procedures forms the basis of the dialog with White and has enabled a pedagogical and thorough approach whereby data has been collected for the purposes of analysis and system optimisation for future projects.

3.0 THEORY

A number of national standards and BIM guideline documents exist around the world. Amongst other things, it is the task of the buildingSMART alliance to harmonise documentation and BIM implementation methods on a national and international level. The US NBIMS was one of the first comprehensive national standards (NBIMS 2007), with Norway, the Netherlands, Denmark and Australia also producing various forms of national guidelines (eg Denmark's 3D Arbejdsmetode).

In Sweden the principle guidelines are to be found within *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt. Del. 8: Digitala leveranser för bygg och förvaltning* (SI 2008). This document contains guidance on the administrative aspects of BIM with reference to other Swedish standards, however lacks a strategic standard method of planning and agreeing amongst project team members a process of BIM implementation with a focus on information exchange. Here the buildingSMART alliance's BIM Guide may be able to bridge the gap.

The BIM guide is a product of the BIM Project Execution Planning buildingSMART alliance™ Project and was developed to provide a practical methodology for project teams to design their BIM strategy and develop a BIM Project Execution Plan. The main concepts behind the guide have been developed to complement the long term goals of the buildingSMART alliance in the development of a standard that can be implemented throughout the AEC&FM industry to improve efficiency and the effectiveness of BIM implementation on projects.

4.0 IMPLEMENTATION

4.1 Case Study: Gyllins Trädgård

The pilot study follows a residential project currently on the drawing board within White Architects Malmö office: Gyllins Trädgård.

Designed to assist White integrate BIM into their working practices, this case project was selected based on that, at time of researching, it was at a suitably developed stage and fulfilled the necessary criteria in terms of participant interest and generic simplicity to implement and test the results of a BIM process centred on an effort to standardise and control information exchange.

At Gyllins Trädgård MKB Fastighets AB plans to build 87 residential units for rent within 9 buildings of 2 to 4 storeys. The project will include 2, 3 and 4 room apartments between 62 and 95 m2. MKB, have provided the project consultants with a CAD-coordination manual which stipulates the client's expectations with regards to the use of 3D design tools and for some of the design team members it is the first occasion of working with 3D coordinated models.

Figure 1: Gyllins Trädgård - Marketing Images (White Architects)

4.2 The buildingSMART alliance™ BIM Project Execution Planning Guide & Gyllins Trädgård Project

The BIM guide details a method for creating and implementing a structured BIM Project Execution Plan and it is proposed that the principle BIM planning procedures outlined in this document be carried out and applied to the case, tuning requirements to the specific project: Gyllins Trädgård. In doing this, this opens opportunities to push forward the frontier of research in this area and identify what is missing from existing models.

This new BIM protocol allows this pilot project to take off where existing information and guidelines left off and provide a platform to move forward with BIM in earnest in a Swedish context and a sound basis for initial dialog, facilitating a method to responding to a number of information exchange issues. Further local refinement might identify the conditions necessary for success and the barriers which might limit a full implementation and associated leverage of system benefits.

The guide is well aligned with the scope and purpose of this study and focuses on defining the necessary information exchanges through a step-by-step planning procedure:

1. Define project and team value through the identification of BIM goals and uses.
2. Develop a process which includes tasks supported by BIM along with information exchanges.
3. Develop the information content, level of detail and responsible party for each exchange.

4.3 Concepts to be tested in the pilot study

It is proposed that a number of important key concepts relating to project coordination and information exchange are tested in connection with a live residential project in Sweden. These include a formal method of establishing answers to the basic who?- what?- when?- how?- questions outlined in the problem statement as well as testing the principles of developing a BIM implementation plan while seeking to promote the development of consistency within the industry with organisational concepts that are simple and flexible.

4.4 Step 1: Identify BIM goals and uses

One of the most important steps in the BIM planning process is to clearly define the potential value of BIM on the project and for project team members through defining the overall goals for BIM implementation. These goals could be based on project performance and include items such as reducing the schedule duration, achieving higher field productivity, increasing quality through offsite fabrication, or obtaining important operational data for the facility. Goals may also relate to advancing the capabilities of the project team members, for example, the owner may wish to use the project as a pilot project to illustrate information exchanges between design, construction and operations or a design firm may seek to gain experience in the efficient use of digital design applications. Once the team has defined measurable goals, both from a project perspective and company perspective, then the specific BIM uses on the project can be identified (Anumba et al 2009).

A BIM use is a unique task or procedure on a project which can benefit from the integration of BIM into that process. Several examples of BIM uses include design authoring, 4D modelling, cost estimating, space management and record modelling. The team should identify and prioritize the appropriate BIM uses which they have identified as beneficial to the project.

The BIM guide provides users with template documents to help record and develop their project-specific BIM implementation plans.

4.5 Data collected (Workshop No. 1)

The initial workshop centred around a line of questioning facilitating population of a *BIM Goals* and *BIM Use Analysis* worksheets in connection with Gyllins Trädgård. The purpose of these worksheets is to assist project team members in the development of BIM Goals and the selection of BIM Uses based on project and team characteristics.

The design team identified a number of key BIM goals, each allocated with a priority rating and a potential BIM use. It is essential to identify the specific goals that will provide incentive for implementing BIM on a project basis, with consideration to potential benefits, team competencies and technical resources.

Table 1: Extract from BIM Goals Worksheet - Gyllins Trädgård

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Reduce design failures	3D Design Coordination, Quantity Scheduling
3	Optimise building rational	Phase Planning (4D Modelling), Site Utilization Planning
1	Establish early control of areas / spaces / relationships	Area Scheduling, 3D Design Coordination

High priorities are to reduce field conflicts through well coordinated 3D design and to be able to leverage data to deliver and control design parameters such as the accommodation schedule against client requirements. These goals were readily implemented by the design team through the deployment of 3D parametric design authoring tools and capable staff.

By identifying such goals the design team made a first step in planning for a level of BIM implementation. The definition of project team BIM goals allows individuals to understand each other's contribution and outlines the motivations behind the forthcoming information exchanges.

Next, the identified BIM goals are translated into actual BIM uses. The relationship between BIM goals and uses is interpretive and in which a common understanding and agreement is reached through early collaboration and planning.

With each use that's being considered, at least one responsible party is identified. Building information data should ideally be entered only once during the building or information lifecycle by the most authoritative source. By reviewing and formally agreeing who is responsible for what information, it enables building information to be coordinated by the correct source, allowing that data to maintain optimum value.

Table 2: Extract from BIM Use Analysis - Gyllins Trädgård

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)					YES / NO / MAYBE
				Resources	Competency	Experience			
3D Design Coordination	High	A	High	3	3	2			**Yes**
		MEP	High	3	3	2			
		SE	High	1	1	1	Training in Revit required	Revit coordination & 2d dwg	

Through auditing a capability rating against each BIM use, responsible parties make an objective judgement with regards to their resources, competency and experience - in other words their professional ability to carry through the BIM use. Together these parameters lead project teams to decide whether or not to proceed with a proposed BIM use. In the case of Gyllins Trädgård, however, a number of aspirational BIM uses were pursued to test results against traditional methods.

4.6 Appraisal

Through this stage of the planning procedure, value is captured by team members articulating the BIM uses to pursue and developing a common understanding of joint goals. Extracted from the BIM use analysis template the plan includes, the following strategic choices can be evaluated as follows:

- *3D Design Coordination:* Here, utilizing collision control tools together with an iterative process of design refinement a significant step forward in the preparation and delivery of a coordinated design information has been realised (see Figure 2). By mitigating potential field conflicts more effectively in 3D, greater cost certainty can be achieved.
- *Design Authoring:* By using BIM tools to generate a composition of parametric objects, the model creating process ensures proper alignment and facilitates a degree of automatic correction - such as adjusting a wall and window schedule in the event of a window deletion - thus reducing the need to manually manage design changes.
- *Design Reviews:* Regular design team meetings with the model as review platform allowed on-the-spot group design decisions to be made, driving an iterative design process, using data to support solutions.
- *Cost Estimation:* Although not completely BIM automated, cost estimates were carried out at incremental stages with increasing level of detail. Quantities were manually extracted but then checked against the models automatically generated quantity schedules. Confidence is still lacking in the accuracy of BIM quantity and cost data amongst some industry professionals however, efforts to test and compare results should in time address this concern.
- *Digital Fabrication:* Here information for the off-site manufacture of timber trusses was released. Whilst not entirely BIM automated, geometric information was extracted from the BIM and augmented with information that was necessary for the CNC machines to interpret and implement the appropriate

manufacturing operations. Early enquiries to ascertain exactly what information the prefabricator needs for his machines could further streamline this area and mitigate re-work.

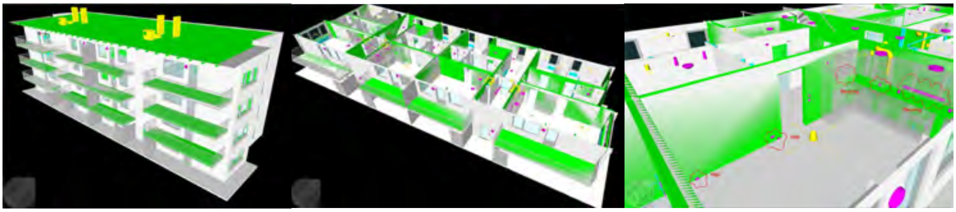


Figure 2: Gyllins Trädgård - Coordination Model (White Architects)

4.7 Step 2: Design BIM project execution process

Once the team has identified the BIM Uses, a process mapping procedure for planning the BIM implementation can be performed. Initially, a high level map showing the sequencing and interaction between the primary BIM Uses on the project is developed. This allows all team members to clearly understand how their work processes interact with the processes performed by other team members. First the high level (Level 1) map is developed (see Figure 3), then more detailed process maps can be added by the team members responsible for each detailed BIM use. The high level map shows how the BIM authoring, energy modelling, and cost estimating, are sequenced and interrelated. The secondary detailed maps records the detailed processes that will be performed by an organization or in some cases several organizations, such as the energy modelling.

Engaging the design team in this process goes some way to determining the 'who' and 'when' questions previously cited.

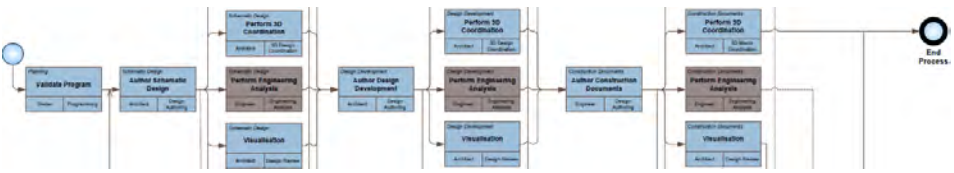
4.8 Data collected (Workshop No.2)

A second workshop was scheduled to record relevant information to facilitate the design of BIM *Execution Process Maps* for Gyllins Trädgård. The overview map below (see Figure 3) shows the relationship of BIM uses which will be employed on the project. This Level 1 process map also contains the high level information exchanges that occur throughout the project. Fundamentally the BIM use work packages or processes develop in information maturity as the task passes from *schematic design* through to *construction documents*.

The BIM uses are arranged according to project sequence, helping to communicate the phasing of each BIM use and define implementation sequence. Responsible parties for defining the information required to implement the process as well as the information produced by the process are identified and graphically notated.

Detailed BIM Use Process Maps are created for each identified BIM Use to clearly define the sequence of various processes to be performed. These maps also identify the responsible parties for each process, reference information content, and the information exchanges which will be created and shared with other processes. Here, beyond BIM process sequencing, dependencies between the processes are defined by considering the connections between processes. Gateways provide opportunity to represent decisions, design iterations or quality control checks.

Figure 3: Extract from BIM Execution Process Map - Gyllins Trägård - Level 1: BIM Execution Planning Process



4.9 Appraisal

This process aims to determine which party is the best authoritative source for a particular piece of information, and what pieces of information each source or design participant needs to provide to others to enable those third parties to perform their tasks. The Level 1 process map allows team members to map what it does, what information it handles, and whether it is the optimum responsible party for that information.
By mapping BIM uses, processes and ultimately information exchanges in this way, it enables the design participants to:

- Appreciate new types of information a team member may be able to share that might be useful to others;
- Which information, provided by others, could help a team member perform its function better;
- How information is used in each team member's business processes and how it flows through their business systems;
- Focus on delivery of real services thus reducing or eliminating low-value data entry tasks;
- Opportunities to eliminate overlaps, redundancies or abortive work;
- Identify information exchanges that accelerate iterative workflow cycles.

The process of simply entering into dialogue and mapping BIM uses and associated work flow can help an organisation discover an ability to exchange information internally among different software applications that it previously didn't know, or that information created for previous projects may now be exploited more effectively for future projects.

The fundamental advantage of agreeing and recording such procedures is that it enables the team members to understand each other's tasks and work towards common goals that are often interdependent on information supplied by each other.

4.10 Step 3: Define Information Exchange Requirements

Once the appropriate process maps have been developed, the information exchanges which occur between the project participants can be identified. It is important for the team members, in particular the author and receiver for each information exchange transaction, to understand the information content.

This information content for the exchange is defined in the Information Exchange table. Here, consultants develop a chart mapping information exchange content, level of detail and responsible party for each exchange. This procedure identifies the vital information required to implement each BIM Use as defined previously.

The purpose here is to document the information that must be passed from one organization (responsible for a BIM use) to enable another to progress with their business process. When information is delivered in the form and quality expected, an efficient workflow is achieved.
In order for meaningful and enabling information to flow, a number of key factors need to be considered:

- The format of the information (type);
- A description of the concepts used / information to be exchange (what) and when;
- A common understanding of each design team member's information needs.

Once defined, an information exchange matrix can form the basis for parties' data interchange, allowing the information to be treated as an asset enabling efficient BIM processes and regulating information sharing between design team participants.

4.11 Data Collected (Workshop No.3)

A third workshop enabled collection of data to complete the BIM plan's Information Exchange Worksheet. This worksheet was developed to aid the project team to define the information required to implement each BIM Use with maximum efficiency. The mission here is to record information delivery expectations against a model element breakdown (the intention is that this should concur with the local classification system) through the scheme design, design development and construction documents stages for each BIM use.

Parties can share a strategic insight into the content, format, responsibility and timing of information exchange enabling optimised efficiency in data exchange through the design period.

Table 3: Extract from Information Exchange Worksheet - Gyllins Trädgård

BIM Use Title	Design Authoring (Schematic Design)			Cost Estimation			3D Coordination			Design Reviews			Energy Analysis			Design Authoring (Design Development)		
Project Phase	Design			Design			Design			Design Reviews			Design			Design		
Time of Exchange (SD, DD, CD, Construction)	SD			SD			SD			SD			SD			DD		
Responsible Party (Information Receiver)	A, SE, MEP			Cost Consultant			A, SE, MEP			A, SE, MEP			Energy Consultant			A, SE, MEP		
Receiver File Format	Revit *.rvt Acad *.dwg						Navisworks *.nwd			Navisworks *.nwd			Acad *.dwg			Revit *.rvt Acad *.dwg		
Application & Version	Revit V.10, Acad, MagiCad						Navisworks V.10			Navisworks, PowerP			VIP +			Revit V.10, Acad, MagiCad		
Model Element Breakdown	Info	Resp Party	Additional Information	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Additional Information	Info	Resp Party	Additional Information
A SUBSTRUCTURE																		
Foundations																		
Standard Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE					B	A/SE	
Special Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE					B	A/SE	
Slab on Grade	A	A/SE		A	A/SE		A	A/SE		A	A/SE					B	A/SE	

4.12 Information Levels

Key to aligning data exchange expectations within project teams is a system for describing information content. In Denmark (bips 2006) and Australia (CRC 2009) similar systems suggesting a hierarchy of information development levels have been articulated. Both systems suggest 7 development information levels ranging from brief to post construction. Representing a simple form of information maturity, an abbreviated information levels code can identify information maturity expectations.

4.13 Appraisal

In a scenario of a heavily laden information model being present, defining information exchanges becomes a critical operation to enable one to distinguish the wood from the trees and avoid laborious and time-wasting filtering exercises. A common frustration in practice occurs when information supplied by another is not what was expected or is of insufficient quantity or quality to carry out the immediate task without additional or subtractive operations. Every element of a project does not need to be present to be valuable therefore, it is important to only define the model contents that are necessary to implement for each BIM use.

If a receiver of information wants to be sure he or she can utilise the information received, the sender and receiver need to agree on which information to exchange. For example, an architect needs to be sure that he receives information from the structural engineer as regards which walls and columns are structurally load-bearing. Similarly, the structural engineer needs to know the use characteristic of the enclosures in order to calculate the correct design loads.

For BIM to be implemented successfully, it is critical that team members consider the future use of the information that they are developing - when the architect adds a wall to the BIM, that wall may carry information regarding the material quantities, structural and thermal properties. The architect needs to know in what way this information will be used in the future. The future use of this data can impact the methods used to develop the model content, or identify quality control issues related to the data accuracy for subsequent tasks relying on the information.

5.0 CONCLUDING DISCUSSION

The buildingSMART Alliance's BIM guide presents a valuable method of determining important prerequisites for effective BIM implementation. Together the BIM plan's planning procedures enable team members to gain a strategic insight into the who?- what?- when?- how?- questions relating to information exchange. The process facilitates a rational of continuous improvement by enabling teams to identify areas where processes are suboptimal and offers meaningful and flexible direction to achieving BIM integration and scope to identify opportunities for standardisation.

It can be observed that some technologies are not being used to their full advantage but enthusiasm amongst design consultants has pushed teams to experiment in parallel with traditional methods in a hunt for confirmation of usefulness.

However, what is problematic is that often project teams have varying levels of competence and willingness to partake in an iterative design process where fees are spent before they're earned. With new processes comes new relationships and organisations, firms cannot afford to view their contribution in isolation. At times it can be a struggle to obtain a consistent information level across all disciplines in a similar time frame but parallel processes are enabling a higher quality of design service to emerge which more and more clients are demanding.

One thing is clear, however, and that is that the participants all recognise the benefit of working in close collaboration from the early stages through design development. The possibility to make early and informed decisions through the use of technology to leverage a high level of quality information at the right time in the process has enormous potential to improve the state of the construction industry by injecting greater certainty.

It was noted that the drive behind BIM on this project has come from the client who has supplied a CAD-Manual detailing a base contractual requirement to produce 3D coordinated models for delivery to the contactor. There is the suggestion that many design consultants in Sweden are committed to implementing BIM since it is being demanded by more powerful actors. They see BIM as the means of addressing design challenges with which they are now faced. They believe that if they do not accept this challenge now, they will be overtaken by their competitors.

White Architects face a transition period between old practices and new while still meeting day to day programme requirements and deadlines. There is an inherent element of risk in changing practice working methods, however, such pioneers are beginning to realize efficiency gains. Although the extent of BIM usage here was somewhat immature, the focus is on perfecting the areas were BIM implementation is successful and were results are trusted. Secondary BIM possibilities are being investigated in parallel, and with experience on the rise, confidence should follow and enable extended uses and greater efficiencies to be leveraged.

As more industry professionals gain a greater understanding of the value of building information created not just through the design phase but through the whole building life-cycle, and learn to manage their own information accordingly, more will be able and willing to engage in value-added information exchange.

This process of attempting to define information exchanges for each relevant BIM use is closely tied to the development of the Information Delivery Manual (IDM) and Model View Definition (MVD) in which exactly which information is to be exchanged in each exchange scenario is specified (buildingSmart 2010). If developed into MVDs the exchange requirements should be assembled into re-useable concepts mapped to specific objects, properties and relationships present.

The conclusion of this preliminary study naturally leads to the development of a more extensive study of information deliveries and standardisation needs using BIM to enable findings to be generalisable and conclusive.

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Paper #2:

A BIM-Info Delivery Protocol

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Authors: Hooper, M. and Ekholm, A.

A BIM-Info Delivery Protocol

Martin Hooper, PhD Student, Design Methodology, Department of Construction Sciences, Lund University, Sweden

Anders Ekholm, Professor, Design Methodology, Department of Construction Sciences, Lund University, Sweden

Abstract

Today, with many of the technological matters of integrated information management resolved (perhaps excluding the matter of interoperability), defining the content and status of BIM information deliveries remains both a practical and theoretical problem.

New BIM tools and new design processes and procedures have led to a certain confusion of what information is needed when for particular BIM uses. This paper seeks to explore and enable a method of defining the content of model information deliverables through a review of 2 key primary specific BIM uses: *3d Design Coordination* and *Early Energy Appraisal* through an analysis of practical application.

The scope of this study is limited to a review of information flow within residential projects in a Swedish context and looks at two case projects with a view to identifying and establishing a common definition of the key BIM objects and properties necessary for particular tasks.

The key deliverable from this study is the BIM-Info Delivery Protocol (IDP) which attempts to align consultant BIM-Info delivery expectations and represents a tangible solution to assist consultant disciplines manage BIM-Info. Concluding reflections consider the positioning of the IDP relative to the ongoing development of IDMs / MVDs and highlight the key constituent parameters of an Information Delivery Specification (IDS).

Keywords: BIM, Building Information Modelling, information exchange, model information content.

1. Introduction

1.1 Background to Study

The context of the study is directed toward the Swedish Design-Construct-Operate (DCO) sector where the concept of *Leveransspecifikationer* (Delivery Specifications) is suggested within the national guidelines for digital information management: *Bygghandlingar 90 – Byggsektorns Rekommendationer för Redovisning av Byggprojekt – Digital Leveranser för Bygg och Förvaltning* (Swedish Standards Institute, 2008). These guidelines recommend the use of delivery specifications to accompany exchanges in digital information at all stages of the design, construct and operate process. However, there is a lack of concrete advice on how to develop information delivery specifications for defining and recording BIM-Info content in connection to or supporting a project based strategic BIM Implementation Plan.

Information is not lacking, however, practical experience in moving forward with BIM beyond office boundaries in Sweden still is in its infancy and there is hitherto an absence of developed examples of delivery specifications to accompany national standards.

1.2 Goals and Research Questions

This study has two goals. The first is to explore and enable a method of defining the content of model information deliverables through a review of 2 key primary specific BIM uses: *3d Design Coordination* and *Early Energy Appraisal* through an analysis of practical applications. The second is to design an associated process that ensures integration of information deliveries into a project plan, thereby securing greater certainty and efficiency of information exchanges.

The central research questions for these goals are as follows:

- How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis?
- Could a standard matrix be established that can be used for various BIM-Uses at various project stages that would help align information delivery expectations?

To answer these research questions five sub questions need to be answered:

- What BIM-Info is needed at what time to enable efficient BIM Discipline Authoring toward e.g., rapid 3d Design Coordination at Design Development Stage?
- What BIM-Info is not needed? – Clarity is needed on what BIM-Info is not relevant at particular stages.
- What level of detail is needed to carry out BIM-Uses at various stages?
- Is there a logical information order?
- What is the logical information order of authoring BIM-Info for early Energy Analysis when it comes to generating BIM objects?

1.3 Problem Status

Whilst organisations such as the buildingSMART Alliance are investing considerable resources towards developing AEC industry standardization in information exchanges, until understanding, control and trust can be gained in the use of IFC, IDM and MVD by DCO participants, a simpler system of describing information content requirements is essential to BIM implementation today on a consultant practice level.

Without a straightforward way of creating project specific IDM's, a clear understanding of the content of MVD's, and the ability to control information flow through such methods, trust may wither and die. Thus the driver for this study: the urgent need for a simple, user-friendly method of describing, in a commonly understood way, information deliverables.

1.4 Hypothesis

Perhaps a simpler method of generating IDM's and MVD's using commonly available tools within organisations would have greater mileage than those developed by external agents. Here it is conjectured that, as a valid alternative, BIM-Info Deliveries developed by architects and engineers for architects and engineers may offer the control, confidence and simplicity necessary for effective information exchange success.

In order for industry professionals to get the best out of BIM tools and work efficiently, one needs a big picture understanding of information need, honing individual tools and processes towards greater efficiency and certainty. Key to doing this is a thorough documentation of one's own business processes – use of a BIM-Info Deliveries Protocol as part of a BIM-Implementation Plan may offer an immediate and tangible solution.

2. METHODS

2.1 Research Design

The research design has been flexible from the start to enable the framework of reference to emerge during the study. Literature review - including national standards guidelines and industry press – together with consultant interviews and discussions revealed a real need for the development of BIM-Information delivery specifications to support cross-discipline communication and downstream use of data. To move forward, two case projects were identified. The first to enable a closer examination of the issues involved. The second to test a protocol proposal and enable categorization the building parts and level of detail required for a set exchanges against a specific BIM-Use.

The case study's strength is its ability to deal with a full variety of evidence - documents, interviews, and observation - beyond what might be available through other research approaches (Yin 2003). Here, two important sources of evidence are: direct observation and systematic interviewing.

Through its natural setting, the case study provides an ideal practical real-life context and a suitable grounded platform to consider and test strategic decisions with regard to information exchanges thereby creating an opportunity to introduce a move towards a greater clarity of purpose and improved efficiency in information sharing.

2.2 Data Collection and Case Description

The collection of empirical material has been assembled to firstly facilitate a deeper understanding of the circumstances and context of the information exchanges necessary to implement the said BIM-Uses and secondly study the BIM-Content to be exchanged at object-level.

To meet these objectives a series of design coordination workshops where carried out in connection with a (real world) residential case study project (Koggens Gränd) facilitating collection of empirical data, together with the generation and examination of a controlled experimental model (KonsultHus).

The known characteristics of this first case fit well with the opportunities to break new ground and strive towards improvements in information management and uncovered a raft of issues to address. The second case enabled the extraction of more detailed information to populate the delivery specification.

2.3 Case #1: Koggens Gränd - Malmö's first owner-occupier flats

Located in the Västra Hamnen area, Malmö, Koggens Gränd is an innovative new residential block with occupancy expected through 2012. As part of a larger development incorporated in the regeneration of Västra Hamnen the scheme presents 31 owner-occupier flats, between 45-72m2.

Prior to May 1, 2009 in Sweden it was not authorized to build owner-occupier flats as new build or through renovation of existing buildings. Koggens Gränd represents one of Sweden's first residential building containing owner-occupier flatted units on a larger scale.

Figure 1: Koggens Gränd – Source: White Arkitekter

The researcher followed this project through its early stages, recording matters relating to 3D Design Coordination and collected further empirical data relating to requirements and procedures for this BIM-Use. In addition, common current practice methodologies were documented with a view to identify key issues to address. Through this case study, a thorough examination of the common issues hindering work-flow of 3D Design Coordination and early Energy Analysis operations was enabled.

2.4 Case #2: KonsultHus - An Experimental Coordination Model

Empirical data reflecting the results from this experimental model, which was developed and used by the author for this study, has enabled collection of further, more detailed information, eliminating unwanted variables, and facilitating a more precise examination of objects and properties required for 3D Design Coordination. 3D Design Coordination implies close collaboration and, on complicated projects - a frenzy of information exchange. For this reason it is critical to record and optimise information flow for this BIM-Use. Here it was examined what BIM-Info one needs to share with each other to allow for example:

- the MEP consultant to proceed with design for plant requirements, ventilation duct sizing and routes, plumbing fixtures and pipe routes, drainage integration, incoming service routes and;
- the Structural consultant to proceed with design for the foundations and structural frame.

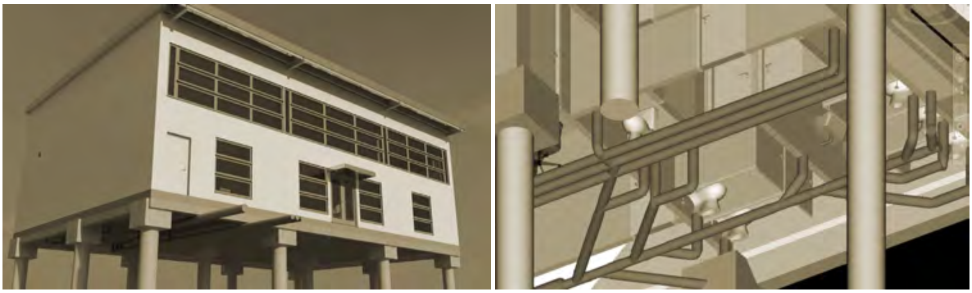

Figure 2: KonsultHus – An Experimental Coordination Model

It is clear that in order to optimise design information production and flow, parties must have at least a modest understanding of each other's information needs and, moreover; if you are not specific about the information you need, how can you be certain you'll get it?

Complaints of holding each other up because of lack of design information, or deliberately holding back design contributions until 'the architect has frozen the design', no longer washes with today's parallel BIM processes and collaborative design environment. Through this case study, an experimental exchange protocol was tested to help monitor the creation, distribution and timing of discipline BIM objects on a need-to-know basis.

3.0 A STATE OF THE ART REVIEW

Many studies have been carried out to investigate, test and report on process development in the domain of BIM, not least information exchange and collaboration. Furthermore many studies still report difficulties and barriers both technical (such as interoperability) and non-technical (such as organisational and team communication). (Pazlar & Turk 2008) for example reports *data distortion and IFC interfaces not working as expected*, (Pfitzner et al 2010) reports on barriers relating *project organisation and commitment among project team members to collaborate.*

Much of the existing research focuses on identifying existing barriers, this paper concentrates on developing a simple tool that may help overcome certain communication barriers.

Here in Sweden, particular hindrances to efficient information exchange in the context of BIM-Uses could be said to reside in under-developed national guidelines (Bygghandlingar 90) and the immaturities of the technical initiatives of the buildingSMART Alliance (including IFC, IDM's and MVD's).

3.1 Bygghandlingar 90 & Delivery Specifications

This publication (Bygghandlingar 90, 2008), represents Sweden's chief guidelines for delivering digital information in connection with construction projects and is a valuable source of logical recommendations for managing building information in an organized and careful manner. However, it does not represent a BIM Standard and requires some development in a number of areas including that of BIM-Info Delivery Specifications. The output from this study aims to provide practitioners with a useable tool to address this deficiency and help the industry move towards procedural standardization.

3.2 buildingSMART Alliance Initiatives

Among the foundational standardization efforts of the buildingSMART alliance and its worldwide counterparts are the Information Delivery Manuals (IDMs) and Model View Definitions (MVDs). These are examples of the sector's collective recognition that better information is needed to support the development of better tools now emerging to deliver construction projects (Smith & Tardif 2008). Technologies such as IDM and MVD are intended to help identify exactly what that information is by defining, for example, a model definition view for automated code checking and the information that must be included to generate that view. However, this is work in progress and is still a long way off being available for all DCO participants; as is the full capabilities of IFC.

4.0 Implementation

4.1 BIM-Info: A Consultant Perspective

Whilst many consultants are demonstrating a strong interest in BIM there is a possible lack of practical knowledge in applying current technology and leveraging the much bragged about benefits of BIM. Other research (Gu & London 2010) has revealed that DCO participant concerns primarily focus on practice, process and technical related issues. Here, through the events and discoveries revealed in particular through case #1 within this study, the following observations are highlighted:

- Significant uncertainty exists amongst design team participant as to exactly what information to provide for each 3D Design Coordination Meeting.
- Because of a lack of clarity, there was certain carelessness in providing quality BIM-Info.
- Quality checks on BIM-Info deliveries appear to be missing or inadequate prior to issue.
- Apprehensions exist in delivering incomplete work or work in progress - suggesting a need for an additional BIM-Info status classification: WIP (work in progress).
- Some design participants were reluctant to engage in design work and contribute to a developing design process prior to the Architects layout being 'frozen'.
- Limited time / budget for design changes or iterations for specialist design participants - instead of productivity gains being fruitfully utilised to optimise the design, it presented an opportunity for some consultant organisations to simply take on more work.
- Among all participant disciplines, the architect was the most active member in attempting to resolve communication issues and align design team expectations in terms of information delivery and content requirements.
- Digital communication and information storage was established through a web portal to a project server. This enabled logging of all communications and a database for all current and live information.
- Folders were set up with associated access rights for each discipline enabling design participants to upload information in a commonly understood fashion.

4.1.2 Key Issues

The emerging key issues that can be identified in connection with the above observations can be categorized and summarized as follows:

4.1.2.1 Practice issues:

- Whilst project team members display enthusiasm and general interest for implementing BIM, there appears to be a lack of a common understanding of what it entails not least in terms of BIM-Info deliverables.
- Time commitment in the early stages presented difficulties and frustration, suggesting a resistance to change or flawed time planning.
- Some localised competence issues in the use of 3D BIM authoring tools / lack of thoroughness in delivering quality information.

4.1.2.2 Process issues:

- Willingness to collaborate and contribute towards the project design on the same information level (LOD) as others within the same timeframe was problematic, suggesting the need for stronger culture of BIM Implementation Planning together with a method of clearly articulating BIM-Info Deliveries.

- Quality Control and validation of delivered BIM-Info was often left to the receiver to sort out - leading to down time for file clean-ups, deletion of duplicate objects etc.

4.1.2.3 Technical Issues:

- Naturally, not all design participants used to same BIM tools for model authoring. The transfer of MEP BIM-Info into the multi-disciplinary model for collision control presented problems. Here a lack of trust in data integrity emerged. The completeness and accuracy of 3D models remain a major concern for the design team.

4.2 Difficulties

In addition, derived from the case #1 design team meeting observations and case #2 practical experiments, a number of specific difficulties were identified relating specifically to 3D Design Coordination and early Energy Analysis.

3D Design Coordination – Common Problems:

- 1000’s of collisions identified late in the design process with little opportunity to correct or solve them.
- Early agreement on tolerance levels is critical including clearance between own discipline objects and other discipline objects.
- Accountability for the maintenance and coordination of objects and properties must be clear.
- Agreement of procedure for managing changes to the design required to mitigate or remove hard, clearance or duplication collisions.
- Missing voids - Lack of accounting for voids for services including type, purpose, discipline, responsibility for correctness.
- Where objects are within the domain of both architect and structural engineer and in addition require input from the services engineers with regards holes etc, difficulties can arise through duplication.

Energy Analysis – Common Problems:

- No clear direction of what objects and properties are necessary for which analysis at what stage.
- Tendency not to focus on authoring the right information at the right time.
- Analysis carried out too late to have any pro-active impact on the design.
- Analysis results miss-interpreted.
- Analysis carried out by external consultant at a single point in time / results not acted on.
- No clear agreement or procedure for managing changes to the design to reduce energy consumption.
- Analysis carried out to confirm suspicions instead of to inform design and drive toward optimised solution.
- Major change in design instructed, focus on energy diminished or extinguished.

This evidence suggests that action is required to address these uncertainties and communication malfunctions. What is needed to combat these failures is clear and user-friendly articulation of process, what it involves and what information needs to be delivered by each party, when.

4.3 BIM-Info Deliveries

As a valid alternative to the rather cumbersome and overly complicated MVD's being developed by the building SMART Alliance and others, this paper offers a simple method of defining, on a project basis, information deliveries for specific BIM Uses.

It has been suggested that if the industry is to move forward with BIM implementation, firms must focus on perfecting what they can deliver (Jernigan 2008). Initially this means reaching for the low hanging fruit such as 3D Design Coordination (through use of collision control tools) and early Energy Analysis (through use of built-in or associated energy simulation tools).

Both these BIM uses instantly add value to the DCO process and product and can be considered strategic, straightforward targets for consultant organisations to master in an efficient manner. What is problematic, however, is for team members to arrive at the same place at the same time with regards to BIM-Info quality and completeness. This is particularly critical in the context of the successful execution of various BIM-Uses including 3D Design Coordination. Project direction and information flow often meanders left and right of an efficient path resulting in frustration, loss of momentum behind value-adding processes, and often considerable time wasted.

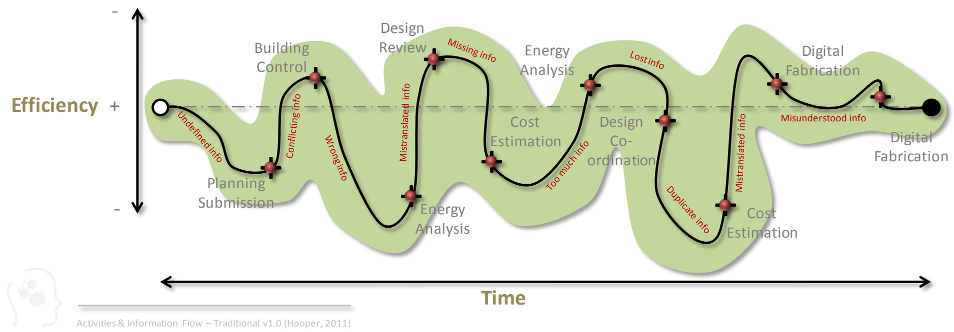

Figure 4: Information Flow – Traditional

Laying down considerable time and effort to carry out what should be routine tasks is a major concern to DCO players. Those who are bearing the pain of BIM implementation are struggling to leverage the benefits of added service and increased productivity as a result of downtime consumed by manually filtering, editing, adding, deleting, finding out if its valid and re-working building design information for what in theory should be sequential BIM Uses.

By encouraging all design participants to engage in work flow design and actively be aware of each other's information needs, the use of a BIM-Info Protocol has the potential to straighten work flow and increase the accuracy and efficiency of information exchange. Coordination efforts here requires time but lays the foundation for greater gains through the process.

Once organisations have succeeded and gained confidence in recording, purposefully designing and optimising their work-flows with attention to information exchange, project standards can develop into office standards and further to a National Standard. Within the sphere of information exchange, this study endeavours to organise and present key prerequisites necessary to set in motion a system design converging on standardisation.

So far this element of business practice within the AEC consultant sphere has been either largely missing or out of date. The figure below suggests a process which might help DCO participants move forward in earnest and articulating BIM-Info content with a view to optimising information flow and reducing exchange failures.

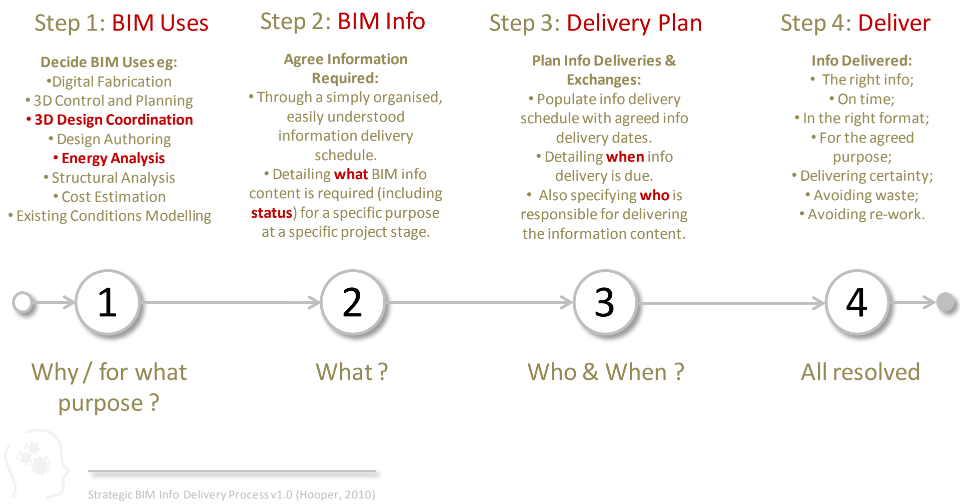

Figure 5: Strategic BIM-Info Delivery Process

5.0 BIM-INFO DELIVERY PROTOCOL (IDP)

Emerging from the observations and results revealed through discussions and experiments, the BIM-Info Delivery Protocol (IDP) is presented below as a sequence of pedagogical steps designed to respond to the research questions.

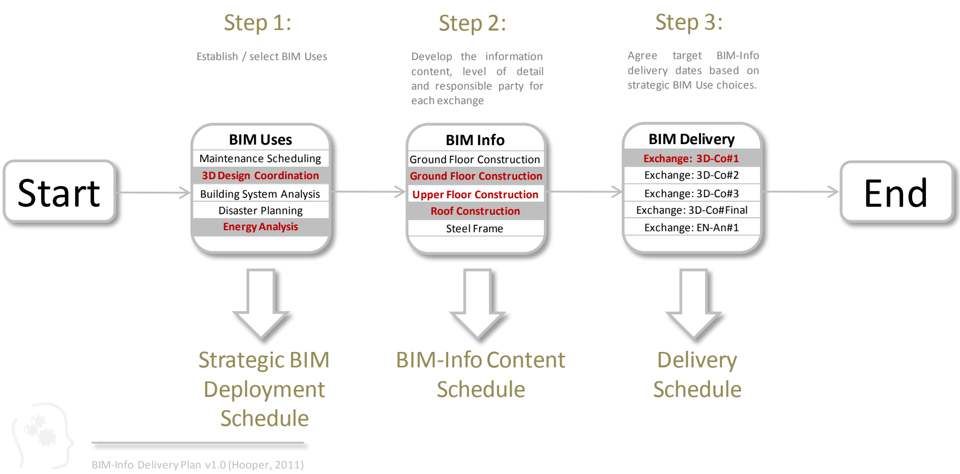

Figure 6: BIM-Info Delivery Protocol (IDP)

5.1 Step 1: BIM-Uses

The buildingSMART Alliance's Building Information Modelling Execution Planning Guide (Anumba et al 2009) suggests a list of 25 typical BIM Uses including of course 3D Design Coordination and Energy Analysis. It naturally follows that teams must establish at the outset the strategic BIM-Uses they wish to deploy on a project specific basis. The decision to implement a BIM-Use must be based on resources, competency and anticipated value to the project (Anumba et al 2009). Against each BIM-Use members should consider and articulate the timing of such activities through the BIM-Authoring stages to enable focus on imminent information demands and optimize information flow. The figure below illustrates how this might be articulated whilst enabling efficient implementation.

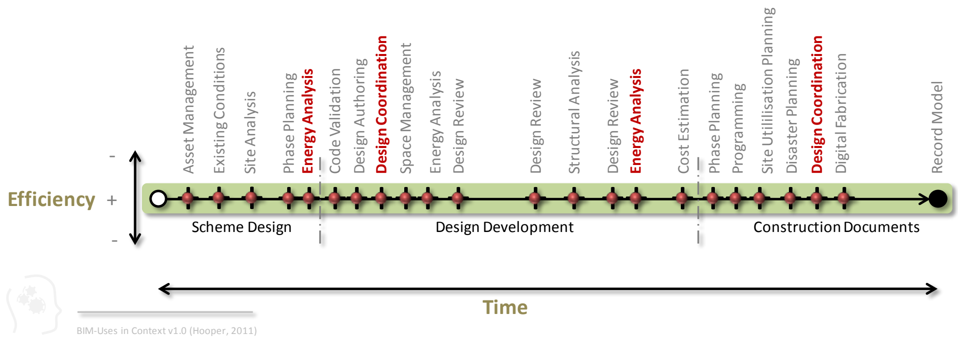

Figure 7: BIM-Uses in context

Often overlooked, there is common business sense to the idea that, if certain design information can be supplied at right time, then its value to the project can be optimized. BIM-Uses should be selected for the right reasons – as drivers to the process and to help provide the data to support strategic decisions along the way.

5.2 Step 2: BIM-Info

Here a definition of the model information content for strategic BIM implementation is articulated through scheduling the key objects with associated level of detail and responsible party. In this instance a BIM-Info Delivery Specification (IDS) template has been developed to express the information content and exchanges necessary to carry out and efficiently implement BIM-Use: 3D-Co (3D Design Coordination).

The main tools used to develop this schedule where Autodesk Revit Architecture together with Microsoft Excel. An important aspect of this study and resultant product is that by utilising industry standard tools and readily understood categories and classifications, consultants can maintain control of model content definitions and thereby build and retain trust in the exchange processes they create.

5.2.1 Identifying BIM Objects & Properties for Strategic BIM Uses

The AIA (AIA 2008) amongst others has defined the concept of Levels of Detail (LOD) described through a sliding scale of LOD 100 – 500. In essence, the levels can be summaries as follows:

- LOD 100: Conceptual
- LOD 200: Approximate geometry

- LOD 300: Precise geometry
- LOD 400: Fabrication
- LOD 500: As-built

The LOD concept, established through the AIA's E202 Protocol published 2008 is now starting to be adopted throughout the world (Statsbygg 2011). This standard together with an appropriate building element classification can be deployed to identify the BIM-Info required for specific tasks, however, in practice additional BIM objects and properties need to be identified out with the scope of most building classification systems. For this reason it is necessary to facilitate flexibility in BIM-Info scheduling and include, where appropriate, scope to articulate request for data such as:

Project Information
- Project Issue Date
- Project Status
- Info Status
- Client Name
- Project Address
- Project Name
- Project Number

Project Units
- Length
- Area
- Volume
- Angle
- Slope
- Currency

Annotation
- Location
- Coordinates
- Position
- Grids
- Levels
- Rooms
- Areas
- Zones

Other
- Voids
- Holes

The need for extra BIM object classifications beyond those to be found in national classification systems is clear. The above categories, identified through the authoring process of the KonsultHus case project, have been included in the BIM-Info Delivery Specification to enable transfer of that information between consultant disciplines in a clear and comprehensive way.

BIM Information Delivery Specifications - 3D Design Coordination

BIM Information Delivery Specifications - 3D Design Coordination v1.0 (Hooper, 2011)

			BIM Use: 3D Design Coordination Stage: Scheme Design Info Exchange: 3D-Co#1 Date: 1 Jan 2011				BIM Use: 3D Design Coordination Stage: Scheme Design Info Exchange: 3D-Co#2 Date: 1 Feb 2011			
BIM-Info	**Responsible**	**Notes**	**Level of Detail**	**Info Author**	**Info Reciever**	**Format**	**Level of Detail**	**Info Author**	**Info Reciever**	**Format**
Annotation										
Location	Arch		✗ - Confirmed	Arch	Struct & MEP	*.rvt				
Coordinates	Arch		✗ - Confirmed	Arch	Struct & MEP	*.rvt				
Position	Arch		✗ - Confirmed	Arch	Struct & MEP	*.rvt				
Grids	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt
Levels	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt
Rooms	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Areas	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Zones	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
SUBSTRUTURE										
Foundations										
Standard Strip Foundations	Struct		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt
Special Foundations										
Slab Foundations										
Pile Foundations	Struct		✗ - LOD 200	Arch	Struct & MEP	*.rvt	✗ - LOD 200	Struct	Arch & MEP	*.rvt

Figure 8: Extract from BIM-Info Delivery Specifications (IDS)

An innovative feature, still under development, is the possibility of automating the extraction of requested BIM-Info through an XML schema, enable through the IDS spreadsheet, thus eliminating manual filtering and if perfected, scope for error. A prerequisite of this novelty is a thorough and complete tagging of objects to the utilized building components classification.

Information										
Construction Information	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Engineering Information	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
Record Information	Arch		✗ - LOD 200	Arch	Struct & MEP	*.rvt				
			Link to Model: Holmes Office - Architecture.rvt				Link to Model: Holmes Office - Structure.rvt			
			Extract Info Content From Project Server				**Extract Info Content From Project Server**			

Figure 9: BIM-Info Content Extraction

5.3 Step 3: BIM-Delivery

Registry of BIM-Info exchanges can be readily recorded and communicated through project networks in accordance with the delivery schedule. However, often neglected is a sub-process of quality control. This is necessary more than ever – not least to demonstrate due diligence – but to ensure the content of BIM-Info Deliveries match with the general expectations of the project team as articulated in the BIM-Info Delivery Specification schedule. This process is essential to eliminate rework for receivers and puts the onus on the supplier to ensure the contents is what it says it is.

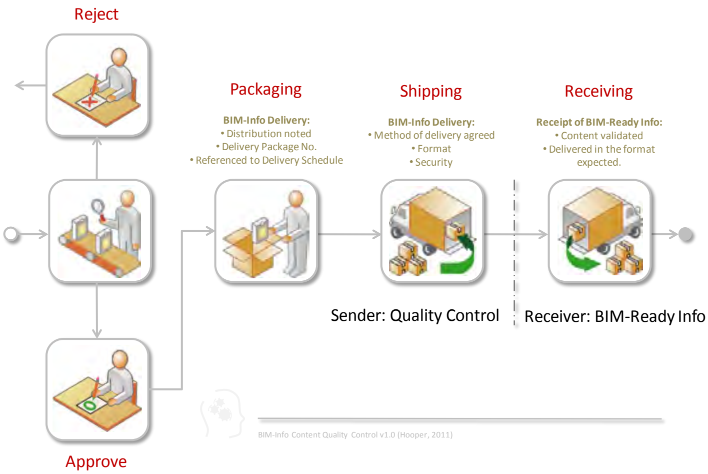

Figure 10: BIM-Info Content Quality Control Measures

6.0 Conclusions

6.1 Summary of Main Findings

The key deliverable from this study is the BIM-Info Delivery Protocol (IDP) which attempts, through use of straight-forward and easy to use tools, to align consultant BIM-Info delivery expectations and represents a development of the concept behind Leveransspecifikationer mentioned but not substantiated in Bygghandlingar 90.

By recording information flow properly we can better understand each other's information needs and reduce the risk for misunderstanding. If handled optimally BIM-Info can significantly enhance the quality of the product and safeguard the success of project. A clear and commonly understood picture of the BIM-Info Deliveries through establishing a project standard BIM-Info Delivery Specification offers a tangible solution to help consultant disciplines manage BIM-Info.

To add maximum value to the project, the timing and content of BIM authorship is critical. By articulating planned BIM-Uses, the necessary BIM-Info needed to carry out these Uses together with target BIM-Delivery dates; project teams can more readily focus on the strategic task in hand and help each other to deliver the intended result in an efficient manner.

The BIM-Info Delivery Protocol (IDP) is a compelling tool for use in the evolving world of virtual design and construction teams and can be used as a basis for a BIM Management Plan. However, industry reference-group feedback has suggested a number of limiting factors including that "it would be an additional burden, indeed laborious, to fill out the IDS when projects are already on a tight time schedule and budget. If teams cannot directly see the positive effects of using such a protocol, it may be difficult to achieve widespread uptake." This protocol represents a tool for improvement, a first step could be to first record one's own strategic information requirements, recognition of this together with patience may prove to be prerequisites.

6.2 Positioning of BIM-Info Delivery Protocol (IDP) v. IDM & MVD

On reflecting on the positioning of the BIM-Info Delivery Protocol in relation to IDM and MVD a number of discrete characteristics can be identified:

- The IDP represents a ready-to-use tool for communicating and aligning information exchange expectations, independent of software application.
- The development of IDM and MVD's have yet to reach maturity and are dependent upon the complete and successful implementation of the IFC model within the BIM authoring software applications – this has yet to be realised and there is resistance within a number of the key software suppliers to do so.
- The principle difference in methodology between the IDP and building SMART's IDM/MVD is that building SMART's purpose is to solve interoperability. Whilst this is a crucial goal, the IDP method is needed as a first step and the results can be used as input to the ongoing work with IDM's and MVD's.
- The IDP is orientated towards the Architects and Engineers who represent the key members of the model authoring team.
- Whilst IDM & MVD require in-depth technical IT and systems knowledge, often outside the scope of expertise of many DCO project participants.
- The IDP may provide the industry with an easy to use, working alternative to IDM & MVD that can be readily developed and re-used.

6.3 The need for a common method of defining BIM deliverables

One of the principle difficulties in realising efficiency gains through the use of BIM is a function of defective communication stemming from, amongst other things, a general lack of standard terminology and methods of describing process and deliverables.

In the absence of existing simple standard methods of defining the content of BIM information exchanges the BIM-Info Delivery Protocol attempts to fill this gap. Furthermore, beyond aligning information needs and creating greater certainty through intelligent and value-adding deliverables, the final built product will have an increased propensity to be as expected.

6.4 Summary of the key features of IDS

The BIM-Info Delivery Specification seeks to provide a simple standard method of describing information exchange content. As a decision-support tool, its key elements can be readily identified per the illustration below.

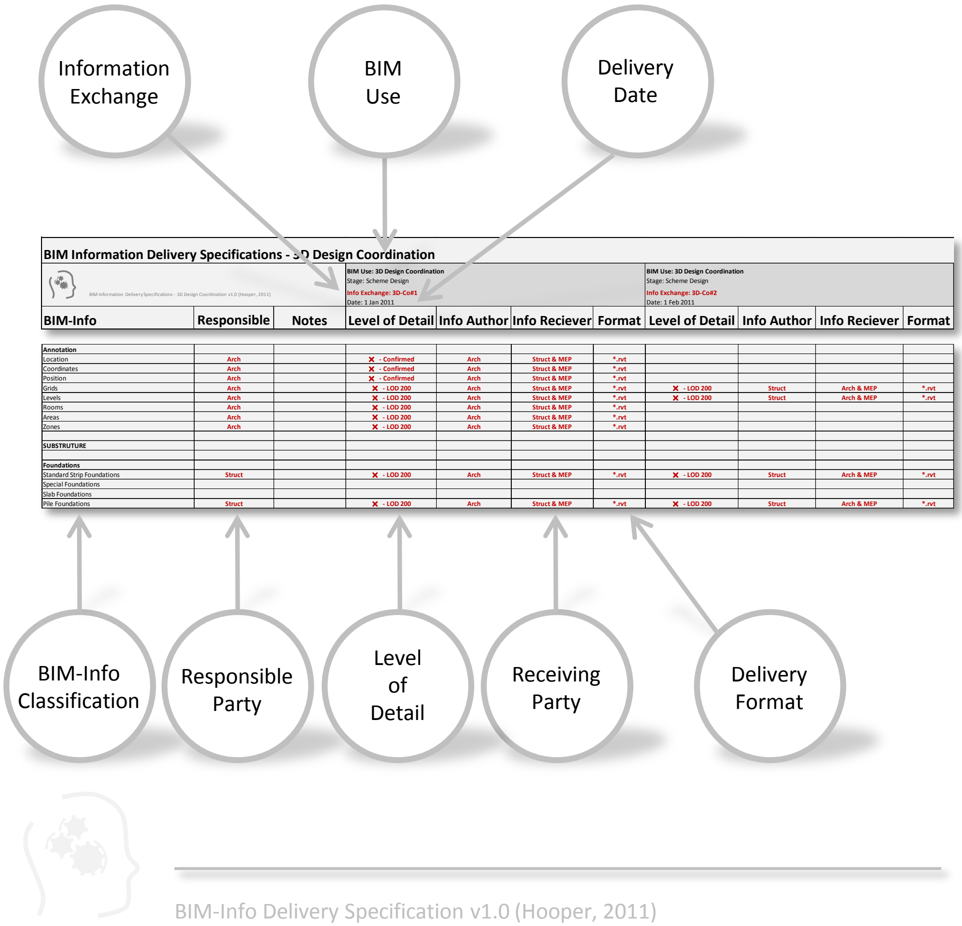

Figure 11: BIM-Info Delivery Specification – Constituent Parts

Through the use of these generally understood and commonly recognised concepts, brought together in a standard way, the IDS can help enable succinct communication of content requirements for key information exchanges. At the core of this process is defining, BIM-Use, Information Exchange (No. within the series), Delivery Date, Responsible Party, Level of Detail, Receiving Party, and Delivery Format.

7.0 Further Research

It may prove possible to generate machine-readable model information content definitions through the XML schema making it possible to standardise such contents and deliver project information through automated processes.

Acknowledgements

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Authors: Hooper, M. and Widén, K.

BIM Inertia: Contracts & Behaviours

M. Hooper[1] and K. Widén[2]

[1] Department of Construction Sciences, Lund University, Faculty of Engineering, Box 118, 22100 Lund, Sweden; PH +46 (0)732-604271; email: martin.hooper@construction.lth.se
[2] Department of Construction Sciences, Lund University, Faculty of Engineering, Box 118, 22100 Lund, Sweden; PH +46 (0)46-2227845; email: kristian.widen@construction.lth.se

ABSTRACT

Whilst Building Information Modelling (BIM) promises significant improvements in construction quality and efficiency, current contractual models do not encourage its use; indeed actively inhibit the collaboration at its core. To help bring BIM into the mainstream, it is claimed we need to re-craft existing contractual relationships to facilitate collaborative decision making and to equitably allocate responsibility among construction participants. This chapter looks at the case of Sweden and aims to identify and appraise observed hindrances to BIM collaboration and digital information stewardship. It presents an understanding of the connections between the commercial environment and contractual provisions that regulate the party's business relationships and the resultant procedural and behavioural phenomena that can be viewed to thwart BIM collaboration and degrade the value or integrity of digital deliverables. The study then, in a more general context, asks what we can learn here that may have wider application through consideration of suitable BIM collaboration support mechanisms that may reduce or remove collaboration barriers, induce open, sharing behaviours and support the creators and users of digital information. Methods employed include a critical review of existing contract forms, synthesized with focus group interviews (FGIs) with representatives from diverse AEC disciplines. Results indicate that a number of systemic difficulties exist that can create an inertia which can be traced through behaviours and circumstances to contractual provisions. An understanding of such difficulties is presented and a consensus emerges on a number of key supporting mechanisms that may better facilitate meaningful early BIM collaboration and oil the wheels of communication without recourse to re-writing the rule-book.

Keywords: BIM, Building Information Modelling, Collaboration, Construction documents, Contracts.

INTRODUCTION

BIM implies an increased collaborative effort in the early stages of construction projects (Jongeling, 2008; Eastman et al. 2012). But in what ways is this prerequisite manifesting itself in contractual provisions and procurement? In the US Ashcraft (2008) has highlighted the need to re-craft existing contractual relationships to facilitate collaborative decision making and to equitably allocate responsibility among all construction participants. Consequently the American Institute of Architects (AIA) has developed through its partners a series of new contractual arrangements compatible with an Integrated Project Delivery (IPD) philosophy. Reports are emerging on the successful and advantageous application of IPD to support BIM (Cohen 2010), whilst elsewhere the industry is toiling with half-hearted collaborative processes, thwarted by contractual inertia imposed though traditional procurement routes.

In Europe, progress towards contractual support for BIM and delivery of integrated processes has been markedly slower. Pfitzner et al. (2010) reminds us that changes are required at national and project level, including commitment among project team members to collaboration. Owen et al. (2010), in connection with collaborative processes and BIM, explains current conditions exhibit underlying cultures of distrust and litigation that impede experimentation, iterative approaches to design solutions, and progress with BIM integration. Furthermore, that silo mentalities prevail and document-based information exchange across professions and throughout supply chains ensure digital information and particularly any associated intelligence, coordination and agility is either corrupted or lost and it passes downstream.

Owen et al. (2010) further argue that successful implementation of integrated processes requires changes including: a team approach, support for innovation and tolerance of failure in a team; strong lateral linkages and decentralized decision making; networks of commitment; and new forms of contracting, transparency and risk management. Finally, Race (2012) claims BIM as a means of cooperating through information management in the project team is currently at odds with the legal and commercial environment in which it has been invented, and that contracts and procurement documentation tend to insulate and isolate rather than actively support collaboration. They set boundaries and barriers which are not conducive to working in a BIM mode.

These studies and reports present a broad range of difficulties associated with BIM collaboration and information sharing within the contractual arena but lack insight and practitioner feedback on perceived connections between contractual provisions and behaviours and secondly on the suitability of emerging measures to mitigate barriers to BIM collaboration and the delivery of integrated digital construction project information. Accordingly, research conducted so far on contract related hindrances to BIM collaboration is limited and requires further investigation. There are areas in need of further investigation which bring together behavioural and procedural aspects of contract execution with the need for improved early collaboration on BIM projects. This may provide a method in which one can consider if and how the traditional mindset can be overcome.

From the above we can identify the following research question: *What is the connection between traditional contracting and BIM inertia and what are the necessary components that may facilitate more effective early BIM collaboration?*

More specifically, the research here aims to examine the connections between the legal and commercial environment of construction contracts and the resulting procedures and behaviours that may be seen to hinder BIM collaboration. An understanding of the issues involved may shed light on the suitability or otherwise of BIM collaboration support mechanisms emerging elsewhere.

Collaboration is at the core of the use of BIM technology across sector disciplines and through facility life cycles. Ashcraft (2008); Knight (2008); Pfitzner et al. (2010); Eastman et al. (2011); Race (2012) all suggest that change in contractual arrangements, whether addendums to existing contracts or entirely new contracts are evitable but there is still little knowledge on what to add or subtract to facilitate a more effective early collaboration centred on the smart use of BIM resources, technology, and applications. This study aims to shed new light on the barriers and challenges to earlier and meaningful collaboration around BIM implementation, presents an understanding of the key issues and considers the suitability of plausible collaboration support mechanisms based on the AIA's E202 Model (AIA, 2008).

This research builds on that in the field and contributes with insights into real world collaboration difficulties in connection with the creation, use and exploitation of digital project information in the commercial and legal context regulated by the construction contract.

The enquiry focuses on phenomena experienced in the Swedish construction industry which can be considered typical (vis-à-vis contracts and behaviours) within the European arena and considers what aspects from the results may have wider relevance or application. The literature review supports the study. The empirical data collected has been limited to interviews with a number of national organisations and covers a broad and representative range of disciplines.

The context of BIM inertia, contracts and behaviours, focuses on those: 1) In connection with the design – construct – operate process generally; 2) In connection with generating and implementing a project-specific BIM-Plan; 3) In connection with planned BIM-Uses and down-stream utilisation of digital information.

The investigations enable an articulation of discrete relationships between construction contracts, the legal and commercial environment, and the circumstances and behaviours that create barriers to collaboration in connection with BIM and the exploitation of digital information. The findings reveal a number of distinct behaviours, remnant from traditional contracting, are present in BIM projects that significantly hinder full utilization of digital data and compromise project outcomes. Finally, broad support for some form of BIM-Addendum to contract exists however a resistance to new contract forms prevails. The question that remains is whether BIM-Addenda will themselves reduce or eliminate barriers to BIM collaboration. Nevertheless, BIM-Addenda are seen as a means to support an improved and meaningful BIM collaboration and represent a first step towards a more integrated approach to project delivery.

The chapter begins with a description of the methods used in the study. The outcomes from document review and industry interviews are then presented which emerge as a set of key issues against which BIM collaboration support mechanisms can be arranged. This is followed by a discussion of the results and their implications.

METHOD OF INVESTIGATION

A qualitative approach was adopted from a critical realism perspective where acknowledgement is made to contextual factors (associated with case) whilst also arguing the phenomena under study can occur in similar settings (Saunders et al. 2009). Adoption of this approach supports the investigation in so far that it allows for the study of a complex and contemporary phenomena over which the investigator had little or no control (Yin 2009). Data gathered has been deductively analysed to expose and interrogate the key components that influence the particular phenomena under study and enable a clearer understanding of both contractual and behavioural challenges to BIM collaboration in context and provide insight into emerging issues that can be deemed as relevant generally.

The main findings on BIM inertia, contracts and behaviours builds upon a critical analysis of the key documents outlined below and applies Focus Group Interviews (FGI's) as secondary research method of data collection to identify where industry perceive hindrances exist and assess the level of concern. FGI's differ from surveys and questionnaires as they not only enable the collection of more in-depth data, but they also provide a forum for the different disciplines to share and clarify their views on various discussion issues (Denscombe 2008).

The presented literature enabled development of the research proposition that *if adequate contractual provision is present to support an integrated BIM approach, behavioural and circumstantial barriers to collaboration may be reduced or eliminated* - which is tested qualitatively. Support for this fundamental proposition is based upon the analysis of the collected data extrapolated from document review and interview responses. Together this aims to provide a new understanding of inertia-making factors and what mechanisms impact on digital information stewardship.

Literature review suggests that existing research tends to focus on outcomes from isolated experiences or obstacles to full adoption of BIM at a more general level. However, it does reveal sufficient evidence to suggest real compatibility difficulties exist between traditional contracting and working in a BIM mode. With this knowledge our proposition is formulated which enables the study to stay within feasible limits (Yin 2009).

The data collection process started with an interview protocol, which was developed to increase consistency of the research (Yin, 2009). Accordingly, all interviews followed similar case questions and collection procedures. The protocol focused on a narrow set of questions designed to unravel known and perceived contractual and behavioural difficulties on BIM projects.

A deductive approach is chosen for maximizing reliability and credibility in the results. The main unit of analysis is evidence of barriers to BIM collaboration with embedded units being the responses from the interview sessions. Analysis began with transcribing interviews into summary statements thereby abstracting and transforming the data into emerging patterns and then into a set of key issues where evidence was convergent and corroborated. This enabled the establishment of patterns and connections between contractual provisions and behaviours on BIM projects and furthermore, their effects. To provide a structure to aid data analysis and presentation of results, the emerging key issues are interpreted into categories and themes (Denscombe 2008). From here a selection of generalised conclusions are drawn.

A Review of Key Documents

As part of the empirical data collection in connection with this study a number of key contextual documents were collected and reviewed including existing local contract documents and BIM supporting documents such as the AIA Document E202-2008 (AIA 2008), Integrated Project Delivery: A Guide (AIA 2007), and the buildingSMART alliance™ BIM Project Execution Planning Guide (Anumba 2010).

Focus Group Interviews

Six interview sessions were carried out with industry participants including architects, engineers and contractors. The selection was based on a prior knowledge of their advanced BIM adoption and targeted to enable collection of empirical data from those who create or author digital information and might be the chief *users* of such tools as the BIM-Docs mentioned above and illustrated in Figure 1.

Whilst owners or clients are important in connection with BIM and setting minimum requirements etc, here, owners were not included in the interviewed groups. Instead, focus is placed primarily on the AEC team, their contracts and behaviours. Typically owners expect or demand data drops or digital deliveries corresponding to phases and are seldom concerned with the *how* aspects of delivery. Whereas, there is usually a myriad of exchanges within the AEC group demanding planning and standardized procedures if the digital data is to maintain its integrity downstream.

Those interviewed are active in all industry sectors (inc. commercial, residential, industrial, civil) and represent the leaders of those BIM adopters in Sweden. The interviews were semi-structured and focused on discussions centring around the identification (from a user perspective) of known process barriers to the use of BIM in connection with the functioning of Traditional and Design & Build construction contracts, and the standard form of consultant appointment. Consideration was afforded to the impact of a standard agreement on digital deliverables (ADL 2010) and relevant aspects of the AIA's Document E202-2008 Building Information Modeling Protocol Exhibit (AIA, 2008). Respondents were asked to suggest where they thought obstacles to collaboration exist, in particular in relation to:

- Existing contractual provisions and BIM.
- Downstream transmission of digital information (information exchange).
- The ability to create and implement common, project-specific strategic BIM plans.
- Successful project coordination with regards to level and commitment to collaboration.

Conducted through a consistent interview protocol, the interviews with industry consultants focused on collecting responses to a concise set of questions and points of view in relation to the diagram in Figure 1 (BIM-Docs: Constituent parts for BIM-Projects + Propositional Integration Components) which derives from and builds upon the principle research proposition. The diagram presents the existing contract documents to be found in Sweden today, together with a number of ancillary documents that are emerging within the industry here and elsewhere that are purported to support BIM processes and facilitate enhanced cooperation. Respondents were asked to consider the relevance, application and suitability of all interconnected documents (existing and propositional) and their influence on project team capacity and propensity to collaborate on BIM projects.

Interviews were carried out at various levels within six large AEC organisations, with consideration to both building construction and infrastructure construction case projects. In all organisations BIM is already an area of strategic interest and well established amongst organisation leaders.

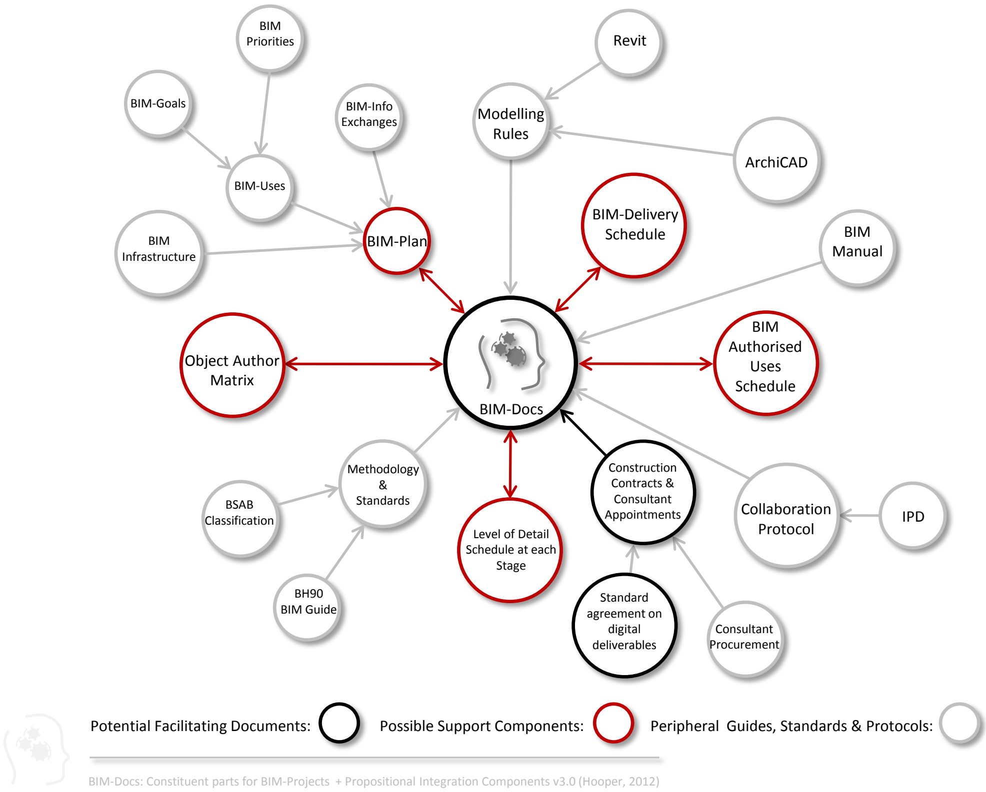

Figure 1: BIM-Docs: Constituent parts for BIM-Projects + Propositional Integration Components

Figure 1 pulls together a number of key concepts that collectively may help to shed new light on the question of what are the necessary components that may facilitate more effective early BIM collaboration and safeguard the downstream use of digital data. The diagram attempts to map out the key existing BIM documents and protocols that have a bearing on the use and implementation of BIM on construction projects today, and combines a selection of plausible collaboration supporting mechanisms based on the AIA's model.

UNDERSTANDING CONTRACTUAL AND BEHAVIOURAL OBSTACLES TO BIM COLLABORATION

This section presents the main results of the study and is divided into findings from the document review and those from the industry participant interviews. These are pulled together with a summarising section reflecting on procedural circumstances and behavioural fallout from contractual inertia.

Outcome from Document Review

Standard form of Consultants form of appointment (ABK 09)

In Sweden, there is only one standard form of design Consultant Appointment (ABK 09) that is recognised nationally. It is neutrally written with regards to the details of how Consultants exchange and deliver design information for construction. Often separate project specific appendixes are added to this form of agreement to deal with matters of information management on ad hoc basis. ABK 09 (BKK 2009) has been developed from previous versions in an attempt to meet today's requirements; however the form makes no reference or accommodation for provisions to support collaboration in connection with the use of digital information and BIM. Edgar (2011) notes that it merely regulates copyright and responsibility for design information presented as paper drawings and as such, is not tailored for digital information or BIM.

Furthermore, ABK 09 lacks any form of specific support for integration. It has no provisions for either strategic collaboration or projects centred around BIM technology and processes and as Blom (2010) states: "*There is nothing in ABK09 that regulates who owns the digital information, what the copyright is worth and what access rights are valid, or even responsibility for the accuracy and correctness of the digital information*." These deficiencies have attempted to be addressed through the option to append a new standard form dealing with digital deliveries (ADL 10). Its deployment so far has been limited but has brought behavioural issues into discussion and reinforces the need for better contractual support.

Traditional form of construction contract (AB 04)

The Traditional form of Construction Contract (AB 04) (BKK, 2004), approaching 10 years old, offers little support to BIM concepts and the implied need for early project team collaboration. The AB family of contract forms are set out with similar chapters covering responsibility, fees, etc. What is not regulated in AB is: collaboration means or methods, compensation or strategic incentives, how sub-contractors are procured and managed. It can be said that the design and construction process associated with the Traditional Form (Figure 2) compromises opportunity for cross discipline collaboration centred around the BIM. The limited overlap between the design phases and construction phases thwarts collaborative efforts from the start. In a BIM mode, however, the effect of misaligned scopes and absent or ad-hoc buy-in to BIM-Project goals can be seen to present a new set of challenges.

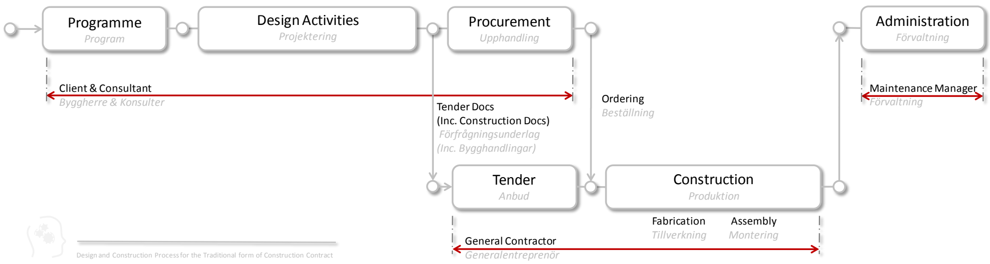

Figure 2: Design and Construction Process for the AB04 Traditional form of Construction

Here the traditional procurement system, shares some of its main characteristics with the British traditional method (except for, the role of the architect). The client typically initially appoints a Project Manager as representative who advises the client on further appointments. Contractors tender on the work based on completed design documentation and the client's only contractual relationship with the contractors is that with the main or general contractor. The main contractor procures subcontractors to carry out work sections but is responsible for coordination of the construction and the performance of subcontractors. Subcontractors may have design portions, but are often on board after the main design effort is complete.

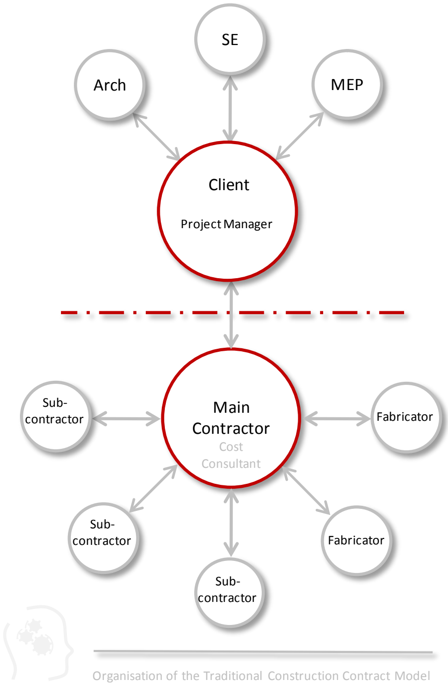

Figure 3: Organisational Structure of the Traditional Procurement System

From the organisation of the traditional model (Figure 3), one can observe that the inherent separation of the client and consultants on one side and contractor team on the other, immediately creates barriers, contrary to the ideas of team-building, collaboration, and working together towards common goals for the good of the project. Separation of not only design and construction activities but contractual relations can be seen to inhibit the necessary free communication, cooperation and feedback between teams. This has been shown to lead to knowledge islands and defensive behaviour (Pfitzner et al 2010).

Design & Build / Performance form of Construction Contract (ABT 06)

Intended for use in connection with so-called turnkey projects, the Design & Build / Performance Contract (ABT 06) presents conditions of Contract for works where the contractor undertakes total execution of the construction and also undertakes to produce all or a substantial part of the design. Here the main contractor's presence through a substantial part of the design and construction phases (Figure 4) enables a high degree of consistency of purpose and team optimisation to occur. However, such contracts can lead to a restriction of competition since only a few contractor organisations have sufficient economic resources to manage the design, meaning only a few can compete for the work.

As with the Traditional contract, D&B / Performance (ABT 06) offers little specific support to BIM or BIM processes per se, but equally no specific hindrance. Often client or contractor organisations will append or insist on the adoption of in-house IT / BIM Manuals setting out strategic and administrative decisions on a project bases. One hindrance here is that there is a lack of National BIM Standards in Sweden and BIM 'demands' are generated by the most powerful actor in the team almost on an ad-hoc basis.

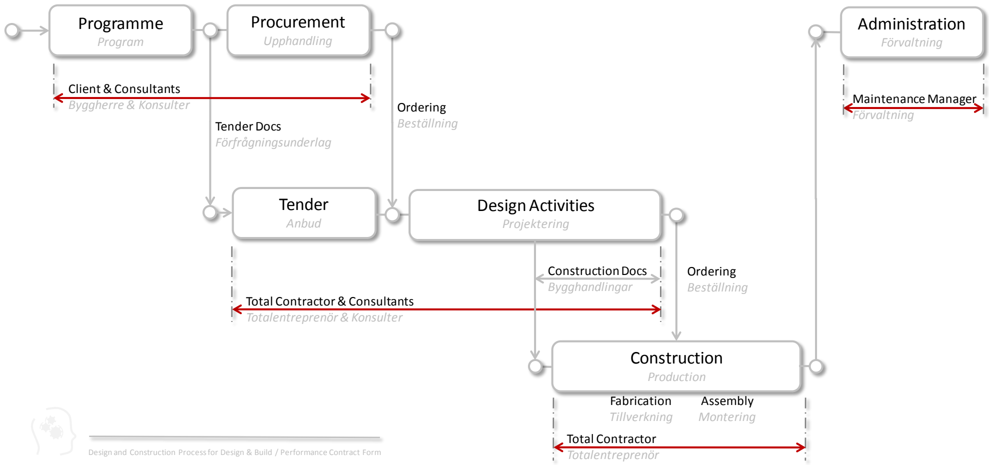

Figure 4: Design and Construction Process for Design & Build / Performance Contract Form

This form of contract corresponds in principle to the British Design and Build procurement in which the client provides a skeleton brief detailing functional requirements upon which the main contractor develops the building design. Clients may employ an Architect to develop a programme and concept design who may later be novated to the Contractor. The number of projects under this form of contract in Sweden varies from year to year, but the system has been known to account for more than 50% of the market (Nordstrand 2009).

This contact procurement system is an example of a response to the increasing need for a more integrated design and construction process. The main contractor is responsible for the whole process of leading and coordinating the integrated design and construction phases and takes total control over the building project. The contractor has a single contract (Figure 5) covering both planning and execution of the building project and is responsible for construction in accordance with the current standards and with the functional requirements laid out by the client.

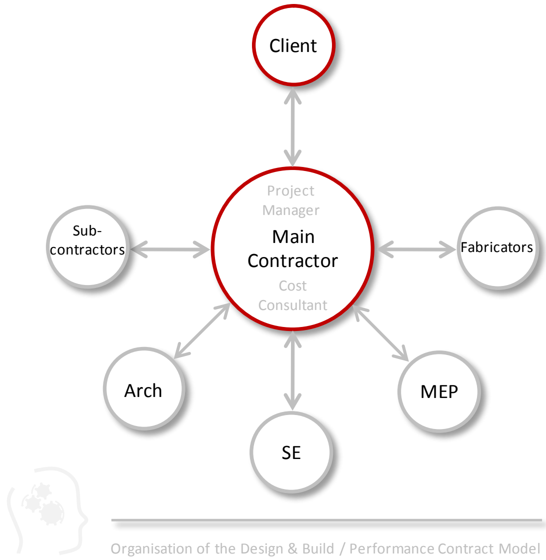

Figure 5: Organisation of the Design & Build / Performance Contract Model

Significant characteristics of the Design & Build / Performance contract in the context of BIM planning, information flow and early collaboration include:

- The Design & Build / Performance Contract offers the greatest potential for meaningful collaboration since a fuller team is assembled from the beginning.
- It provides a suitable platform for partnering agreements – a move toward IPD.
- The contractor has the opportunity to demand project team compliance with project goals as opposed to only internal organisational goals.
- Client has a single point of contact. Less control over detailed aspects of the design.
- Contractor is responsible for design *and* construction which more readily enables a more robust digital information stewardship through the presence of a downstream continuum from the start.
- Construction work can be started earlier as design work can proceed in parallel, however, the time required to prepare work packages depends on the complexity of the project.
- Statutory Consent is a concern since building permits are often not applied for until the contractor is appointed and can take an uncertain amount of time to be granted. Delays in this respect can have serious consequences.
- To be successful, tender documentation must be explicit regarding requirements and expected operation and maintenance costs.
- Such contracts can lead to a restriction of competition since only a few contractor organisations have sufficient economic resources to manage the design, meaning only a few can compete for the work.

Notwithstanding, a number of major contractors are developing various forms of transparent construction contract with clients - partnering solutions – which demonstrate a desire for greater collaboration and can be seen to represent a move toward IPD.

Agreement on Digital Deliveries (ADL 2010)

Supported and available through OpenBIM, the Agreement on Digital Deliveries (ADL 2010) is intended to address the contractual deficiencies of the standard Consultant Appointment (ABK 09) with regards to the adoption of BIM and the use of digital information. It contains formal clauses to facilitate agreement concerning delivery and use of digital information for building construction projects (a similar form is expected to emerge for infrastructure projects). The form can be used to regulate and agree the details regarding delivery of digital information, specifically:

- The rights to the output from the commission.
- Delivery specification of digital information.
- Control of receipt of that digital information.
- The client’s use and access rights to the digital information.
- The suppliers / consultants responsibility for the digital information.
- Archiving of design material.

The motivations behind such an appended form are clear, however a number of opportunities have been missed. Examples of parts that continue to be problematic and need to be further investigated include:

- The scope of the model including which systems and disciplines to be included for which uses.
- The level of development in models for different stages.
- The accuracy and status of BIM content (eg, as scanned, as measured, as designed, etc).
- Whether the model shall constitute the contract documents or should the extracted ‘dumb 2D drawings’ be the only valid document.
- Review and approval processes of design proposals / digital information content.
- If the model contains too much information how one must sort out what applies for the purpose.
- Ownership, copyright, etc. need to be reviewed in relation to AB and ABK.

AIA Document E202-2008 & Integrated Project Delivery

The AIA Document E202-2008 Building Information Modeling Protocol Exhibit (AIA 2008) in the US has been developed specifically to support BIM collaboration and enable project organisations to leverage the benefits of BIM in a systematic way. It presents a formal means of agreeing BIM project priorities and deliverables in a standardised form, enabling teams to proceed with foresight, setting out what models are to be produced and how the models can be used. The document includes provisions to agree: *BIM Delivery Schedule, BIM Uses Schedule, Level of development at project stages, Model Authorship* and *Model Use Authorisation*.

The E202 establishes protocols on expected level of development (LOD) and authorised uses of the BIM data on a project basis. It assigns specific responsibility for the development of each model element to a defined LOD at each project stage. By contrast, in Sweden there is a lack of standard documentation to enable the expected scope and objectives for BIM to be agreed, detailed and suitably documented. It is conjectured that an adapted version of these five concepts may be of practical application in Sweden to support cross boundary BIM collaboration. By formalising these five concepts through a standard set of contractual provisions, project participants can nurture a greater clarity of purpose and remove confusion around matters of authorship, liability and intellectual property.

Integrated project delivery (IPD) is already in use in some form on many projects around the world. It yet has to make its debut in Sweden although it is the source of intense discussion for key stakeholders in the Design-Construct-Operate (DCO) industry. Whilst BIM offers the possibility of dramatic advances in project information coordination and collaboration, the full potential of BIM will not be achieved without adopting structural changes to project delivery methods (Autodesk, 2008). IPD offers an opportunity to redress traditional difficulties where key issues regarding compensation, contractual relationships, risk allocation, and so forth can be overcome. Greater awareness, owner mandates, and industry initiatives are critical to the widespread adoption such of new delivery methods.

The AIA defines IPD as: “*a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction*.” (AIA 2007)
Accordingly, the definitive characteristics of IPD include:

- Highly collaborative processes that span building design, construction, and project handover.
- Leveraging the early contributions of individual expertise.
- Open information sharing amongst project stakeholders.
- Team success tied to project success, with shared risk and reward.
- Value-based decision making.
- Full utilization of enabling technological capabilities and support.

With IPD the relationships of project participants are fundamentally altered, which gives rise to the demand for new forms of standard contract documents (such as the ConsensusDocs and AIA E202-2008) that address important new BIM collaboration issues. Already changes in business models, scopes of services and deliverables are redefining the relationships of interested parties around measured outcomes. The IPD philosophy offers impetus towards improved project coherence through combating fragmentation.

The buildingSMART alliance™ BIM Project Execution Planning Guide (BIM PEPG)

The buildingSMART alliance™ BIM Project Execution Planning Guide (BIM PEPG) (Anumba et al, 2010) is a new supporting guide with the primary aim to help construction professionals clarify roles and responsibilities, determine scope and level of detail, cut costs and optimise return on investment (ROI). The plan claims that to successfully implement BIM, a project team must perform detailed and comprehensive planning. A well documented BIM Project Execution Plan will ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow. A completed BIM Project Execution Plan should define the appropriate uses for BIM on a project (e.g., *design authoring, cost estimating*, and *design coordination*), along with a detailed design and documentation of the process for executing BIM throughout a project's lifecycle. Once the plan is created, the team can follow and monitor their progress against the plan to gain the maximum benefits from BIM implementation.

The plan suggests that project participants from the earliest stages generate a strategic BIM-Plan that enables agreement on common goals through 4 key steps:

- Identify high value BIM uses during project planning, design, construction and operational phases.
- Design the BIM execution process by creating process maps.
- Define the BIM deliverables in the form of information exchanges.
- Develop the infrastructure in the form of contracts, communication procedures, technology and quality control to support the implementation.

BIM PEPG provides a useful resource for teams to set out project goals as part of an integrated effort to collaborate meaningfully and deliver a BIM project. However, pilot studies on digital information exchange (Hooper & Ekholm, 2010) that sought amongst other things to assess the suitability and practicality of implementing such a project-orientated strategic BIM-Plan, identified that although players thought it was a good idea to have a strategic BIM-Plan in place, a number of execution difficulties emerge:

- The BIM-Plan required to be implemented at the early design phases meaning owner, design team and contractor buy-in. Many key project participants were not and could not be present – such as the main contractor and key sub-contractors – since they had not been appointed yet and where simply not on the scene.
- Absence of key players during the implementation of a so-called project-wide BIM Implementation Plan compromised its purpose and diluted its credibility.

- A tendency for individual consultant disciplines to focus on their own contribution rather than the down-stream use and value of their design effort prevailed.
- Participants agreed that some sort of common strategic BIM plan was of benefit and helped to address the deficiencies of existing guides.

Yet a shift in project organisation from Design & Build / Performance contract model toward IPD indicates it may be possible that the fundamental difficulty associated with the timing of appointments and formation of the core team can be overcome. It is further conjectured that as part of a move to incorporate collaboration supporting mechanisms and protocols, a project specific, common strategic BIM-Plan is a necessary component to enable delivery of a collaboration-rich project.

BIM Inertia – Contracts

Table 1 presents a summarized and categorized overview of contracts and their respective characteristics pertaining to BIM projects.

Table 1: BIM Inertia – Contracts

Contract	Risk	Fees / Reward	Responsibility	Intellectual Property	Legal Liability	Insurance	Incentives (for project success)	Industry Tendencies
ABK 09	Individually managed, transferred to the greatest possible extent.	Individually pursued; minimum effort for maximum return.	Responsible for professional execution of defined scope of work. Duty of care to discover and resolve any failures in timely fashion.	Consultants often pressurised to 'sign-away' Intellectual Property Rights. Clients insist on being allowed to use the data as they wish.	10 year joint defect liability in connection with consultants design contributions.	Consultants responsibilities insurance required based on contract value. Traditional liability.	Credibility. Bonuses available.	Individuals and companies protect their contribution to the project and project self-importance. Information issued on a need-to-know basis.
AB 04	Individually managed, transferred to the greatest possible extent.	Individually pursued; short-cuts and economies sought at every opportunity; minimum effort for maximum return.	Execution of clients requirements through implementation of consultants designs and documentation.	N/A	10 year defect liability for construction works.	Insurance cover for 1st and 3rd person claims.	Greater profits.	Re-work; installation difficulties, blame culture; construction budget and programme overruns.
ABT 06	Individually managed, transferred to the greatest possible extent.	Individually pursued; short-cuts and economies sought at every opportunity; minimum effort for maximum return.	Execution of clients requirements through implementation of consultants designs and documentation.	N/A	10 year defect liability for construction works.	Insurance cover for 1st and 3rd person claims.	Greater profits.	Re-work; installation difficulties, blame culture; construction budget and programme overruns.
Partnering	Collectively managed, agreed & monitored through steering group.	Partial sharing project profits; value-based.	Collective competencies optimised, project targets articulated.	N/A or as AB family of contracts.	ABK 09, AB 04 or ABT 06 are used as as legal basis below the partnering letter of intent.	ABK 09, AB 04 or ABT 06 are used as as legal basis below the partnering letter of intent.	Part share in project profits.	Use of Partnering is increasing but only within contracting organisations.
IPD	Collectively managed, appropriately shared.	A portion of remuneration is tied to project success; value-based.	All project team members responsible for the success of the project. Responsibility for data accuracy defined in the **Object Author Matrix**.	Use of digital information defined in the **BIM Authorised Uses Schedule**. Copyright protection for model authors.	Project participants remain responsible for individual scopes of work, IPD approach should not alter traditional approach.	Insurance cover for 1st and 3rd person claims requires tailored to align with scope of IPD duties.	Share in project profits.	Individuals care more about the results than their own ego.

BIM Inertia - Contracts v2.0 (Hooper, 2013)

Outcome from Focus Group Interviews

In seeking to collect empirical data from industry participants, interview discussions centred around responses to probing questions connected with the practical use and application of the documents cited in Figure 1 on BIM projects were conducted. Identification of perceived barriers or inadequacies was sought. Specifically, respondents were asked to *suggest (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of said documents.* We then turned to ask where *participants thought obstacles to collaboration exist, in particular in relation to downstream transmission of digital information (information exchange); the ability to create and implement common, project-specific strategic BIM plans; and successful project coordination*. Finally, responses were sought in connection to the propositional diagram (Figure 1: BIM-Docs: Constituent parts for BIM-Projects + Propositional Integration Components) which suggests a number of key concepts purported to support an integrated delivery process. Here respondents were asked whether *there is appetite in the industry to use some or all of these concepts in practice today. And to suggest where they thought obstacles exist in adapting these as national branch standard to support BIM collaboration.*

Variance of points of view across sector disciplines was observed as minimal and considered insignificant for this study. For this study, focus is placed on reporting on matters where consensuses of opinions were revealed. Responses are summarised and are later reflected upon as procedural circumstances and behavioural fallout from contractual inertia. Table 2 presents a categorization of the key issues that emerged from discussions which can be distilled meaningfully into 3 themes: *Procedure, Circumstance* and *Behaviour*.

Table 2: BIM Inertia: Obstacles to BIM Collaboration

Procedure

Current standard forms of agreements **are neutrally written** with respect to information management.

Low levels of support for BIM processes exist within these contractual forms of agreement, however appended documents can be included to clarify how information management should be performed.

As models and the data within them are **not considered contract documents**, they are essentially shared with a precautionary **'for information only'** status, compromising their potential downstream value.

The larger individual sector organisations have developed their **own in-house IT/BIM manuals** in attempt to address a lack of national standards. However, it is observed that the in-house IT/BIM manual contributes to **fragmentation of approaches** since there is **no common standard** for their content and scope.

BH90, the industry's digital information handbook could be said to represent something of a hinder due to it is **abstract concepts** and that it **lacks concrete examples** for users.

The matter of **copyright and intellectual property rights** (IPR) is a concern. Often designers are forced by client or contractor to waive the copyright over their designs without any compensation.

The traditional contract (AB 04) is the most **problematic** with regards to the value adding potential of BIM and project outcomes as **contractor claims** are more frequent.

The AB family of **contracts collectively fail to adequately support BIM planning**, decision making and early collaboration that is critical on BIM projects. Such matters are usually dealt with in a more **fragmented way through appended documents**.

The Public Procurement Act requires **separate budgets** are established for consultant contributions, project management, construction work etc. Affecting a fragmented approach to procuring sector players.

- Design consultants are commissioned on time-cost basis and thereby compelled to watch closely their **allotted budget of time and money** so as not to make a loss out of the commission.
- Furthermore, **no incentive for adding value** to the project exists, quite the opposite, consultants are under pressure to produce the necessary documentation for the minimum cost.

Circumstance

A **lack of standardised documents** prevails. Areas in need of further investigation include: A method of describing scope of model(s), LOD, Level of Accuracy, A standard information approval scheme, Model ownership & copyright, and whether the model itself should constitute a contract document or 2D drawings extracted from the model.

Responsibility for the accuracy of a data rich model is exponentially greater than the information on a 2D drawing.

There are a number of particularly acute areas where the responsibility (for authoring and maintaining correctness) of digital information remains problematic including **holes, doors, geotechnical data and quantities**. Where **multi-party input is required, confusion about overall responsibility is exists**.

Issues of responsibility are often resolved on an **ad hoc** basis. Precarious and negotiated consensus has to be achieved by **unstructured and sub-optimal means**, exposing teams to **unnecessary risk**.

There is a feeling in the industry that **risk and reward is not amicably distributed** amongst project team members – design consultants in particular feel they are getting a bad deal for their effort.

Still much **repetition in data** entry due to lack of information stewardship, reliability, chain of information responsibility.

Imbalanced investment v. economic benefit across sector.

Limited scope to realize **win-win initiatives**.

Difficulties is distinguishing and **defining the boundaries** between company BIM business strategy, project based BIM-Strategy and national BIM-Strategy.

Time & money catch 22 - when there is good economic conditions and pressure in the industry there is not the time to spend in developing BIM expertise, when there is a depressed economy there isn't the money to invest in BIM.

Fragmented industry **compartments efficiency initiatives**.

Behaviour

A tendency exists for organisations to develop **isolated internal standards** for the benefit of their own organisation resulting in **compromised cross-sector co-ordination**.

A fear exists of data being wrong. An associated resistance exists to share that information till the author can define its status under current standards.

The submission of drawings (the use of which can be more easily controlled) as part of the contract is preferred. It is considered a more **comfortable means** of formal information exchange.

Whilst construction contracts themselves present **little direct hindrance** to BIM collaboration, many administrative and **behavioural obstacles** to collaboration and BIM processes exist which are interlinked. For those who are not BIM-ready a **traditional mindset prevails.**

Resistance to change and the preservation of the **traditional mindset** in which project participants consciously or otherwise **raise barriers around their contribution** or design deliverables making it **difficult to implement new collaborative procedures**.

High dependence on informal **trust** and **management prioritisation of *internal* optimisation over *project* optimisation.**

Contractors **re-model** the entire projects to enable 4D (Programming) and 5D (Cost Analysis) capabilities of BIM. To address this **re-work** issue contractors have developed BIM-Manuals which are issued to consultants on BIM projects.

Lack of adherence to existing process improvement internal and external **standards**.

Disintrest in following through common objectives following initial enthusiasm.

Ambivalence towards each others BIM-Information requirements.

Lack of knowledge of interoperability standard IFC – **tendency to reject** utilisation / only use if forced. **Lack of trust in IFC.**

BIM Inertia: Obstacles to BIM Collaboration v1.0 (Hooper, 2013)

Regarding the proposition presented through Figure 1: BIM-Docs: Constituent parts for BIM-Projects + Integration Components, the following observations are noted:

- ***Level of Development Schedule at each Stage*** – was something that all respondents thought would be useful to aid and support collaboration. Currently this is missing and no comprehensive standard method of presenting this information as part of contract documents exists in Sweden.
- Many questions remain over the responsibility for the correctness of digital information. For this reason amongst others, a standard form of ***Object Author***

Matrix was considered of value in conjunction with an information approval system.

- Whilst a number of internal *BIM-Plans* exist (taking various forms) a standard project specific ***BIM-Plan*** with an objective to align to whole-team BIM-Goals was recognised to be of benefit.
- Scepticism prevailed regarding the relevance of an ***Authorised Uses Schedule*** (documenting how the recipient of a model may use the data) – since today models are generally only issued for information only, and for this reason authors see no reason to regulate the recipient's use of it. But a model can potentially be used for a raft of different uses (costing, scheduling, performance simulation, code checking, and visualization, to name just a few), it seems obvious that the author of the model should define the suitability of the model for a particular use.
- It is acknowledged to be of **national interest** to have such concepts accepted as **sector standards**. Obstacles **include lack of client interest** and **absence of state intervention**.

A general consensus emerged agreeing that if these supporting components were lifted from being ad-hoc to being formulated into readily available sector standards, the industry may benefit from a more integrated approach through an enhanced scope for meaningful collaboration. The augmented diagram presented as Figure 6 summarises the substance of the respondents' reactions to the proposed chart, extracted from field notes. It furthermore suggests that a core of interconnected supporting mechanisms are desirable amongst AEC players which may, at least in part, address the observed inertia in BIM collaboration that can be seen to be generated by behaviours and circumstances stemming from, inter alia, the traditional construction project mindset.

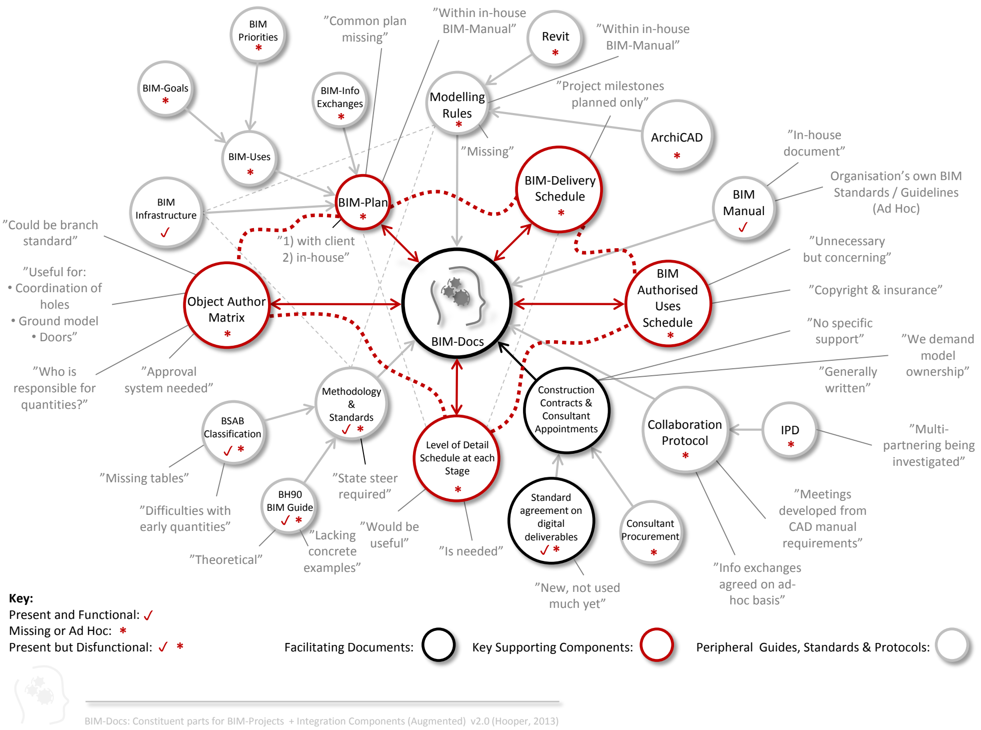

Figure 6: BIM-Docs: Constituent parts for BIM-Projects + Integration Components (Augmented)

Reflections on Procedural, Circumstantial and Behavioural Fallout from Contractual Inertia

Key phenomena or patterns are observed. Here, the raw qualitative data summarised in the previous section is examined through an emerging set of procedural, circumstantial and behavioural issues, stemming to a greater or lesser extent from contractual provisions or the lack of them. These are reflected upon through attaching effect and outcome parameters and cognisance is considered to the impact of plausible BIM collaboration supporting mechanisms. Table 3 presents a simple breakdown of patterns observed interpreted as fallout from contractual indifference to BIM processes and integrated approaches. The results can be seen to shed new light on the connections between contractual provisions and procedural circumstances and behaviours on BIM projects that may have wider application.

Table 3: BIM Inertia: Contracts & Behaviours – Effects & Outcomes on BIM Projects

Procedural / Circumstantial / Behavioural Issues	Effect on BIM Projects	Outcome on BIM Projects	Impact of Plausible Supporting Mechanisms
#1: Lack of Standard BIM-Orientated Contracts	Compromises & ad hoc negotiations	Confusion, resistance to change	Reduce
#2: Lack of Standard Documents (inc. BIM-Addenda)	Fragmented approaches, confusion	Lack of confidence, expense, setbacks	Reduce
#3: Isolated Initiatives	No integration, limited gains	Compromised cross-sector coordination	Reduce
#4: The Fear of Sharing	Late decision making, poor coordination	Loss of value, missed opportunities, waste	Eliminate
#5: Responsibility for Accuracy & Multi-Party Input	Confusion, missing info, error	Blame-game	Eliminate
#6: Comfort Zone	Missed opportunities	No positive outcome	Reduced
#7: 2D = Contract Documents, 3D ≠ Contract Documents	Limited value creation, lack of confidence	Loss of value, missed opportunities, waste	Eliminate
#8: Issuing data with 'For Information Only' status	Information used at own risk	Loss of value, missed opportunities, waste	Eliminate
#9: Traditional Mindset	Resistance, lack of commitment	Frustration, disappointment	Reduce
#10: Ad Hoc Negotiations	No control	Increased risk	Reduce
#11: Imbalanced Risk & Reward	No incentives to add valve	Focus on own contribution	N/A
#12: In-House BIM-Manuals & Fragmented Approaches	Short term order, long term chaos	Most powerful actor benefits the most	Reduce
#13: Abstract Concepts & Lack of Concrete Examples	Confusion, no sense of direction	Creation of own concepts & examples	N/A
#14: Copyright & Intellectual Property Rights	Frustration & marginalisation	Compromised protection of original ideas	Eliminate
#15: Claims Culture	False budgets, no positive outcome	Overspend & delay	N/A
#16: Inadequate & Non-Standard BIM-Supporting Mechanisms	Confusion, chaos	Lack of confidence, missed opportunities	Eliminate
#17: Dependency on Trust & Co-operation	Setbacks, frustration, time wasted	Surprises, overspend & delay	Reduce
#18: Whim of Individuals & Anti-Teamwork Attitudes	Risk, frustration, lack of commitment	No positive outcome	Reduce
#19: Public Procurement, Compartmented Budgets & Teamwork	No connection, or incentives to add value	Loss of value, missed opportunities, waste	N/A
#20: Re-work: Re-Modelling & Repeat Date Entry	Risk of error & waste	Duplication of effort, 'wins' negated	Reduce
#21: Confidence & Existing Standard Solutions	Traditional thinking, stagnation	Compromise, limited value added	Reduce
#22: A Collaborative Culture	Cooperative dispositions	Low no. of lawsuits	N/A
#23: If no clarity on Status of Deliverables & Model Status	Data Misuse, confusion, error	Poor coordination	Eliminate
#24: If no clarity on BIM-Uses	Data Misuse, confusion, error	Re-work & waste	Eliminate
#25: Lack of definition of Cross-Party Interface	Communication fiasco	Frustration, disappointment	Eliminate
#26: Timing & Scope of Appointments	Compromised cross-party strategic buy-in	Loss of value, missed opportunities, waste	N/A

BIM Inertia: Contracts & Behaviours – Effects & Outcomes on BIM Projects v1.0 (Hooper, 2013)

In Table 3, 26 discrete issues surfaced as being significant in the context of BIM projects resulting in, amongst other things, setbacks and frustration. Understanding traditional behaviours and their impact on BIM project outcomes brings the need for decision-making and collaboration supporting mechanism into focus. Whilst not all obstacles can be removed through the application of BIM-Addenda championing BIM collaboration supporting mechanisms, a number of the most important issues can be suitably addressed, enabling teams to affect a greater level of integration.

DISCUSSION AND IMPLICATIONS

This chapter examines the connections between the commercial environment and contractual provisions that regulate party's business relationships and the resultant procedural and behavioural phenomena that can be viewed to thwart BIM collaboration and project outcomes. Whilst this research focuses on the case of Sweden, the patterns observed can be deemed typical and therefore can be seen to strengthen and broaden the application of the emerging results.

The findings indicate that most industry representatives perceive similar patterns of existing barriers to BIM collaboration, however are hesitant to place the fault directly on contracts themselves, rather on a combination of circumstances and behaviours associated with traditional mindsets and the commercial environment. The emerging issues cited in the results point towards a more tacit set of phenomena that can be seen to relate to contractual provisions (or the lack of them). A certain consensus emerged on ways to tackle said difficulties however procedures remain ad hoc and a lack of standard approach prevails.

Having rationalised the attributes of certain BIM inertia into a set of re-occurring procedural, circumstantial and/or behavioural issues one can more readily draw an understanding of the connections to contractual provisions and in the case of Sweden the lack of standard BIM collaboration supporting clauses or addenda. Furthermore, the repeat occurrence of particular behaviours and associated effects provides strong evidence to show that teams require support on BIM projects to better manage decision making and deliver a more integrated approach to project execution. The balance between enabling and disruptive tensions that traditional contractual arrangements can generate offers us insights into what collaborative processes are important. Project outcomes purporting attributes of misaligned goals or divergence over methodology can readily be traced back to poor or non-existent provisions leading to protective behaviours. Accordingly, it is recommendable that branch standard supporting mechanisms are adopted to avert setbacks. This is consistent with past research. The novelty of this research is that it provides a more comprehensive view of those behaviours that hinder collaboration and can lead to inertia on BIM projects. This extends previous studies, for example, Gu and London, (2010) which highlights the need for decision-making frameworks to integrate solutions to both technical and non-technical challenges or Rekola et al. (2010) which simply classifies problems into technology, people and process categories.

The contribution of the research is an improved understanding of BIM inertia, extended insight into the connections between specific behaviours, traceable circumstances and BIM project outcomes, and a knowledge of a local consensus behind the need for, and focus of, a number of BIM collaboration support mechanisms.

CONCLUSIONS

This chapter investigated contractual and behavioural challenges to BIM collaboration and digital information stewardship. It highlights a number of discrete phenomena viewed as detrimental on BIM projects and validates the need for tailored BIM collaboration supporting mechanisms to underpin the value and downstream utility of authored digital information about facilities. To the original research questions of *what the connection is between traditional contracting and BIM inertia and what the necessary components are that may facilitate more effective early BIM collaboration*, we can now say, first that traditional project structures and contracts can create discrete and often competing agendas and associated behaviours. Lack of contractual provisions that support technology, people and processes, can be said to be particularly problematic when working in a BIM mode. Here a whole new set of procedural, circumstantial or behaviour issues can emerge if left unchecked. Difficulties can be traced through commercial and legal pressures to protective behaviours which can compromise collaborative efforts and ultimately project outcomes.

Respondents highlighted the need for five key supporting mechanisms, which if standardised, may offer a means to avoid communicative setbacks and frustration on BIM projects. Whilst ensuring collaboration and making BIM work on a project wide basis may come down to the individual behaviours of the parties' involved, certain contractual provisions can provide the framework to encourage and support collaboration and guide team players to realising project BIM objectives with minimum friction.

To the question of *what we learned here that may have wider application through consideration of suitable BIM collaboration support mechanisms that may reduce or remove collaboration barriers,* we can conjecture that the five collaboration support mechanisms cited deployed as a project wide or even national standard BIM-Addendum may, in theory, offer the *active collaboration* support necessary to reduce or remove BIM inertia. Further work is required to test and tune this hypothesis and assess the real impact of BIM addenda on project outcomes, however results support Kuiper's (2013) conviction that 'bolt-on' addenda to existing contract arrangements appear to be a necessary stepping stone towards delivering integrated projects and this work contributes toward unravelling the uncertainty over what such addenda should contain and what should be standardised for the benefit of the industry and project outcomes. It will take time to establish proven best practices and further time for de facto standards to emerge. But what this study shows is that if one wishes to remove or reduce BIM inertia one must first understand the behaviours and outcomes one wishes to change.

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Paper #4:

Automated Model Progression using Level of Development (LOD)

Type: Journal Article

Status: Submitted & Under Review
Construction Innovation

Authors: Hooper, M.

Automated model progression scheduling using Level of Development (LOD)

Abstract

Purpose - Level of Development (LOD) is a key parameter for describing digital content in a Building Information Modelling (BIM) context. It is seen an important vehicle for specifying information exchange throughout a facilities lifecycle. However, hitherto there has been little research examining how, beyond the theoretical concept, LOD can be being applied and smartly utilised in practice. This study seeks to unravel the concept and reveal new insights into its application from a design management perspective.

Design / Methodology / Approach - Following a literature and document review, two small-scale case projects were identified. The first to temper the state of the art theory and understand what happens in practice today – discovery led. The second, to drill down to the core of LOD utilisation to support planned model progression and test a plausible novel methodology to automate associated work-flow – theory led.

Findings - Results suggest that a lack of consistent understanding and utilisation exists and particular LOD errors are highlighted, but moreover that LOD can be so much more useful if integrated into a BIM-like workflow. Consequently, a new method of automatically comparing planned model progression with the current state of the model is presented.

Practical Implications - Advancement of the understanding of the concept and application of LOD and its usefulness has significant implications for design information management research.

Originality / Value - Fresh insights into LOD, concept and application are presented. The emerging proposed utilisation framework is novel and targets removal of known labour-intensive activities associated with LOD matrices whilst facilitating rich re-use of efficient model progression knowledge.

Keywords: BIM, Building Information Modelling, LOD, Level of Development, Model Progression.

Paper type: Research paper

Introduction

Background

The concept and possible application of *Level of Development* (LOD) was pioneered by Vico and Webcor in 2005 as part of their Model Progression Specification (Vico, 2012). It was later refined by the AIA's IPD Task Force and adopted by the AIA in late 2008 (AIA, 2008). Versions of the same concept emerged around the world in BIM Standards & Guidelines about the same time: *Informationsniveauer*, BIPS (2009), *Detaljeringsgrad*, SIS (2008), *Model development Phases & Information Content Levels*, CRC (2009). The latest and perhaps most important publications advocating and explaining LOD are the AIA's new *G202-2013 Building Information Modeling Protocol Form* (AIA, 2013) which provides the basic LOD definitions together with a standardised responsibility matrix, and *Level of Development Specification* (BIM Forum, 2013) which attempts to clarify what the designations may mean for a comprehensive range of building systems.

Utilisation of LOD as object status identification parameter enables one to filter out which objects and object properties are relevant for particular purposes, in other words, that information required to carry out a specific BIM-Use. The expected benefits of using LOD as model parameter are improved effectiveness and efficiency in communicating and executing model development by allowing model content to be fully and clearly defined (Bedrick, 2013). However, current debates (McPhee et al., 2013a, 2013b & 2013c; Kastell et al., 2013b) question its usefulness and furthermore, together with associated Model Progression Specifications (MPS) are critical of the labour-intensive, complicated schedules that are managed outside the BIM model. Nevertheless, it is claimed we need LOD employed in a consistent way in order to benefit from automation (McPhee, 2013a). Moreover, if we are to allow that definitions of digital information deliverables be comprehensible by both man and machine, standardisation of methods to describe them seem an obvious boon. That is, by asserting better control of digital deliverables through LOD, we can improve accuracy of information exchanges by increasing knowledge about the reliability and specificity of a facilities digital representation.

Problem statement, Research Question & Aim

Today where LOD & MPS are not utilised, (and hence scope of service content, extent and usability of deliveries left open to interpretation) downstream users of digital content use it at their own risk (Edgar, 2011). Mismatches occur resulting in confusion, frustration and missed opportunities (Hooper & Ekholm, 2012). Accordingly, a central issue is how to better facilitate adoption of LOD and associated responsibility matrices by improving their integration into BIM workflow. By viewing LOD as a linchpin to BIM - it is sits between the crucial systems of *Information Deliverables* and method to describe them and *Contractual Agreements & Responsibility for Information* – the aim of this research is firstly to uncover mechanisms facilitating and constraining utilisation of LOD to support information stewardship and secondly propose a method to automate model progression scheduling using LOD as pull parameter.

Methodology & Result

This objective is pursued by: 1) a review of the state of the art in LOD utilisation; 2) the study of a construction project in a major construction company where BIM has been used in an advance way; 3) development and exploitation of an experimental LOD model; 4) an analysis of empirical data and ratification of what is happening. This leads to the development of a promising new framework for integrating LOD utilisation into an automated workflow using model rule-sets and model checking tools.

Understanding LOD – Concept & Application

Literature Review

A literature review focusing on BIM and specifically the utility of LOD is provided to establish a context for the research. The concept and application of LOD in BIM projects is still relatively new, consequently there are limited existing studies to build on. This review therefore goes beyond academic publications to also include standards, guidelines and reports generated by government and other regulatory bodies, (AIA, 2008) (AIA, 2013a) (AIA, 2013b) (BIM Forum, 2013) (BIS, 2011) (CIC, 2013) (SIS, 2008) (Svensk Byggtjänst, 2011) current expert debates, (Kastell et al. 2013a) (Kastell et al. 2013b) (McPhee, 2013c) blogs, (McPhee, 2013a) (McPhee, 2013b) (Renehan, 2013) (Van, 2008) and articles published in respected online newsletters (Bedrick, 2008) (Bedrick, 2013) (Byggindustrin, 2013) that reflect the latest developments and philosophies of LOD in BIM.

Whilst technology has enabled a whole new level of collaboration through the use of proprietary BIM tools, the industry has some catching-up to do in terms of establishing common understandings of BIM concepts and applying consistent methodologies that may enable value-adding stewardship of digital information through construction project phases (Ekholm et al. 2013). A number of recent reports and standards (AIA, 2013; BIM Forum, 2013; Cuneco, 2012; Bedrick, 2013,) are advocating or reinforcing the importance of the concept of Level of Development (LOD) to support digital deliveries, however current debates (McPhee et al., 2013a, 2013b & 2013c; Kastell et al., 2013b), suggest both the concept and application of LOD today remains something of a theoretical and practical problem within the world of BIM.

Becerik-Gerber & Kensek (2010) highlight a lack of research on this topic and underline a need to research mechanisms [such as LOD] that may go some way towards providing standardised solutions to questions like: *what level of information is needed at each stage and who is responsible for it?* The AIA's Document E202-2008: Building Information Modeling Protocol Exhibit (AIA, 2008), recently updated as a set of digital practice documents (AIA, 2013b & 2013b), aims to address this question with a standardised protocol but it remains a high maintenance, stand-alone process that is created and managed outside the BIM.

In 2008, Bedrick highlighted that: '*at the core of architectural design is the process of moving from approximations to progressively more precise information. Representations of building elements in a BIM, though, are exact, whether they're intended to be or not, and can give a false indication of the precision actually known at a given point in the design process. Add to this confusion the fact that it is possible to use a BIM for many purposes (costing, scheduling, performance simulation, code checking, and visualization, to name just a* *few), some possibly not considered by the author of the BIM. The need for a framework for defining a BIM's precision and suitability for specific uses becomes obvious'* (Bedrick, 2008). From these circumstances the AIA's E202-2008 Building Information Modeling Protocol Exhibit (AIA, 2008) emerged as a stand-alone document designed to be appended to contract documents on BIM projects. Model Element Author (MEA) and Level of Development (LOD) arranged in associated model element classifications are cited as the 2 key ingredients that must be decided and recorded at the outset to avoid subsequent confusion and risk. Lighthart highlights LOD can be utilised as an alignment tool, then later in the process as means of checking contract compliance (McPhee et al. 2013b).

Since the AIA's first official publication of AIA E202, the concept of LOD has gone through further refinement. Expansion and clarification of the concept through description and graphic representation can be found in BIM Forum (2013). However, reports on the efficient application are few. We know that the utilisation of MPS and associated LOD tables can be obscure, time-consuming, even difficult to relate to, but how has the research community responded? Leite et al. (2011) reports on the impact of Level of Detail (LoDt) on modelling effort through design development. However there is little research on LOD, or the impact on hours spent modelling and administrating model progression diligently and if / how processes could be streamlined to utilise LOD more effectively. Whilst Leite et al. (2011) highlights the impact of modelling effort to achieve various LoDt's and notes effects on modelling man-hours, they side-step the BIM LOD indices of *reliability* and *specificity*.

Choi et al. (2011) assumes a rather simplistic interpretation of LOD in their study of data interaction. Li et al. (2008) refers to LOD, but proposes a different nomenclature with similar taxonomy scale. He refers only to geometry. Neither object properties or the real meaning of LOD (*reliability* and *specificity*) surface. Chang & Shih (2013) are nearer the mark in reference to the AIA's standard definitions, though later regresses to project stages. However Chang & Shih do provide us with insight as to what a model with respective LOD's might contain and even suggests selections of functions a model at a particular LOD should be able to fulfil. But the question remains, as an alternative to manual personal checklists (which we observe are emerging as a quick-fix solution), is there a way LOD utilisation could be better integrated into BIM workflow though automation?

Whilst the idea of LOD is not new, its meaning and application in a BIM context has created notable confusion which has manifested in ad hoc utilisation and regression to an understanding of it as simply quantity of detail instead of reliability and specificity of information. To move forward we must look again at current debates and how consultants are using LOD in practice. McPhee, for example, offers us a number of problematic scenarios and argues both for and against its use (McPhee et al. 2013c). McPhee (2013c) asks *what is LOD, is it useful or just another pointless deliverable*? Highlighting that even after the publication of the Level of Development Specification (BIM Forum, 2013), confusion remains about what LOD levels mean and how they should be used.

The argument deployed most often against the use of LOD and MPS, whether brokered by the AIA's Protocol Exhibit (AIA, 2013) or another system, is that its use implies high maintenance activities carried out outside the BIM. This position has been most famously advanced by McPhee et al., 2013a, 2013b & 2013c in current debates involving industry experts. He articulates: '*All the BIM guides have some form of LOD table in them. They are invariably enormous complicated schedules that are managed separate to the BIM model'* (McPhee et al. 2013b).

Re-Occurring Issues: Confusion & Frustration

Collectively we can observe the re-occurrence of several emerging issues concerning LOD concept and application; moreover the main reasons why hitherto the application of LOD has been both inconsistent and weak can be assigned or designated to these same issues, namely: 1) a lack of consistent understanding and utilisation of LOD in practice; 2) scepticism over its usefulness; and 3) difficulty in integrating LOD & MPS into a BIM-like work flow, vis-á-vis a dissatisfaction with the management of it outside the BIM in high maintenance stand-alone documents. These issues are echoed by Lighthart (McPhee et al. 2013b) who reports widespread confusion as to how it can be applied, frustration over its high maintenance legacy and division over its usefulness. Even Guttman, subcommittee member of the action group that spawned the original AIA E202, expresses concerns about the practicalities of LOD: *'I have always been troubled by the way that we sometimes promote standards that are not really based on a history of industry practice'* (McPhee et al, 2013c). All this suggests a need for further investigation into firstly its usefulness and secondly it's integration into BIM work-flow. That way, given time, we may discreetly address the issue of inconsistent utilisation.

To the question: *'is it useful?'* Lighthart intimates it would be so much more useful if LOD in association with MPS could be used to automatically check planning progression against the status of the model (McPhee et al, 2013c). That way the concept can be applied and managed within the BIM. Here we can start to consider where contribution can be made to the current state of knowledge. But first where does LOD sit in relation to developments at buildingSmart? Formal grouping of model contents into *views* is one of the initiatives led by buildingSmart (BuildingSMART, 2014). The idea is that model view definitions (MVDs) groups model contents, expediently identifying objects and object properties to be used at a certain LOD, for example to perform energy calculations, an acoustic analysis and the like. This work is still under development, however more MVD's are emerging. Related to this are Cuneco's latest initiatives (Cuneco, 2012).

A Danish Initiative

Cuneco (2012) are developing a novel method of deploying LOD in Danish practice. Their Method and Structure for Information Levels (Cuneco, 2012) explains a discrete LOD concept and application and proposes its integration to their construction classification system (CCS) and implementation in IFC. This represents a bold step forward for the concept and application of LOD and testament to its importance as object parameter. This together with other Cuneco initiatives is set to push the Danish BIM standardisation efforts further to the forefront.

Research Gap & Contribution

In this respect, this study seeks not to re-invent the wheel, rather to explore alternative ways in which LOD can be used to support model progression. Hitherto, there is a lack of insight into how one might utilise LOD to ensure design information is being authored sequentially and make best use of both office resources whilst focusing on value-creating activities. Both Cuneco (2012) and BIM Forum (2013) describe the benefits of LOD employment in similar terms: to support information production and exchange. However there is little case evidence to support this, and it has not been within the scope of the guidelines or standards to offer examples. It is here, together with the offering of an alternative methodology, contribution can be made to the current state of knowledge.

Lighthart (McPhee et al. 2013c) suggest there is room for greater clarity, and implies something tangible to test: is there a way of automatically verifying model content against intended use and programme, that could then be standardised and become a universally accepted norm? This research takes this question and suggests, develops and tests a theoretical framework demonstrating how this might be achieved.

Methodology

Research Design

The research design has been flexible from the start to enable a framework of reference to emerge during the study. The literature reviewed; current international debates, the emergence of new supporting documents (LOD Specification 2013, AIA G201&202 2013), together with consultant interviews and discussions revealed a real need for research in the rather specialised theme within the field of BIM: Level of Development. To move forward, two small scale but very different case projects were identified. The first to temper the state of the art theory and understand what happens in practice today – discovery led. The second, to drill down to the core of LOD utilisation to support planned model progression and test a plausible novel methodology to automate associated work-flow – theory led. The aim is to remove the mundane high maintenance activities currently associated with LOD tables by adopting standardised rule-sets to automatically check the model against planned progression.

Method Execution

Execution follows a number of sequential steps, namely: a review of the state of art in LOD utilisation; isolation of the issues, analyses of a strategic case project; ratification of what's happening and finally development of a possible framework for integrating LOD utilisation into an automated workflow (Figure 1). Conclusions reflect over the positioning of the results against the current state of knowledge.

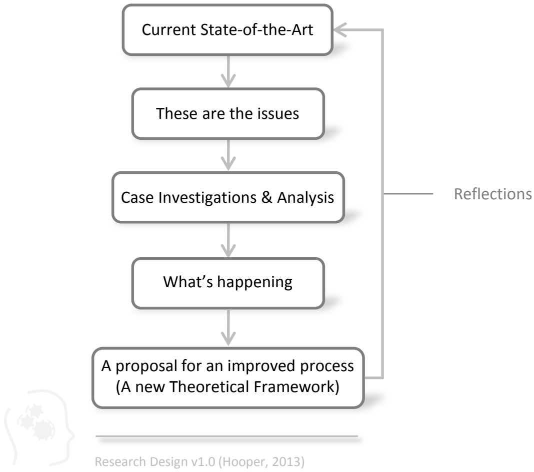

Figure 1: Research Execution

Rationale

A qualitative approach was adopted from a critical realism perspective where acknowledgement is made to contextual factors (associated with case) whilst also arguing the phenomena under study can occur in similar settings (Saunders et al, 2009). Adoption of this approach supports the investigation in so far that it allows for the study of a complex and contemporary phenomena over which the investigator had little or no control (Yin, 2009). Data gathered has been deductively analysed to expose and interrogate the key components that influence the particular phenomena under study as described by Denscombe (2008). This enables a clearer understanding of both utilisation of LOD in context and provides insight into emerging possibilities that can be deemed relevant generally.

Data Collection Instrument and Process

The literature review supported the formulation of a testable hypothesis which enables the study to stay within feasible limits (Yin, 2009). The data collection process started with an interview protocol, which was developed to increase consistency of the research (Yin, 2009). Accordingly, all interviews, associated with Case #1 followed similar case questions and collection procedures. The protocol focused on a narrow set of questions designed to unravel what happens in practice and facilitated the production of the Case #1 process map upon which we later build our new LOD work-flow. Further empirical data was collected through documents, telephone and e-correspondence. Case #2 allowed us to edge forward in developing a new theoretical framework for automated model progression scheduling using LOD. The case study's strength is its ability to deal with a full variety of evidence - documents, interviews, and observation - beyond what might be available through other research approaches (Yin, 2009).

Data Analysis

A deductive approach is chosen for maximizing reliability and credibility in the results. The main unit of analysis is evidence of barriers and opportunities for LOD utilisation to support digital deliveries and model progression, with embedded units being the responses from interview sessions. Analysis began with transcribing interview responses into statements, abstracting and transforming the data into process-orientated events where evidence was convergent and corroborated. This enabled the development of a process-map recording what happened in Case #1. The emerging process-map is then re-worked to leverage LOD and feeds into the development of a new theoretical framework which is tested in Case #2.

Data Collection and Case Descriptions

The collection of empirical material has been assembled to firstly facilitate a deeper understanding of the circumstances and context that LOD as object parameter may be used, and secondly study model progression though the design and construction process and identify if and how automation is feasible. To meet these objectives a series of interviews with key personnel within design consultant and contracting organisations were carried out in a connection with a replacement bridge project where BIM is used in an advanced way (Bridge over Arbogaån near Röfors) together with the generation and examination of a controlled experimental model (The LOD Experiment).

Case #1: Bridge over Arbogaån near Röfors

In order to correlate state-of-the-art theory on LOD utilisation and understand how it might be adopted usefully in practice, we selected a suitable case project - Bridge over Arbogaån near Röfors, Sweden (Figure 2). The project, initiated and commission by the Swedish Transport Administration (Trafikverket), involved procuring a replica replacement 63.5m long bridge over a river near Röfors in Sweden. It was a small enough project to allow us to look closely at the content and purpose of information exchanges and understand what happens in practice. The project was a pilot where the team sought to break new ground with regards to integration of process, combined project tasks and data control utilising BIM. Significantly, the tender documents were let as a BIM model and digital documents instead of traditional drawings and specifications, and the contract documents hierarchy was amended to place BIM deliverables in the centre. The case is intrinsically interesting and a unique opportunity emerged to study it. The bridge was completed in August 2013.

Figure 2: Bridge over Arbogaån near Röfors (Source: Trafikverket)

Case #2: The LOD Experiment

The second case, The LOD Experiment (Figure 3), was initiated through the need to establish a platform to develop and test our theoretical proposition. The rational here is that we establish a secondary case for the purposes of theory-building and theory-testing. This theoretical exemplar enabled us to experiment with crucial object parameters and capabilities of modern model-checking tools. The digital project, based on a simple 2 storey dwelling, was created using a common BIM-Authoring tool and represented a necessary component of a research effort designed to produce both theoretical and practical results.

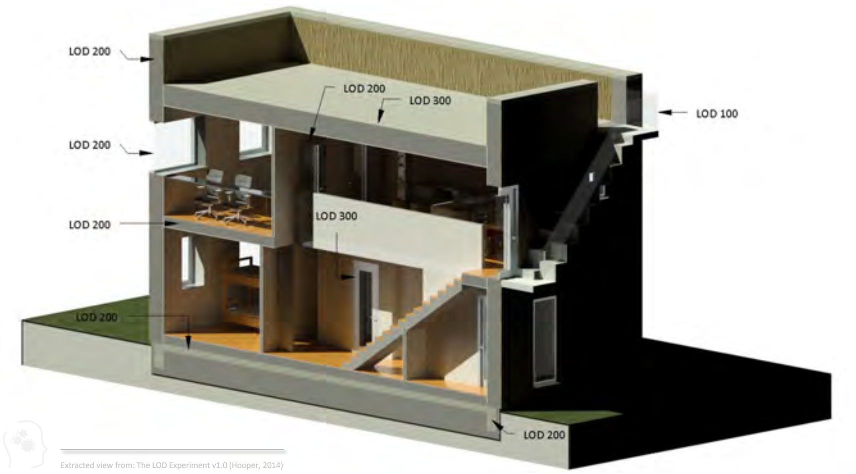

Figure 3: Extracted view from: The LOD Experiment (Source: Lund University)

A purpose-made rule-set was created to automatically interrogate model compliance with the delivery specification. The BIM-Use adopted was *3D Design Coordination* at *Scheme Design* stage.

Theory

Current theory suggests LOD is a key parameter for describing and aligning digital information content in a BIM context (Bedrick, 2013). On the one hand it represents an important component to describe a BIM-Info Deliverable (specificity and reliability of digital objects), and on the other, a unit to describe authorship responsibility connected to a party's contractual obligations. Figure 4 suggests LOD may represent something of a linchpin to BIM.

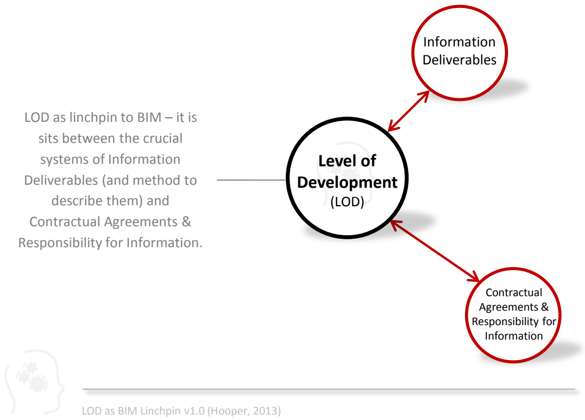

Figure 4: LOD as BIM Linchpin

Some object attributes are straight forward and can be readily automated and managed in the model including, *object author*, *object creation* and *last changed date*, and *object classification*, but others, for example *object status* and *Level of Development* are more awkward to handle. Whilst it is straightforward to stamp a drawing with a 'Preliminary' or 'Tender Document' or 'For Construction' status, in a BIM project it is less clear. Objects can have different statuses at particular project stages; whole models are unlikely to ever have one particular status (McPhee et al., 2013b). This is where the LOD parameter helps. It enables downstream users to understand the degree of completeness vis-á-vis how much they can rely on the information at object level (OpenBIM, 2013b).

Figure 5 illustrates key information deliverable parameters and where the LOD component fits in. Here we can understand what the relevant indices are, what they do and the potential to automate their production and management through model development phases.

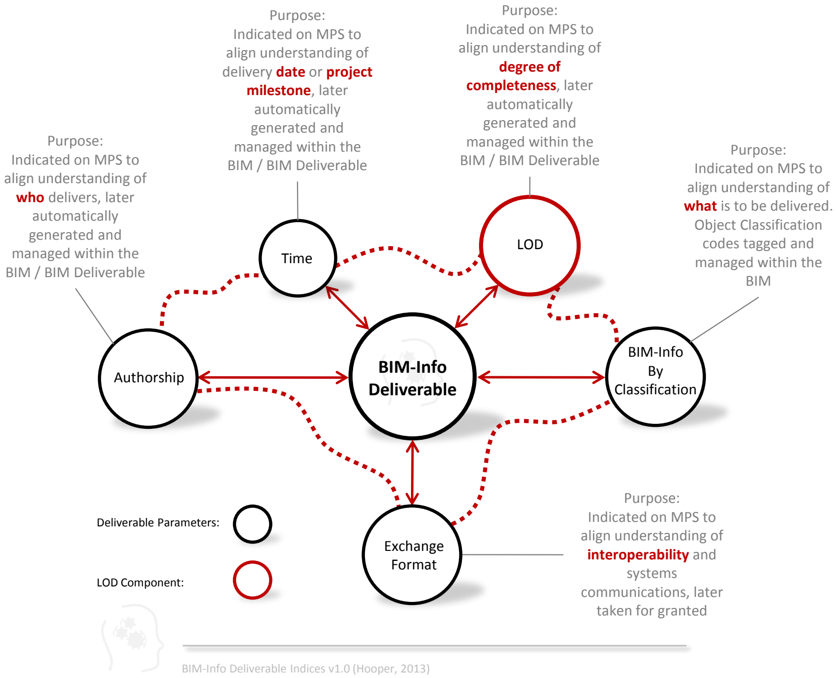

Figure 5: BIM-Info Deliverable Indices

Lighthart & Succar, further dissects LOD into 2 important indices: *reliability* - the degree to which users can rely of the information; and *specificity* – the degree of geometrical and information accuracy (McPhee et al., 2013a) (McPhee et al., 2013c). Furthermore, in reference to the AIA's fundamental definitions of levels LOD 100-500, Succar (McPhee et al., 2013b) points out that whilst it is awkward to assign anything but a round number LOD (100-500) without opening up a whole new can of worms as to what is meant, '*LOD tries to paint a complex picture with a single colour (5 shades allowed). It is an excellent way to make all pictures similar but adding extra colours can make the picture a little more expressive*'.

LOD can, however also be expressed through object class and attributes. For example, at a certain LOD an object may be classified as an Element according to ISO 12006-2 (ISO, 2002), stating that its function is determined. Another LOD may require that the composition of the object is determined (by classification), or that its U-Value or loadbearing capacity is determined (by additional attributes). Furthermore, IDM (Information Delivery Manual) based on ISO 29481-1&2 is an emerging method of defining information exchange requirements on a software implementation basis. Ratified through BuildingSmart, the IDM method uses the open interoperable data model (IFC) and the output is often a MVD (Model View Definition) containing a subset of the IFC data model (Bips, 2014). The whole depends on comprehensive software implementation.

However, even used in its crudest form (LOD 100-500); Level of Development forms a crucial component of a digital delivery specification (Figure 6). In the example below, BIM-Info Classification listed on the left, followed by Responsible Party, LOD, Author, Receiver and Delivery Format. The target LOD enables alignment of expectations, and if used as the AIA intends, can form the backbone to information exchanges between parties and processes.

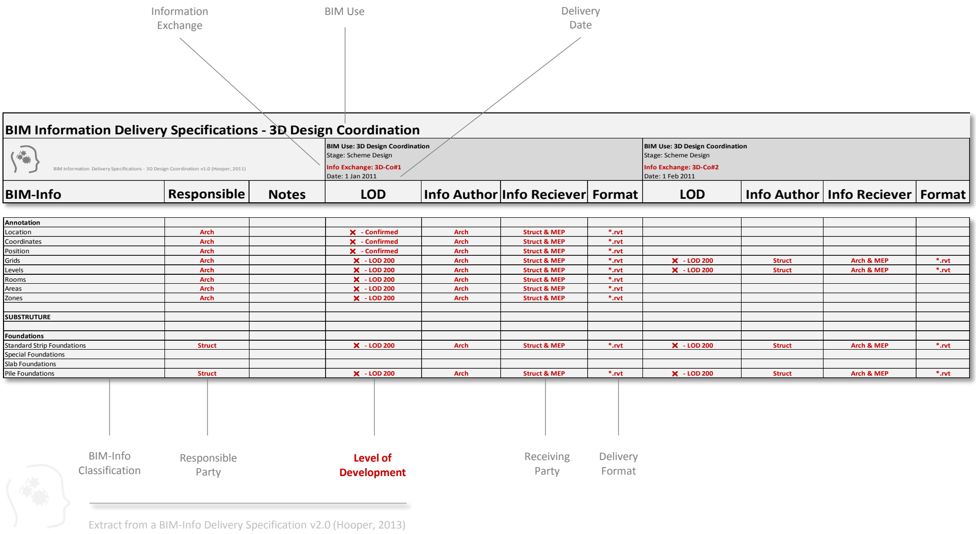

Figure 6: Extract from a Digital Delivery Specification (Source: Hooper & Ekholm, 2012)

We conjecture that, in theory, it should be possible to exploit LOD deployed in delivery or model progression specifications (MPS) in a way that eliminates mundane manual tasks and assists authors in producing the right information at the right time, for the particular purpose. Figure 7, suggests a model of how this might be done using proprietary specification, modelling and validation tools. The delivery specification describes model content requirements using amongst others, LOD as object parameter. The BIM author populates the model accordingly and a rule checking tool is used to validate content. Non-compliances are highlighted for the BIM author to action.

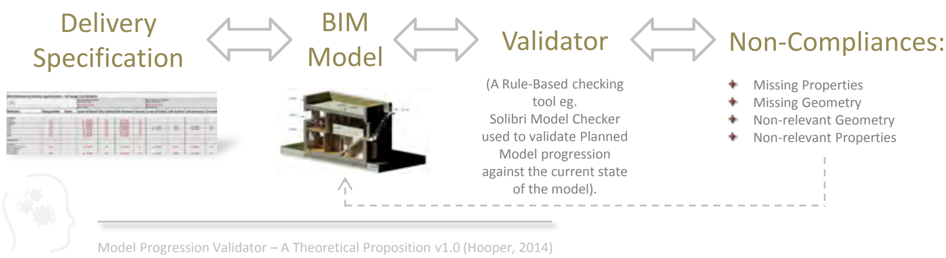

Figure 7: Model Progression Validator – A Theoretical Proposition

Results

Taking the resultant model development process from Case #1, we are able to develop a new LOD utilisation framework designed to exploit LOD and guide the model development process more effectively that is tested in Case #2. The intentions are to develop an automated mechanism that may ensure the project is on track and enable implementation of optimal BIM-Uses along the way, thereby adding value to the process and maximising opportunities to leverage the data behind the virtual building.

Case #1: Observations

The main result of the Bridge over Arbogaån case study is an annotated process map (Figure 8) which firstly attempts to reveal what happened, and secondly inform us how we may improve and better leverage LOD.

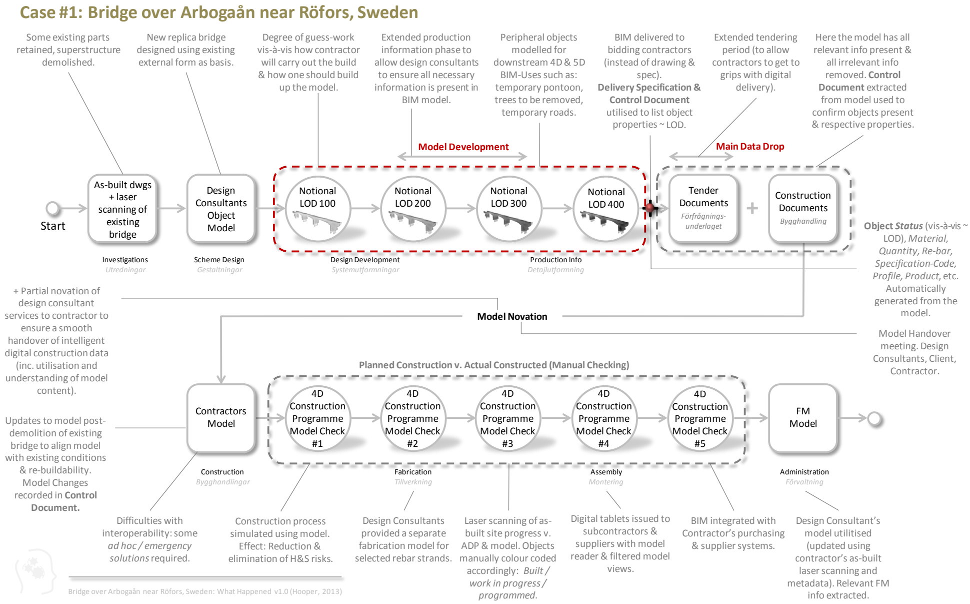

Figure 8: Bridge over Arbogaån near Röfors: What Happened

Whilst the intended benefits of delivering digital information to site and later for FM were realised, we noted that utilisation of LOD (per the AIA's nomenclature) was only notionally observed through the crucial model development stages. The main reason for this was that there was no need or desire for design iteration - the bridge was simply to be a replica of the existing, whilst adopting current road safety standards and increased bearing capacity. The challenge was to incorporate all this into the existing external geometry and deliver a digital product model for tender and construction (OpenBIM, 2013a).

The impact of unambiguous digital information deliverables, defined through alternative parameters such as specification codes had a positive effect on the project outcome. Not just in hard terms: on time, on budget, but significantly on working relations. Colleagues became closer and more focused as a result of the new way of working (purposefully exploiting the digital asset) and common goals emerged from better defined, richer and more accessible deliverables. A key member of the design team was novated to the contracting team to enable a smooth transition of design information to the contractor domain. A significant effect of delivering contractual documents digitally instead of in paper form is that it *enabled* downstream BIM processes to be executed without quibble about responsibility for accuracy and correctness, avoiding the scenario of downstream users utilising the intelligent digital information at their own risk which hitherto has been an issue in Sweden (Edgar, 2011).

However, observations suggest that a lack of consistent understanding and utilisation of LOD exists and, in concurrence with the literature, discussions implied certain scepticism over its usefulness and reveal difficulties in managing object status and LOD expediently.

Unravelling Misconceptions about LOD

Whilst earlier findings on digital authorship (Hooper & Ekholm, 2012) suggest: 1) a tendency to focus on authoring the wrong information to the wrong LOD for BIM deliverables on the information delivery critical path; 2) adoptive work and laborious effort on carrying out changes; 3) a tendency for BIM authors to wait till the other has reached a certain LOD till they commence their BIM contribution; 4) wasted opportunities, and delays in arriving at genuinely optimised solutions. Here, emerging from case investigations and more open discussions are 4 rather fundamental *LOD errors* which can be paraphrased into the following observations:

- LOD Error #1 - We can't see the wood for the trees: A serious consequence of a lack-lustre attention to level of development is the dire effects of content hoarding - models laden with irrelevant, wrong or out-of-date information making it simply not possible to see the wood from the trees.

- LOD Error #2 - Using objects that may cover all eventualities: Whilst it may seem a good idea to adopt objects that appear to cover all eventualities, they may come to serve as a hindrance to down-stream users. The information, the object, instead of being smart and actually meeting the needs of all users, becomes clumsy and un-usable, suggesting conflict between *versatility* and *usability*.

- LOD Error #3 - Quick-Fix, reactionary ad hoc solutions in emergency situations: A lack of industry-wide pre-defined standard solutions prevails. Fumbled, quick-fix solutions are often favoured to get deliverables issued on time, prioritised ahead of developing robust solutions and re-using knowledge which may render the process of model development more efficient, and improve output quality.

- LOD Error #4 - Individual checklists v. Standardisation: Working in a BIM mode demands a level of standardisation in both concepts, routines, processes and data formats (Ekholm et al, 2013). Whilst use of individual checklists is one way to organise one's own work and move ahead in earnest, digitalising and re-use of knowledge associated with routine activities can be seen as obvious benefit supported by BIM.

Case #1 provided us with a process map illustrating what may happen in practice today in a typical BIM project of its type. It has given us clues as to where improvements can be made in a process where joined-up thinking is a key ingredient for success.

Outcome from Case #2

Moving forward, The LOD Experiment, a digital test-bed project, was established to examine the plausibility of our testable hypothesis that: *if there is a way of automatically comparing planned model progression with the current state of the model, MPS can be better integrated in to BIM work flow, LOD can be more useful, and mundane tasks can be eliminated.*

Emerging from our in-house trials is a possible new framework, presented as a sequence of process steps, for integrating LOD utilisation into an automated workflow (Figure 9). In step 1 we establish and select our BIM-Use, and in step 2 distribute the associated Model Content, Structure & LOD Parameter Guide (MCSLPG). (As a more robust alternative to personal checklists, we created a standardised, re-usable model content specification that is used to guide authors in what material to author – facilitating re-use of knowledge). In step 3 BIM authors proceed with creating the object-orientated 3D model, which is then automatically validated in step 4 using a rule-based model checking tool and a machine readable version of the MCSLPG. The validation process highlights *'bad objects'* ie, those objects that are not fit for purpose, being for example incorrect level of development for the BIM-Use. Step 5 allows for the release of an automatically generated burn-down chart (Scrum theory see Schwaber & Sutherland, 2013) illustrating planned model progression v. the actual state of the model. This can be viewed as a valuable contribution to the model development process and supports both BIM authors, project managers and stakeholders in understanding the current status and outstanding effort. Completed and remaining tasks are listed which can then be actioned in step 6. Finally, a lean, compliant model emerges in step 7.

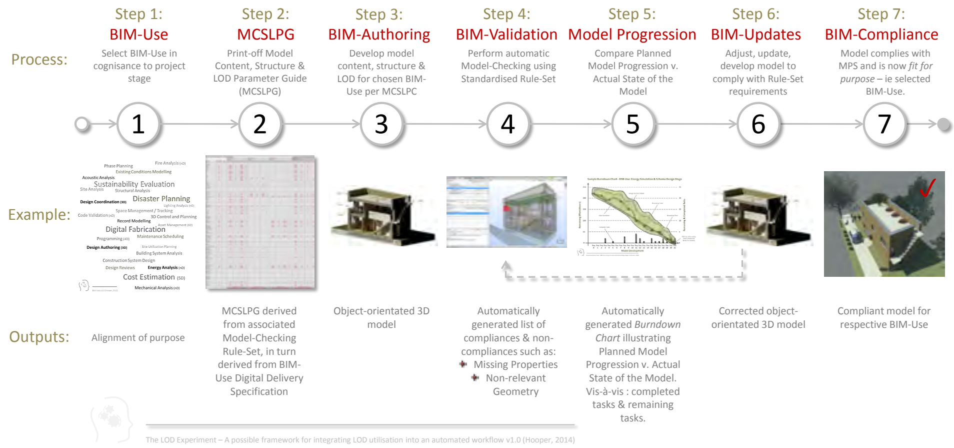

Figure 9: The LOD Experiment – A possible framework for integrating LOD utilisation into an automated workflow

This seven step BIM-Use orientated workflow is tested using proprietary BIM applications (Autodesk Revit & Solibri Model Checker). Two commonly deployed BIM-Uses were tested: *3D Design Coordination* at *Scheme Design Stage*, and *Energy Simulation* at *Design Development Stage*. A corresponding delivery specification is exported from a standardised model-checking rule-set crucially detailing, *BIM-Info Classification*, *LOD*, and *BIM-Info Author*. These rule-sets were created within Solibri Model Checker for the pilot and can be re-used. To control the experiment and validate compliance of the resultant model, the BIM was manually checked. Despite only 2 BIM-Uses were tested, the principle displays robustness and potential to support other applications. However, to be of wider function, a broader range of rule-sets should be created to support alternative parallel processes such as cost analysis.

It is conjectured that if one substitutes this kind of work-flow during the model development stages, implementing multiple BIM-Uses in parallel, it is possible to assume a greater level of information leverage, and benefit from not only model development efficiency gains, but also better quality authorship.

Concluding Discussion

Introduction

Today the MPS with specified LOD participant outputs or exchanges exists as stand-alone documents - not very BIM. Furthermore, industry experts question the usefulness of LOD and its suitability as BIM content descriptor. This research examined the concept and application of LOD in a BIM context and presents a novel method of exploiting it to support the information production process through utilisation of standardised model rules enabling automatic checking of model progress against planned model development. Whilst Case #1 exhibited little substantive utilisation of LOD (since, amongst other things, a single discipline model was all that was required), it did enable us to highlight where potential for improvement lay. In Case #2 the key research proposition is tested and verified allowing for tentative conclusions to be drawn. First, that better integration and automation is possible and second, that there is great potential to re-use knowledge-based processes and leverage value through efficiency gains and improved information quality. Although the cases explored where dissimilar in type, the relevant aspects in digital information management were common. The patterns observed are deemed typical and therefore can be seen to strengthen and broaden the application of the emerging results.

Significance of the Results

An attempt has been made to develop a new scenario where LOD may be more useful in BIM projects. This is done with BIM-Use delivery specifications translated into re-usable model checking rule-sets supported by LOD definitions. The LOD utilisation framework serves the following purposes in facilitating model progression:

- To facilitate accurate representation of actual model status v. planned model progression;
- To capture and reuse knowledge;
- To enable a platform for quality control;
- To leverage existing BIM tools;
- To maximise automation and remove mundane, labour intensive tasks in which if errors occur, present adverse cost consequences;
- To facilitate and encourage sequential model development through standardised milestone gates;
- To facilitate a logical information maturity with reusable tools.

Our findings are important; they tell us that greater and more consistent knowledge is required about new industry concepts whilst presenting an application where success has been realised.

Contribution

We have studied LOD, its use in practice, attempted to unravel misconceptions about it and through the new LOD utilisation framework sought to reduce the possibility of LOD frustration through automation of process. This work has therefore contributed with first, a literature and case review of LOD in practice and second, a novel method of employing LOD that may reduce or remove the known labour-intensive activities associated with MPS and help design authors focus on creating critical path information. It is also expected to improve the construction industry's potential for reuse of knowledge across stakeholders. Furthermore, it is conjectured that the framework and associated rule-sets will support the systematic creation of digital design information on BIM projects and enable greater opportunities for design authors to exploit the digital asset through deployment of multiple and sequential BIM-Uses through the design development stages.

Although such a method could also be used on traditional, manually controlled projects, it shows great potential to support BIM project participants and reuse of intelligent processes in a way that is readily transferable. This is seen as crucial in promoting the industry's productivity performance. The quality, success and value of automated model progression scheduling using LOD must now be developed through further practical testing, implementation in real projects and further adaption based on feedback from practical application.

To the original research question: *is there a way of automatically verifying model content against intended use and programme that could then be standardised,* we can now reference a method that does just that. Furthermore, the framework may function not only as a method to compare planned against actual model progression, but as an early-warning mechanism to guide the design consultants to author the right objects & properties on the BIM-Use critical path, avoiding expensive man-hours engaging in pointless finesse. To get started one needs only to create a specific BIM-Use delivery specification and associated model checking rule-set.

The main contribution is insight into how LOD can be applied expediently and awareness of the need to structure digital content to facilitate real-time cross-checking with scheduled deliverables. This knowledge is important in order to enable BIM information authors to align information deliveries or data-drops with the expectations of downstream users. Vico, a construction costing and programming software company, highlight that one does not need to meticulously plan model progression if one is simply using the digital model for visualisation, however, where exploiting 3D coordination, 4D Programming, 5D Cost Analysis and 6D Asset Management functionality, utilisation of LOD in association digital delivery specification and model progression is essential (Vico, 2012). Here our proposed framework represents a flexible model for integrating LOD into a BIM-like workflow, whilst facilitating rich re-use of information content knowledge. This work can also be viewed as a contribution towards BuildingSmart's IDMs / MVDs insofar as it offers a tentative business case for automated model progression. However, in the first instance represents a *here and now* proposition to current difficulties in model authoring control.

The idea behind the use of LOD to support model development is that by attaching an LOD status attribute to objects in conjunction with standardised re-usable checklists (detailing BIM-Use content), one can with much greater certainty guarantee a certain quality of information at a given point in time (Kastell, 2013b). Other disciplines have then the possibility of organising their respective contributions around status-marked LOD objects in a way that allows recognition of object specificity and reliability.

Further research
A further step to reach standardisation and dissemination into practice may be possible through buildingSmart. Further research could be in transforming and combining this effort into an IDM / MVD together with extended validation cases.

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Paper #5:

BIM Standardisation Efforts – The Case of Sweden

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Authors: Hooper, M.

BIM STANDARDISATION EFFORTS - THE CASE OF SWEDEN

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Martin Hooper, PhD Student
Dep. of Design Methodology, Construction Sciences, Lund University, Faculty of Engineering, Lund, Sweden
Martin.Hooper@construction.lth.se

SUMMARY: Nations around the world are feverishly developing new standards relating to Building Information Modelling (BIM) in the construction industry which may enable teams to leverage greater value from BIM implementation and model authorship efforts. This study reflects on ongoing standardisation initiatives in Sweden and considers where current research efforts fit in. There is limited research presenting stakeholder perceptions on current BIM standardisation efforts whether driven by industry representatives or the research community. To address this gap, through a national survey, we studied the impact and correlation of particular process-orientated standardisation initiatives and related research efforts within the field of BIM. The aim is to determine the level of importance of common themes and establish their legitimacy. BIM experts are asked to rank individual standardisation projects and research themes and offer comment on their relevance in a context of national BIM initiatives. In doing so, we capture views on the value and contribution of ongoing BIM standardisation initiatives, are able to position current research efforts within a landscape of other national strategic BIM programmes and gain insight to the level of integration between industry and research communities working in this field. We found broad underlying support of the ongoing BIM standardisation efforts happening in Sweden. Results indicate scepticism over standardised BIM-Planning protocols such as those to be found in the US, but strong support for national BIM guidelines and associated state-driven vision. In addition, respondents highlight a number of alternative standardisation needs that are either missing or low priority on the national BIM standardisation agenda, including requirements management and measures to overcome barriers to BIM. Difficulties exist in translating standards from theory into practice and more local case examples are needed. Our findings are important; they tell us which standardisation efforts are important and help us to understand what aspects are essential to support stakeholders in achieving common BIM goals. They indicate emerging trends upon which further studies can build and contribute to literature on state-of-the-art BIM standardisation.

KEYWORDS: BIM, Building Information Modelling, Standards, Standardisation, Research Initiatives.

1. INTRODUCTION

The construction industry, like many other production industries, is regulated by a myriad of standards, guidelines, codes of practice and regulations. These enablers and controls make construction projects safer, reduce failures and aim to increase quality (Winch, 2010). They also represent and disseminate a collective understanding of the relevant principles applicable to our projects, enable and align stakeholder’s expectations of project results (PMI, 2008) and aim to render the world equivalent across cultures, time, and geography (Timmermans & Epstein, 2010). Be it material strength and suitability, calculation method, quality levels, practice methodologies and outputs, the use of standards ensure progress and wellbeing in society. They are critical when communicating between stakeholders in a fragmented industry in temporary project organisations (Gustavsson et al, 2012).

Standardisation consists of building a society around a standard with an implied script that brings people and things together in a world already full of competing conventions and standards (Timmermans & Epstein, 2010). Samuelson (2011) highlights a tendency for sector culture to optimise at individual or organisation level only, not the entire process (since nobody owns in the whole process in construction). Consequently, it is important for us to categorise and understand the strategic difference between branch or sector standards and organisation standards (which may be even company secrets) in a BIM context. This study looks at those emerging standardisation efforts relating to the use and application of BIM in construction that are now underway in Sweden and which may reflect the broader trend of standards development in this field generally. Here we define

BIM as an end to end delivery methodology. Standards related to IT are usually divided into three parts (Figure 1) being: *Concepts*, *Data Model* and *Process*. Common concepts and classification of concepts are necessary for everyone to speak the same language. Neutral formats for data models required for systems and players to exchange information clearly. Finally, a uniform processes for information delivery and a common working methodology is necessary (Ekholm et al, 2010). Around these 3 divisions we can arrange BIM standardisation themes.

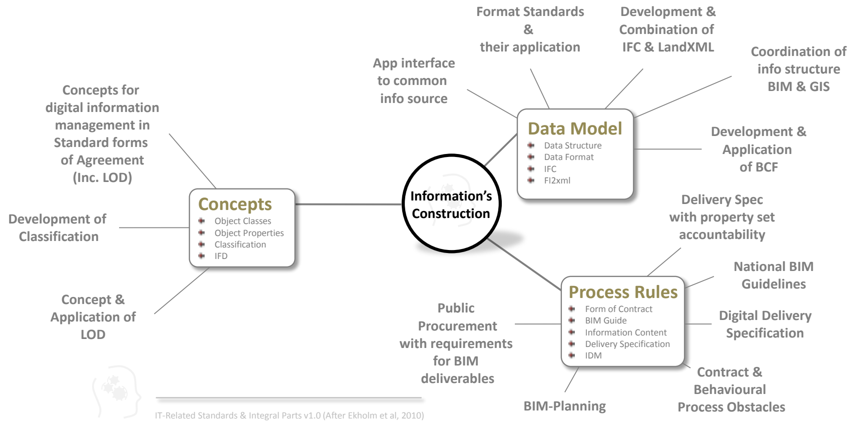

Figure 1: BIM Standardisation information platform (after Ekholm et al, 2010)

A growing awareness of the importance of the management of the standardisation and adoption processes for the eventual success of BIM has led to many studies (Howard & Björk, 2008; Gu & London, 2010; Ekholm, 2012a, 2012b; Hooper, 2012; Ekholm et al, 2013). This work has focused on a wide range of standardisation and adoption issues and has identified a number of promising initiatives. But what do other domain experts and industry stakeholders in general, think about the focus of current standardisation efforts and what they mean for them?

There have been other detailed studies into the level of integration of information technology (IT) in construction (Samuelson, 2010, 2011, 2012; Gustavsson et al, 2012). The objective of the study reported in this paper is to identify which BIM standardisation initiatives are of most interest and to whom, to assess the extent to which these standardisation needs are aligned with research efforts and to legitimise (or otherwise) existing research efforts and position them in the landscape of national BIM standardisation initiatives.

Ekholm et al (2013) presents a comprehensive set of 10 BIM standardisation projects based on industry collaborations and observations from what is happening elsewhere. However, hitherto there have been few studies to evaluate stakeholder perception of their importance. Early appraisal may provide an indication of the likely level of adoption.

To get a broad view it was decided to carry out a quantitative study (with some qualitative aspects) using experts informed opinions on the status of national BIM standardisation initiatives and ongoing research efforts in the field. 67 survey results were collected within 10 construction industry discipline stakeholder groups. The data is organised, comments analysed and a synthesis of the views is presented in this paper.

This study does not cover in depth specific international technical standardisation efforts, for example, IFC, IFD, IDM, MVD, COBie, OmniClass, however it does touch on these and their respective perceived level of relevance in Sweden. The focus is rather on considering the merit of process and organisational standardisation such as BIM contract support, BIM terminology and the concretisation of national BIM guidelines.

The remainder of this paper is structured as follows: it starts with a background into previous research and findings within standardisation efforts. The method used is explained which leads to a presentation of the results. A discussion section considers their meaning. The paper ends with a summary of the conclusions drawn from the main results, identifies contribution and positions this work in the field.

2. BIM STANDARDISATION EFFORTS

2.1 Standardisation & BIM

Standards are critical when communicating between different specialists over long periods (Howard & Björk, 2008). The most ambitious programme for standardisation, the industry foundation classes (IFC), has been under ongoing development since its first release in 1997 and only now successful case projects are emerging. Meanwhile nations, companies and individuals have been developing and attempting to standardise other BIM related best practices, in a rather fragmented and self-centred way, in anticipation of realising BIM benefits (Azhar, 2011). Maradza et el. (2013) in their study of standardisation of BIM in the UK and the US observes on the one hand a rapid process of development, but excessive self-interest, minimal end user participation and incompatible processes are emerging. Whilst Samuelson's IT Barometer surveys of the Nordic countries (2010 & 2012), continues to show low awareness of standards relating to IT in construction.

Howard & Björk, (2008) finds standards are only nominally supported - no-one is against them but few apply them comprehensively. Official endorsement helps but promotion essential. Furthermore, since there are so many standards relevant to BIM, a framework for presenting them, showing their capabilities, stage of implementation and potential benefits, would help users understand their impact on the supply chain. In a broader context, Timmermans & Epstein (2010) highlight the potential for collateral damage that standardisation may cause for those who defy standards and attempt to trace the ironies of unintended consequences of non-compliance.

Research on BIM benefits (Azhar, 2011) and IT in construction generally (Samuelson, 2010, 2011, 2012; Gustavsson et al, 2012) confirms expectations are not yet being met whilst also indicating that a lack of consistent adoption of particular standards represent a barrier to realisation of expected benefits such as improved productivity. Gustavsson et al (2012) furthermore advises that much that has been written about BIM hitherto aims to convince others on the possible benefits of using IT-tools whilst side-stepping in-depth reflective discussions on the organisational prerequisites needed for these benefits to be realised.

The UK has its BIM Task Group spawning the UK BIM Strategy 2011 (BIS, 2011) which mandates a certain level of BIM implementation on public projects by 2016. It is supported by the newly released BS1192 standards (BSI, 2013 & 2014) and other standardised documentation such as the CIC's BIM Protocols (CIC, 2013) to help the industry deliver. The US has its National BIM Standard (NBIMS) (NIBS, 2007) and a raft of support documents such as those published by the American Institute of Architects (AIA) (AIA, 2008, 2013a & 2013b). Where is Sweden?

In 1998 the research and development programme ITBoF (Information Technology in Building and Property) was launched in Sweden. It incorporated 70 discrete projects divided into research, standardisation and implementation. Within the area of standardisation the relation between IFC and the established Swedish construction classification system BSAB was investigated. Amongst other things the evaluation indicated a lack focus on *process-orientated* standardisation. A new programme – ICT 2008 – was later launched to address process standards and initiate pilot implementations to help align benefit expectations. By 2009 the industry was mature enough to initiate a sector-wide research and development programme driven by a consortium of industry representatives and lead by the umbrella organisations OpenBIM. OpenBIM's programme includes *application projects, development projects* and *research projects* which collectively aim to advance the sectors transition to object-orientated information management. OpenBIM, now incorporating other related organisations including the local chapter of BuildingSMART, has re-branded itself as BIM Alliance Sweden and continues in its role to spread good experience in BIM through the sector and promote associated standards (Ekholm, 2011).

More recently an SBUF (Development Fund of the Swedish Construction Industry) project supported by BIM Alliance Sweden was launched titled BIM Standardisation Needs. It was performed in collaboration with industry organisations and sought broad support from the sector. The final report recommends a comprehensive set of *10 BIM Standardisation Initiatives* set out by Ekholm et al. (2013) as part of a national drive to bring BIM mainstream. Meanwhile, Jacobsson & Linderoth (2012) reminds us, there are a number of significant differences in the construction industry compared with other industries when it comes to driving changes and development processes. Firstly, that the sector is project-based, meaning that partners collaborate in isolated constellations for limited periods. This makes it difficult to take advantage of learning knowledge development.

Secondly, there is a power imbalance in the industry which means that bigger organisations within the sector do not have the same influence over their suppliers as for example Volvo, Ericsson or Ikea who own and control the whole process. The result is that this places the responsibility on the leadership within the construction sector to drive change and steer the direction of national development in construction including standards and their application.

Linderoth (2013) further warns us that we should not get locked into insisting on so-called *'best-practice'*, which might in the long run turn out to be the worst practice. Implying that those who stick to today's best practices are likely to be tomorrow's losers. Rather, players should feel the way forward with caution and be flexible. A business-as-usual approach to working routines leads to stagnation. In the US a standard BIM Addendum (Low & Muncey, 2009) was developed through industry consensus to enhance and leverage possible benefits to be gained through the use of BIM and the principle of a federal model. This and other so-called consensus documents were established by industry and research organisations honing in on eliminating known barriers to BIM whilst adopting a life-cycle perspective.

2.2 Standard Solutions & Innovation

CIFS (2011) argues that we need standard solutions in order to be innovative. Further remarking that in a time where we strive for the unique and the remarkable, the term *'standard solution'* implies something grey and boring. Like the word *'routine'*, we mostly use it negatively. However, we could not manage without either routines or standard solutions. Without them, we would have to start over each time and our projects would never get off the ground. We need the familiar and well tested. In the context of BIM there is good reason to support standard solutions for without them, we would be unable to create new things and be innovative.

2.3 To standardise or not to standardise

Meanwhile Schäfermeyer & Rosenkranz (2011), in the broader context of production, ask the question: to standardise or not to standardise? They define that: *"A process is only successfully standardised if it is executed each time in a predefined (optimal) way by processing the same activities in the same order and producing exactly the same specified output"*. Bilal (McPhee et al, 2013) remarks standardisation of workflows is desirable within manufacturing and prefabrication industries where the same products are generated repetitively, however suggests there is less clarity whether this definition is applicable to BIM processes within AEC industry.

Lighthart (McPhee et al, 2013) offers a counter-argument affirming that the existence of the NBIMS and other similar standards worldwide is testament to the need to standardise what we in the AEC industry have been doing for centuries. The latitude those standards allow, and the lax enforcement of those standards from office to office testifies to the difficulty of setting standards for conveying information that everyone can live with all of the time. Hence, some prefer guidelines only.

Today the larger contracting companies employ standardised BIM-Manuals when procuring design services (Skanska, 2014). They set out particular demands on BIM-Authors (the design team) categorised into general requirements and project-specific, and may include modelling guidelines pertaining to particular BIM-Uses which are desirable to be executed. The question here then is: what is within these so-called organisation-specific BIM-Manuals that may be standardised to the benefit of the wider industry?

Other studies (Gobar Adviseurs, 2010 & Hooper, 2012) consider the positioning and impact of a broad range of existing national BIM guideline documents and standards worldwide. Hooper (2012) finds that the impact of discrete in-house BIM-Manuals which are emerging in Sweden as a response to a lack of state leadership in BIM adoption may have an adverse effect on the nation's competitiveness. Furthermore, because many BIM practice procedures are hidden within organisation's discrete BIM-Manuals, with restricted audiences, the nation runs a real risk of developing a *constellation of fragmented approaches* – something the SBUF project BIM Standardisation Needs aims to address.

Samuelson (2012) finds that many industry practitioners consider a lack of standards a major obstacle to the effective utilisation of IT in construction. The same survey reveals Architects invest the most amongst consultants in BIM and drive comes mostly from enthusiastic individuals (bottom-up) as opposed to management (top-down). Claims that there is a lack of standardisation in the construction industry to support BIM processes are corroborated by Gu & London (2010) and Azhar (2011) who highlight challenges that standards aim to address.

2.4 Research Gap & Contribution

Notwithstanding previous research, the question remains, what standards are important to whom and how much? Furthermore, what level of importance does each standardisation initiative hold generally? This study aims to reveal new perspective on those BIM standardisation efforts going on in Sweden and evaluate alignment with associated research initiatives.

3. METHOD

3.1 Rationale

A quantitative survey approach was adopted from a realism perspective (Saunders et al, 2009). Application of this approach supported the investigation of the phenomena under study in so far that it allows for the collection of data from a cross-section of relevant people, from a wide and inclusive population that may enable generalizable results to emerge (Denscombe, 2008). Surveys enable collection of empirical data based on real-world observations, and add credibility and robustness to the results (ibid).

3.2 Survey Design

The survey questionnaire was designed to measure respondent's opinions on current standardisation efforts quantitatively in a way that can be readily repeated, comparable and cover all categories of industry stakeholders. The goal was to collect at least 50 completed questionnaires, our target sample population being those with prior BIM expertise.

3.3 Method Execution

To access a reasonable sample size, cooperation with BIM Alliance Sweden – a national membership-based body responsible for coordinating BIM standardisation efforts and promoting the use of BIM in industry – was sought. Respondents were asked to answer a short web-based questionnaire concerning their understanding of BIM research and standardisation efforts. The aim of the survey is to describe the current situation and the purpose to obtain data for mapping and drawing conclusions (Denscombe, 2008). The questionnaire was circulated, initially through directly emailing a group (Cluster 1) of known BIM experts from diverse disciplines in Sweden (100 members), then to increase sample size the same questionnaire was made accessible and visible though BIM Alliance Sweden's associated discussion forum on Linked-In (Cluster 2). The BIM Alliance Sweden Linked-In discussion group forum has in excess of 1500 members. This bolstered the response number from 25, a response rate of 25%, to 50 completed questionnaires. The questionnaire was then circulated through the BIM Alliance Sweden's mailing list (Cluster 3), being around 1000 members - a pool of industry representatives from diverse disciplines.

The total response rate across these 3 clusters could not be measured since those in Cluster 1 (known BIM experts) could also exist in Cluster 2 (BIM Alliance Sweden's Linked-In Discussion Forum and, or Cluster 3 (BIM Alliance Sweden's mailing list)) since anonymity was preserved. The response rate could therefore have been higher or lower. However our priority was to capture as high a number of responses as possible to support a sound result. Combined these data collection opportunities enabled pooling of 67 completed questionnaires from a broad range of experts.

3.4 Sampling Framework

The sampling framework, an objective list of the population from which respondents are selected (Denscombe, 2008), is made up of those who have prior knowledge of BIM, experience of its impact on the industry, and include Construction Clients, Owners, Architects, Engineers, Contractors, Suppliers, Facilities Managers, Software Suppliers, and Academic Experts. The survey questionnaire was produced, distributed and the results collected and analysis through an online survey tool (Survey Monkey).

3.5 Data Analysis

The quantitative data is presented in a way that reveals trends as opposed to hard facts. Participants are asked to provide nuanced responses (scale of 1-5) to propositions and rank the importance of current standardisation and research efforts, also on a scale of 1-5. Interpretation of the supplementary qualitative data collected focuses on patterns (Czarniawska, 1998) and representative extracts were selected to construct the narratives.

4. A REVIEW OF BIM STANDARDISATION NEEDS AND RESEARCH INITIATIVES – SWEDEN

The following section presents the results of the survey on a review of BIM standardisation efforts - the case of Sweden. The returned questionnaires provided adequate quantitative data to generate a series of readily understood charts and diagrams which, for simplicity and accuracy, were directly derived from those automatically generated within the selected web-based survey tool. The emerging results are delivered in a form that may provide interesting insight into industry views on ongoing efforts, and prioritisation. They present a snap-shot in time. Qualitative aspects, in the form of re-occurring commentary, were recorded and augment the quantitative data.

A total of 67 completed questionnaires were collected. Respondents were first asked to confirm their discipline background to later enable an analysis of discipline trends. Figure 2 presents the distribution of respondents. A high proportion of Architects (22% being 15) and Academic Experts (29% being 19) responded which, whilst cannot be said to reflect the relevance of BIM standardisation efforts across an industry of diverse stakeholders, does indicate interest levels across the sector.

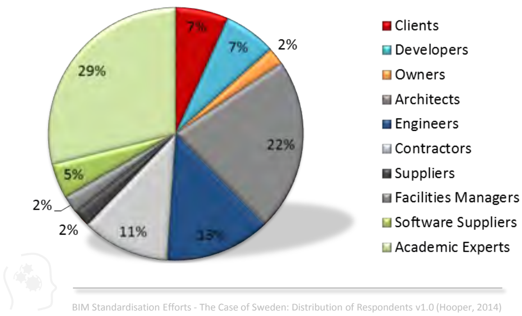

Figure 2: Survey Results - Distribution of Respondents

A lesser proportion of Owners (2%), Facilities Managers (2%) and Suppliers (2%) responded. Within the 10 main discipline areas, a small number of respondents also branded themselves as particular specialists including BIM-Strategists, Project Managers and Responsible for IT.

4.1 Improvements since introduction of BIM & Experienced BIM project benefits

The first question: *what has improved since BIM and by how much?* sought a soft introduction to the questionnaire where common perceptions in improvements since BIM could be measured generally. In concurrence with other surveys (Samuelson, 2012; McGraw Hill, 2009 & 2010) improved *Communication* ranked highly. Predominantly Architects and Contractors thought *Project Results* improved whilst Clients were less certain. The impact of BIM on *Accuracy* and *Project Planning* was smaller but still significant. Other highlighted improvement areas included better design information coordination, efficiency and review. Curiously 2% thought accuracy had been very negatively impacted since BIM (Figure 3).

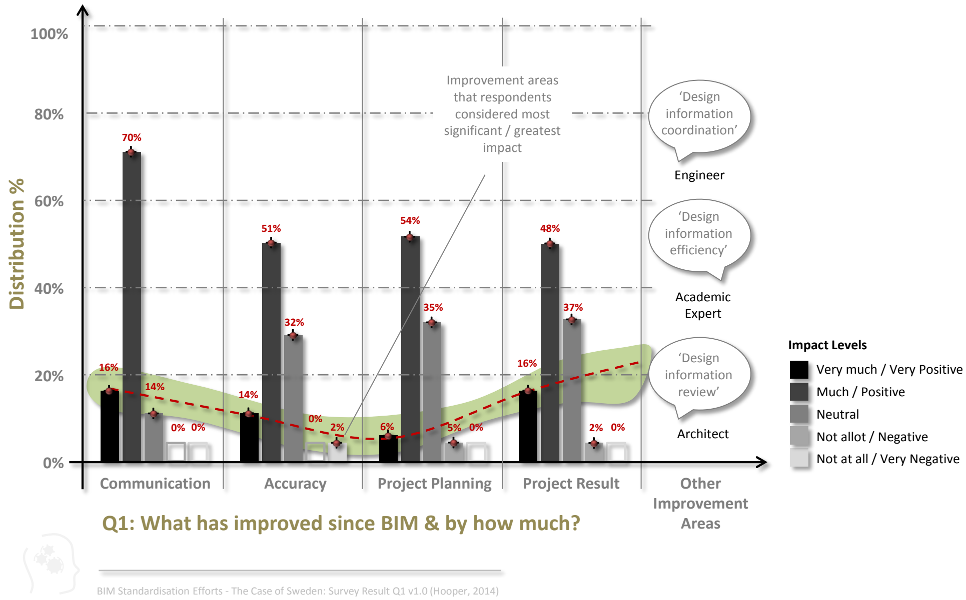

Figure 3: Survey Results - BIM improvements & perceived impact levels

The second question: *which BIM benefits have you witnessed or experienced and how much?* sought to encourage respondents to think about their own circumstances and reveal trends in experienced BIM project benefits. Categories include: *Improved Decision Support*, *Quality of Output*, *Productivity* and *Confidence in Completeness of Scope*. Informants provided a similar response profile to question 1 (Q1) – being a higher impact on decision making and lesser in other categories. An aggregated 4% witnessed no or a negative impact on *Confidence in completeness of scope*. Others experienced benefits through fewer claims, better coordination and access to current information (Figure 4).

There was no obvious trend amongst Clients however; *Improved Decision Support* and *Confidence in Completeness of Scope* had benefited most. Architects and Engineers thought positively about *Improved Decision Support*, *Quality of Output* and *Confidence in Completeness of Scope* but were less convinced about gains in *Productivity*. Whereas Contractors where generally very positive about gains in *Productivity*. Academic Experts where generally very positive across the board with some neutrality on *Productivity*.

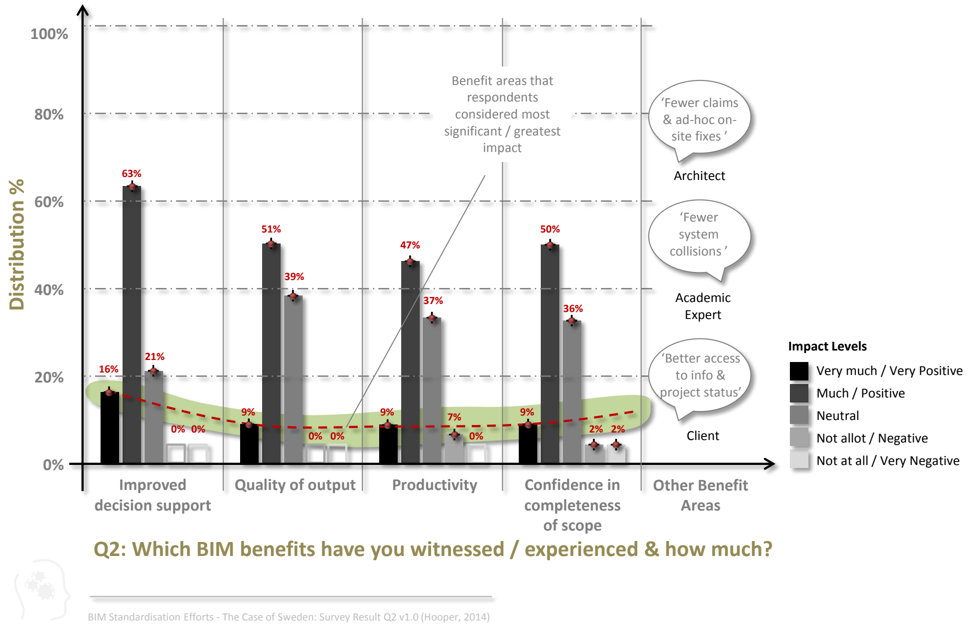

Figure 4: Survey Results - BIM benefits witnessed & perceived impact levels

4.2 10 BIM Standardisation Projects

The third survey question introduced respondents to the *10 BIM Standardisation Projects* recommended by Ekholm et al. (2013) and endorsed by BIM Alliance Sweden. We asked: *which BIM Standardisation initiatives are important and how much?*

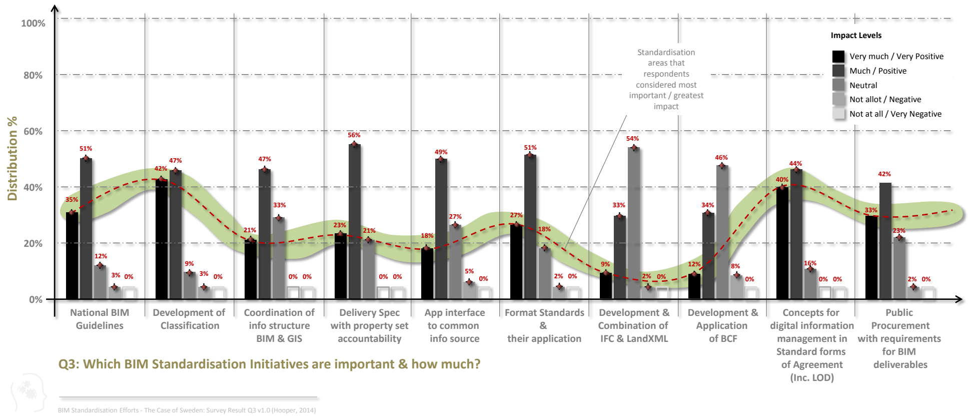

Figure 5: Survey Results - Standardisation Initiatives & perceived impact levels

Here we can readily identify that standardisation efforts relating to *National BIM Guidelines*, *Classification*, and *Concepts of digital information management in Standard form of Contract* are considered the most important, with around 40% of participants designating each of these initiatives as very important (Figure 5). There was a significant level of neutrality across the categories, indicating uncertainty, but low levels of negativity. None of the 10 BIM Standardisation Projects were considered completely irrelevant and, in general, a positive level of support exists for each. However, lower levels of support emerged for *IFC & LandXML* and *BCF (BIM Collaboration Format).*

All Clients & Developers strongly supported the need for *National Guidelines* and, like Contractors, indicated the most scepticism to the usefulness of *IFC & LandXML* and *BCF (BIM Collaboration Format).* Amongst the different disciplines Architects and Engineers assigned consistently the highest importance to *Classification* as did around half of the Academic Experts. There is generally significant support across the board with Architects showing the highest level of enthusiasm for all. Contractors place more consistent support for *Concepts for digital information management in Standard forms of Agreement* and *Public Procurement with requirements for BIM deliverables* than any other discipline and some highlighted a specific need for *BIM-oriented standard forms of agreement* and *standardised organisation of BIM-requirements for publically procured projects.* Academic Experts gave the most inconsistent responses, with no one category showing notably more or less support than others, with the exception of *National Guidelines*. In other categories no particular patterns were observable, results were sporadic.

4.3 Research Efforts & where help is needed

The fourth question sought to identify where the industry feels help is needed and refers to categories in which research is being carried out with national financial support. The chart below (Figure 6) shows high levels of support for research on *Digital Delivery Specification*, *Contract & Behavioural Process Obstacles* and *Concept & Application of LOD*, with increased neutrality on *BIM-Planning.*

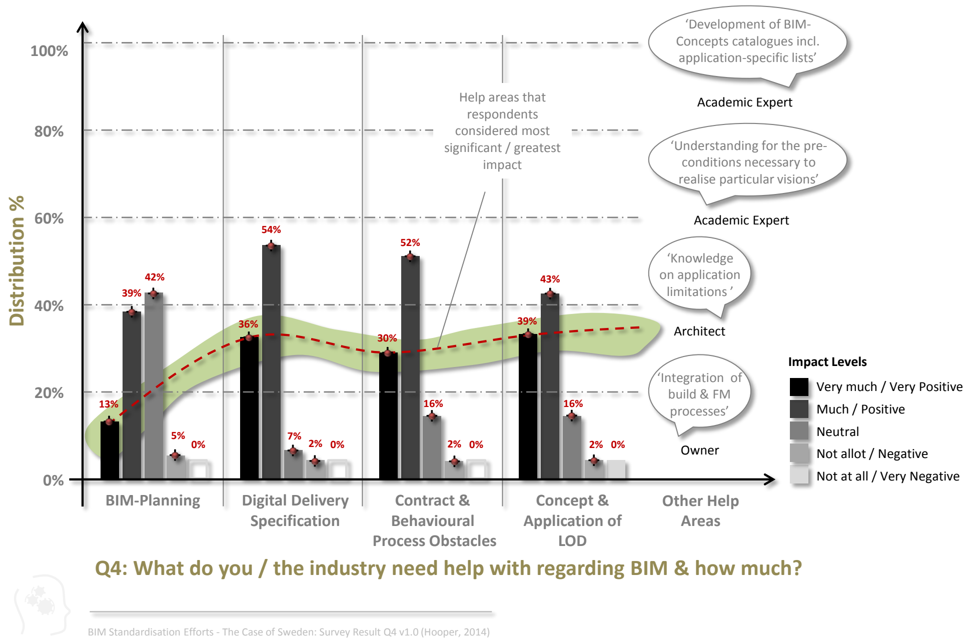

Figure 6: Survey Results - BIM help needed & perceived impact levels

Strong support was present across all categories. Amongst the categories *BIM-Planning* received the most neutral backing across all disciplines. Other emerging patterns were less obvious; however Architects and Engineers displayed the most support for *Contract & Behavioural Process Obstacles* with around 40% awarding the highest impact level. *Digital Delivery Specification* and *Concept & Application of LOD* received strong support and *BIM-Planning* again was assigned the most neutrality and the most negative impact ratings. Contractors indicated evident neutrality to *BIM-Planning*, were modestly positive to *Digital Delivery*

Specification, and offered the strongest support to *Contract & Behavioural Process Obstacles* and *Concept & Application of LOD.* A similar profile emerged from the Academic Experts albeit more nuanced. Of all, Clients were most positive about *BIM-Planning* with around 30% awarding the highest impact level. Strong support also emerged for *Digital Delivery Specification* and *Concept & Application of LOD* with around half designating these as top priority. Other participants were too small in number to draw generalizable conclusions.

4.4 Alignment of BIM Research & Standardisation Efforts

The fifth and final survey question asks: *What is lacking or misaligned in research and national initiatives to support BIM Standardisation efforts?* In an attempt to measure the level of alignment between the *10 BIM Standardisations Projects* and current research efforts in the same field, we employed a combination of both quantitative and qualitative units of analysis. Firstly we transcribed commentaries and interpreted them into short statements grouped by respondent discipline (perspective). We then aggregated re-occurring themes and quantified occurrences under theme headings accordingly. The table in Figure 7 summaries a selection of responses. What is interesting here is who said what insofar that we can start to identify patterns in common perspectives.

Discipline	Lacking or Misaligned Standardisation Efforts
Construction Client	'A common set terminology (& concepts).'
Construction Client	'A common definition and understanding of what BIM is & is not. Too many discrete interpretations'
Architect	'State leadership to drive BIM-initiatives / development.'
Architect	'Much is misaligned. Great ignorance in the industry, many discrete fantasies about what BIM is and is not, open formats and software.'
Architect	'Branch standardisation of the basics: roles & responsibilities, requirement documents, project stages, LOD.'
Architect	'A common understanding of LOD and practical object definition levels for model purpose (ie. generic furniture objects through design phases, product specific for construction documents).'
Architect	'Insistence and realisation of the branch adopting open standards throughout, not only amongst BIM-Experts.'
Engineer	'Important to coordinate standards that also function for quantity analysis of BIM models.'
Engineer	'Difficulty in translating between the extremely theoretical world (eg. ISO work) to the practical reality many of us find ourselves in.'
Contractor	'Focus should be more on removing barriers to use of BIM in production.'
Contractor	'Qualitative research on the benefits of BIM for different players (eg. Owners & FM).'
Developer	'The collection, analysis and evaluation of requirements management documents (eg. MPS).'
Academic Expert	'We should take advantage of lessons learnt from successful standardisation efforts in other fields.'
Academic Expert	'Research and development of BIM in the early project stages.'
Academic Expert	'Requirements management, verification and analysis in terms of building functions and values'
Academic Expert	'FM processes'
Academic Expert	'Case evidence of the true benefits of BIM at discrete stages to discrete players.'
Academic Expert	'Development of BIM-Concepts catalogues, incl. application-specific lists.'
Academic Expert	'Lack of national guidelines together with a state endorsed national BIM strategy may present a hinder to reaching consensus over standardisation efforts..'

Q5: What is lacking or misaligned in research and national initiatives to support BIM Standardisation efforts?

BIM Standardisation Efforts - The Case of Sweden: Survey Result Q5 v1.0 (Hooper, 2014)

Figure 7: Survey Results – Alignment of BIM Research & Standardisation Efforts

Highlighted are certain lacks in understanding and utilisation of Level of Development (LOD) to support information deliveries and state engagement in promoting standards. Scope for improvement in alignment resides in the transition of theoretical work to practical implementations and that more local case examples are needed. Furthermore that we should take advantage of lessons learnt from successful standardisation efforts in other fields.

A broad range of perceived lacks or misalignments emerged. The chart below (Figure 8) presents the level of re-occurrence of specific themes. 23% indicated a desire to better align industry standard BIM concepts – taking the form, for example, as some sort of national reference source or database. Also significant (16%) was concern over a lack of state leadership, vision and the need for national guidelines. There were calls for alignment on model progression, status and LOD (10%) and further work requested on classification (7%). Others (5%) identified a gap between theoretical and practical implementation, expressing that ISO standards are obtusely assembled and problematic to apply in practice. Lower on the chart are appeals to increase focus on requirements management, cognisance to other industries and case evidence of BIM benefits (each at 3%). Surprisingly there was little comment on contractual requirements.

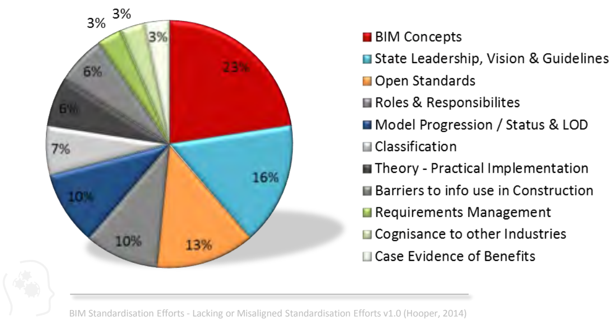

Figure 8: Lacking or Misaligned Standardisation Efforts: Re-occurring themes

5. DISCUSSIONS & CONCLUSIONS

5.1 Introduction

We sought to ascertain the value and contribution of resent BIM research efforts and position them within a landscape of other national strategic BIM development and standardisation initiatives and have now reported on the present state of opinion on current BIM standardisation efforts within academic and industry spheres. We can now say with greater certainty that most of the 10 *National BIM Standardisation Projects* have a high level of support; however there was a general consensus that *IFC & LandXML* and *BCF (BIM Collaboration Format)* assumes a lower level of overall importance at this time. A possible explanation for this may be a lack of understanding of these concepts amongst participants. It was not possible to generalise or identify specific trends outside the main participant discipline groups being: Clients, Architects & Engineers, Contractors, and Academic Experts. This left trends associated with Owners, Suppliers and Facility Managers difficult to measure.

5.2 General Observations

The survey respondents highlight different aspects of BIM standardisation needs. The general conclusion that stands out most clearly is that there is not just one way to organise and prioritise standardisation efforts, not even within the same industry. More than anything, the study highlights diversity. Looking at particular trends we can observe, Clients and Developers found improvements in *Communication* but were less convinced about overall improvement in *Project Results* so far. Looking forward, they thought *National Guidelines* were essential and expressed strong support for *BIM Requirements* on public projects. Architects, for instance place higher importance on front-end standardisation activities such as *BIM-Planning, Digital Delivery Specification* and *Classification* whilst less on downstream pursuits. They called for a state organ to drive BIM standardisation and

National Guidelines. Contractors observed improvements in *Communication* but where more neutral on *Project Results*. They found *Productivity* increases and indicated support for research in standardised *Contractual Support*. They were not so interested in standardised *BIM Concepts*. Academic Experts observed improvements across the board since BIM with greater neutrality on *Productivity*. They recommend effort on *National Guidelines* and *Classification* whilst also placing providence in *Digital Delivery Specifications* and standardisation of *BIM Concepts*.

This indicates a certain imbalance and needs to be considered in relation to the overall benefits that future adoption of particular standards may imply. There are compelling arguments both for and against adoption of standards or embracement of standard solutions (compare with Linderoth, 2013; CIFS, 2011; Timmermans & Epstein, 2010). But one thing is for sure: timing, positioning and the establishment of specific benefits associated with the adoption of particular standards can be viewed as critical (compare with Howard & Björk, 2008).

The diverse rolls found in construction and stakeholder's individual propensity to benefit from BIM standardisation efforts is significant. Some have specific objectives and goals and need standards to support the means to these goals. Others create and maintain their own standards and compel others to comply (Linderoth, 2009; Hooper, 2012). The results here indicate variations in attitudes to standardisation and the meaning of the *10 BIM Standardisation Projects* for them and the broader industry. Many question the relevance of *Development & Combination of IFC and LandXML*. Uncertainty emerged regarding the need for *BIM-Planning* (an essential activity to realise common benefits of BIM efforts). However, a general level of support for ongoing BIM standardisation efforts was observed and evidence of positive alignment of themes within research, improvement areas highlighted. Finally, there was call (predominately Architects and Engineers) for state driven promotion of BIM Standards whilst Academic Experts advocated borrowing from neighbouring industries.

5.3 Contribution

This work has therefore contributed with a comprehensive survey presenting a snap-shot in time of the views of 67 diverse industry representatives on BIM Standardisation efforts in Sweden. The findings of this study provide useful information for the AEC industry, practitioners and researchers alike, on the positioning and perceived level of importance of ongoing standardisation efforts relating to BIM. This is valuable because it enables us to objectively understand their usefulness. Our findings are important; they tell us that greater knowledge is required in *Digital Delivery Specification*, *Contractual Support* and *Concept & Application of LOD* whilst confirming, at a general level, that most disciplines attach a significant level of importance to all *10 BIM Standardisation Projects* – and in particular *National BIM Guidelines*, *Classification* and *BIM Concepts for Digital Information Management* (such as LOD). The data implies that a new determination is required to align industry and research community efforts to deliver BIM Standards starting with a cross disciplinary effort to deliver *Nation BIM Guidelines* in a form that reflects the AEC industry's needs and expectations.

5.4 Context, Significance & Implications of the Results

The survey was carried out in Sweden where a strong contractor-led AEC sector exists. Some state organisations are now demanding BIM. A central government mandate, of the kind found in the UK, Denmark, Norway and Finland is absent; however the level of BIM maturity places Sweden firmly on the map (WSP & Kairos Future, 2011). The context has its particular characteristics, nevertheless this survey is of international appeal since the subject and themes are of universal applicability and results may inform trends connected to international standardisation efforts such as those by buildingSmart.

The results, emerging from the ordinal data mapped to the Likert scale (Denscombe, 2008) adds legitimacy to the selected *10 BIM Standardisation Projects* highlighted by Ekholm et al. (2013) and underpin research efforts in the field such as Jacobsson & Linderoth (2013); Gustavsson et al (2012); Samuelson (2012); and Hooper (2012). Furthermore the data collected from this survey, if corroborated with further evidence, could be used to help allocate an accordant scale of resources to the *10 BIM Standardisation Projects*. It may also offer insight into market interests that may inform new value propositions in bringing BIM products and services to market. Validity of the data, analysis and organisation of it into charts was maintained by utility of a reliable online survey instrument ensuring accuracy. Explanations derived from the automatically organised data-set were deductively extrapolated.

5.5 Further Research

Whilst the results of the survey only represent a snap-shot-in-time, they do provide a state-of-the-art picture of stakeholder opinion on current BIM standardisation initiatives in Sweden and supply us with insight on which we can extrapolate trends and emerging themes. A re-run of the survey on completion and implementation of said initiatives could provide industry leaders with valuable feedback on whether planned standardisation efforts have made a difference.

6. ACKNOWLEDGEMENTS

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About the Author

Martin Hooper is a British Architect and doctoral researcher (BIM) at the Division of Design Methodology, Faculty of Engineering at Lund University, Sweden. He has 10 years + international industry experience as Architect. His research drives towards revealing and articulating key prerequisites for successful BIM adoption through an investigation into BIM-standardisation needs and support systems.