THE IMPACT OF DIGITALISATION ON THE MANAGEMENT ROLE OF ARCHITECTURAL TECHNOLOGY

JAMES HARTY

A thesis submitted in partial fulfilment of the requirements of the Robert Gordon University for the degree of Doctor of Philosophy

This research programme was carried out in collaboration with The Copenhagen School of Design & Technology

May 2012

Colophon:

Typeface: Times New Roman, 11 Point (font size)

Paragraph: 1½ line spacing with 0.76cm indent, justified text

Page: A4 sheet with 3cm margins and 1cm gutter, double sided

Produced in Microsoft Word 2007/2010

All referencing compiled by Refworks

Table of Contents and Indexing generated from Microsoft Word 2007/2010

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Acronyms

Generally, acronyms are identified at their first occurrence, as well as being listed here with their definitions

- 2D: Two Dimensional (Drawings)
- 3D: Three Dimensional (Geometry)
- 4D: Fourth Dimension (Time)
- 5D: Fifth Dimension (Resources)
- 6D: Sixth Dimension (Life Cycle Assessment)
- 7D: Seventh Dimension (Sustainability)
- 8D: Eighth Dimension (Maintainability)
- 9D: Ninth Dimension (Acoustics)
- 10D: Tenth Dimension (Security)
- 11D: Eleventh Dimension (Heat)
- ADT: Architectural Desk-Top (Autodesk)
- AEC: Architecture, Engineering & Construction
- AECO: Architecture, Engineering, Construction & Operations
- AFR: Accident Frequency Rate
- AGC: Associated General Contractors (USA)
- AIA: American Institute of Architects
- AIDC: Automatic Identification and Data Capture
- ASC: Associated Speciality Contractors (USA)
- BEPOI: Business Enterprise Performance Optimisation Incentive
- BIM: Building Information Modelling
- BIMF: Building Information Management Framework
- BIM-M: Building Information Modelling and Management
- BIm^3: Building Information Modelling Maturity Matrix
- BIMMI: Building Information Modelling Maturity Index
- BER: Building Energy Rating
- BPMN: Business Process Model & Notation
- BR08: (Danish) Building Regulations 2008
- BR10: (Danish) Building Regulations 2010
- BREEAM: British Research Establishment Environmental Assessment Method
- BSRIA: Building Services Research and Information Association

- CABE: Commission for Architecture and the Built Environment (UK)
- CAD: Computer Aided Design
- CAFM: Computer Aided Facilities Management
- CAWS: Common Arrangement of Work Sections
- CBA: Cost Benefit Analysis
- CEO: Chief Executive Officer
- CFO: Chief Financial Officer
- CIAT: Chartered Institute of Architectural Technologists (UK)
- CIB: Conseil International du Bâtiment" (International Council for Building)
- CIBSE: Chartered Institute of Building Services Engineers
- CIO: Chief Information Officer
- CIRT: Construction Industry Roundtable
- CI-SfB: Construction Index-Samarbetskommitten För Byggnadsfrågor (SWE)
- CM: Construction Manager
- CMM: Capability Maturity Model
- CMMS: Computerised Maintenance Management System
- CMO: Chief Marketing Officer
- CNC: Computer Numerical Control
- COAA: Construction Owners Association of America
- COBie: Construction Operations Building Information Exchange
- COO: Chief Operating Officer
- CPD: Continuing Professional Development
- CPMS: Capital Planning & Management System
- CRISP: Construction Research & Innovation Strategy Panel
- CRM: Customer Relationship Management
- CURT: Construction Users Roundtable
- DB: Design & Build
- DBB: Design, Bid, Build
- DEC: Digital Equipment Corporation
- DGN: Microstation drawing file format
- DGNB: Deutsches Gütesiegel Nachhaltiges Bauen (German Sustainable Building Council)
- DIT: Dublin Institute of Technology

- DOCS: Design, Owner, Contractor, Sub-contractor & Surety (ConsensusDOCS)
- DOGS: Design Oriented Graphics System
- DRM: Digital Rights Management (Music industry)
- DWF: Autocad drawing web format
- DWG: Autocad drawing file format
- DXF: Autocad drawing exchange format
- ECM: Enterprise Content Management
- ECTS: European Credit Transfer System
- EJCDC: Engineers Joint Contract Documents Committee (US)
- EPBD: Energy Performance of Buildings Directive
- EPC: Electronic Product Code
- ERG: Efficiency & Reform Group (replacing OGC)
- ERP: Enterprise Resource Planning
- FCI: Facility Condition Index
- FF&E: Furniture, Fittings & Equipment
- FIDIC: International Federation of Consulting Engineers
- FM: Facilities Management
- FRI: Association of Consulting Engineers (DK)
- gbXML: Green Building Extensible Markup Language
- GML: Geography Markup Language
- GPD: Gross Domestic Product
- GPS: Global Positioning System
- HGML: Hyper Graphics Markup Language
- HERD: Higher Education Research & Development (Irl)
- HSE: Health and Safety Executive
- IaaS: Infrastructure as a Service
- IAI: International Alliance Interoperability
- IATGN: Irish Architectural Technologist Graduate's Network
- IBM: International Business Machines
- ICAT: International Conference of Architectural Technology
- ICC: International Code Council
- ICL: Incentive Compensation Layer
- IFC: Industry Foundation Classes

- IFMA: International Facility Management Association
- IP: Integrated Practice
- IPD: Integrated Project Delivery
- ICT: Information Communication Technology
- IGES: Initial Graphics Exchange Specification
- IGM: Implementation & Governance Manager
- IMT: Information Management Technology
- ISO: International Organization for Standardisation
- IT: Information Technology
- JCT: Joint Contracts Tribunal (UK)
- JOC: Job Order Contracting
- KF: Konstruktørforeningen (DK)
- KPI: Key Performance Indicators
- LAN: Local Area Network
- LEED: Leadership in Energy & Environmental Design
- LCA: Life Cycle Assessment
- LOD: Level Of Detail
- MBA: Master of Business Administration
- MPS: Model Progression Specification
- nCRISP: New Construction Research & Innovation Strategy Panel
- NFC: Near-Field Communications
- NSB: National Building Specification (UK)
- NURBS: Non-Uniform Rational B-spline
- OED: Organisational Effectiveness Director
- OGC: Office of Government Commerce (UK replaced by ERG)
- OGC: Open Geospatial Consortium
- OJEU: Official Journal of European Union
- PaaS: Platform as a Service
- PAFEC: Programs for Automatic Finite Element Calculations
- PDP-11: Programmed Data Processor-11 (model number)
- PGCert: Post Graduate Certificate
- PPCert: Professional Practical Certificate
- PIM: Project Information Modelling
- PM: Project Manager

- PSM: Professional Science Masters Degree
- QS: Quantity Surveyor
- RDI: Research, Development & Innovation
- RDP: Remote Desktop Protocol (/Services)
- REN: Real Estate Norms
- REST: Representational State Transfer
- RFID: Radio Frequency Identifier
- RFP: Request For Proposal
- RIAI: Royal Institute of Architects of Ireland
- RIBA: Royal Institute of British Architects
- RICS: Royal Institute of Chartered Surveyors
- ROI: Return On Investment
- RPL: Recognition of Prior Learning
- RTPI: Royal Town Planning Institute
- RVT: Revit file format
- SaaS: Software as a Service
- SABER: Simplified Acquisition of Base Engineering Requirements
- SBEM: Simplified Building Energy Model
- SIC: Standard Industrial Classification
- SMACNA: Sheet Metal & Air Conditioning National Association (USA)
- SME/SMB: Small & Medium Enterprise/Business
- SOA: Service Oriented Architecture
- SOAP: Simple Object Access Protocol
- SPC: Special Purpose Company
- SPICE: Structured Process Improvement for Construction Enterprises
- STEP: Standard for the Exchange of Product (model data)
- URL: Uniform Resource Locator
- VAX-11: Virtual Address eXtension-11 (model number)
- VPN: Virtual Private Networks
- VTT: Valtion Teknillinen Tutkimuskeskus (Research Centre, Finland)
- WAN: Wide Area Network
- WSN: Wireless Sensor Network
- WYSIWYG: What You See Is What You Get
- XML: Extensible Markup Language

Declaration

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Acknowledgements

A great debt of gratitude goes to my parents, Nan and Fin, who sadly did not see this work's completion. This is dedicated to them. They have been my shinning light throughout and the source of my passion.

I would like to thank The Copenhagen School of Design and Technology, who have generously sponsored this work, and I would like to acknowledge the role Niels Barrett, Michael Hartmann, Erik Kærgaard Kristensen, Kave Amag and Yrsa Gregersen played in supporting me at the start of this wonderful journey. Special mention too goes to Lars Hartmann Petersen for giving me the final berth. It has been a great opportunity to test and try some of the many aspects of this work and in that thanks and forbearance is rendered towards my colleagues and the many students, without whom this would not have been possible. Of those, special mention must go to Sean Termansen, Mike Coombe and Peter Erler, together with Kristel Reseke and Juan Cai, as well as Sigurður Andri Sigurdsson, Nadeen El Erkessousi and Irina Bandurevskaja.

I would also like to thank Richard Laing, Tahar Kouider and Amar Bennadji of The Robert Gordon University, who acted as my supervisors, as well as Graham Paterson, Graham Castle and Mohammed Kishk for their valued input and feedback. Special mention must also be made of Bernice West, who was instrumental in developing relevant academic skills for a task of such complexity. It has been a great pleasure visiting Aberdeen and indeed having Aberdeen visit Copenhagen, as this work has been long distance, part-time.

Finally, mention must be made to my patient wife, Lene, who has been there for me through thick and thin and never complained once! It's warmly appreciated!

KEA
COPENHAGEN SCHOOL OF
DESIGN AND TECHNOLOGY

THE ROBERT GORDON UNIVERSITY ABERDEEN

1. Abstract

'The Impact of Digitalisation on the Management Role of Architectural Technology'

By James Harty, in fulfilment of a Doctorate of Philosophy at The Robert Gordon University in September 2011

Building information modelling (BIM) is not only an authoring tool for architects and engineers, but also an analysis tool for all stakeholders in the supply chain procurement process. Analysis tools such as the code checking of building regulations and environmental simulations that can report on heating loads, daylighting and carbon use will influence the adoption of intelligent modelling faster and further than previously thought. The benefits for clients should not be underestimated either and some are already reaping them where project certainty is to the fore. However, the professional language that architects and engineers espouse is a latent force that can run counter to fostering collaboration. An emerging professional, the Architectural Technologist, can bridge that divide and adopt the adjunct role of manager in the integrated project delivery.

The impact of digitalisation on the management role of architectural technology leads to four objectives namely; the practicalities of integrating drawing operations; the practicalities of design processes within the databased controlled programmes; the mapping of the overall process pitted against individual responsibility, data reliability and standard risk and the significant contribution to an understanding of how IMT's will drive changes within the discipline of Architectural Technology through the next decade.

These objectives were then tested to establish whether there was an evolution in the manner in which the design team is structured. They included; how the opportunities for BIM are impacting design strategies, how they are impacting associated management structures and a deeper analysis of the changing role of the architectural technologist as a result of adoption.

In conclusion, two streams were identified where one points to the educational set-up where primarily there is an apparent latent talent shortage waiting to be filled. Secondly, to the industry where project certainty will evidently drive the adoption of building information modelling and integrated project delivery as both clients and contractors will require projects to be delivered in BIM formats.

1.1 Keywords

BIM, Collaboration, Trust, Supply Chain Management, LCA, IPD & LOD

2. Preamble

It has been a great privilege and honour to be invited to study the impact of technology in a core area of the construction industry's development and growth, at such a pertinent time. Through my five years part time study, together with over one year of writing up, much has happened on this subject. On the one hand, there is an industry that needs research into this new phenomenon, while on the other there is an education that must try to prepare its graduates to cope and be an integral part of this new future. Nevertheless, back in 2005 there was a slightly different agenda, not significantly so, but enough to warrant mention here.

'The Copenhagen School of Design & Technology', who initiated and sponsored my research, needed to take stock of its position, both at the time and more importantly to predict rather futuristically where it might find itself in 2030. Currently the school offers among other degrees a *'Bachelor of Architectural Technology and Construction' Management* through a three and a half year vocational course. A plan was needed, making an appraisal of the school's worth and potential, to better inform its decision making process.

Then the school was what could be regarded as a polytechnic with aspirations to become a new university, in line with the Bologna Agreement of 1999. Assessing various institutions with whom to work, *'The Robert Gordon University'* was seen to have come through the same or a similar process, and this was seen as a noteworthy position. A collaborative process was set-up, where the school's syllabus and role was strategically divided into six subject areas and this set the tone for this work. These areas included architectural technology, design management, construction management and facilities management together with a profile of the changing undergraduate role and the development of the profession.

I was allocated *'architectural technology'* and my initial brief was to assess what the content and profile of the education, related to construction design, would be in a highly industrialised and global future in 2030. I was to underpin that answer so well that it would influence the future political action within the field of education, while outlining those changes and improvements that could be made within the existing system. I was to describe the situation, as it was then, the direction of its present movement with regard to roles, techniques and skills, and to suggest amendments to aim for a more suitable structure and content of the education for the future.

At *'The Copenhagen School of Design & Technology'*, methods are being explored to marry the divergent disciplines or at least to allow them to mutually co-exist. This research attempts to map the issues and demonstrate a method of integration.

A constructing architect in Denmark graduates with a Bachelor of Architectural Technology and Construction Management after three and a half years, Pedagogically, and traditionally, the course is structured through group work in a matrix diagram on project driven semesters. This is a huge benefit where collaborative work is involved and this is the case with BIM. A broader definition of BIM is Integrated Project Delivery (IPD) where collaboration is critical (Eckblad, Rubel, et al. 2007) which is at the core of this process.

The school's new course syllabus is making in-roads in this direction, looking to introduce an appreciation of accountable sustainable mechanisms from the first semester to parallel elective classes in Facilities Management in the fourth semester. This aspect is further being tackled at the school, trying to harness the demands and requirements of the FM process within the BIM process. This part is most interesting with regard to the education that is offered at the Copenhagen School of Design and Technology and their job opportunities upon graduation.

Being an architect, who had taken the inaugural CAD course in Dublin upon graduation in 1983 this was most welcome. I began on computers such as DEC's PDP and VAX-11, using now obsolete PAFEC software called DOGS, which progressed to an IBM-PC using Autodesk's AutoCAD (both of which came on to the market on the last week of the three month course). I have therefore had a unique insight through my career of how digitalisation has been embraced. I have witnessed, first-hand, the divide that arose between management and operatives, the bottlenecks that arose through design and production and the high turnover of IT people beyond the scope of this work during the *'dot-com-boom'*.

So, when I first sat down with Richard Laing, my supervisor, we very quickly reached a consensus that this work would need to address the effect of the digital process on technology and an appraisal of its management. There was also agreement that we could not look into a crystal ball and predict the future. We could monitor trends and report on those but any such work had to be founded on solid ground.

Several aspects of the research also impinged both on the education and the industry, and there was a parallel but disjointed discourse to be examined between the two. Prime here was the fact that the subject matter was and is changing at a rate of knots, and that education is moving away from the learning by rote model to more flexible methods, embracing life-long learning and similar. *'Change'*, in all its forms, is a word that crops up time and time again.

If technology is the application of skills and knowledge, in an architectural context we have seen this transcend the master builder's all conquering style before the Renaissance, to the design team's procurement methods of the Modern Movement. Architectural technology's role can be said to have replaced the co-operation that happened between the architect and the craftsmen, by bringing the resolution of the construction into the drawing office.

However, a 2D lined construction detail, of a key junction, cannot be *tested* per se. It is the result of known or expected performance, rooted in prior experience. Bring in new materials, new legislation or new requirements and the result can become conjecture. How can the (temperature) line-loss be plotted from outside to inside, the dew point found, thermal bridges exposed so that they can be remedied before execution on site, and so prevent ticking time bombs that can appear many years after completion or long after hand-over.

We have successfully built, and will continue to do so, but unlike any other transaction in society, it is more a process than a product, more an art than a machine, and more a skill than a repeatable exercise. Because of location and place, no two buildings are the same and no two buildings behave the same. Mechanisms are therefore needed to control this process in some form or manner, because building is a heterogeneous process, adding value to society in a holistic manner (Hagedorn, W., Prof., Dr. 2012).

During my work, this process has also grown to include sustainability, where the operation and maintenance aspects of building loom larger than previously thought, where methods to map and monitor are driving the changes in how buildings are made. So now there is an authoring of buildings, which is accountable for much more, and this must be tested, analysed and better inform the design process, in ways that could not be accomplished without a *'model'*.

This is the first time that the term model is introduced. Digitalisation in the industry has become inextricably bound with modelling, and more importantly Building Information Modelling (BIM), because of the three dimensional qualities afforded by this virtual world. But more significantly, this 3D world has the ability to hold data. As trivial as it may sound this is the driving force that means BIM is here to stay, and that it will not be replaced with another technology in the near future.

Soon better simulation will be possible as rain and wind is driven through a construction, as avatars evacuate a building under fire escape procedures or even as induced ageing highlights possible weaknesses in the construction. Already behaviours and properties are being programmed where these attributes are quantified and measurable. Code checking already documents building regulation compliance, there is much more to come.

Sure, it will unfold and be toned, but the closest you can get to reality, with something that is not reality, is a model, *by definition*. Following this, it could be seen that there would be an impact on working practices and methods within the construction industry and that it would affect how we teach and what we teach. From this process, the title of the work became manifest as:

'The Impact of Digitalisation on the Management Role of Architectural Technology.'

This title has remained unaltered since then.

3. Introduction

3.1 The Challenges Emerging in Relation to BIM

Mayne (2005), said during the *'Building Information Panel Discussion'* at the AIA National Convention in Las Vegas that:

> *'It's about survival. If you want to survive, you're going to change; if you don't you're going to perish. It's as simple as that... you will not practice architecture, if you are not up to speed with this...'*

This was in response to:

> *'By what means do the architects in this audience accelerate their understanding of this new technology and all its implications for practice?'*

During the discussion, MacLeamy said:

> *'This is happening, get with it or get over it. If we don't do this, I don't believe that we are going to be in business.'*

Meanwhile, Burns added:

> *'You should encourage/lobby your local architecture school or your Alma Mater, to invest in this new technology...'*

Equally compelling and from the complete opposite end of the scale, a study in Hong Kong by Tse (2008), saw the barriers to adoption as:

- No need to produce BIM
- Existing CAD systems were adequate
- No desire to commit to extra cost
- Lack of skills
- BIM could not reduce drafting time
- Not enough features
- Not required by clients
- Not required by other project team members

Of these, arguably the only remaining barrier is lack of skills (Economist 2009). At that time, BIM was seen as a technology. Now it is accepted as a process (Eckblad 2007).

Above and beyond the technology and the management, there is also its impact on society, and how buildings shape our lives, and influence our quality of life. Barrett (2010) address these concerns in looking at both what society deserves and how new methodologies augment change. Underwood (2011) also reflects on the impact of BIM where it is often seen by management as a utility tool (and not an intrinsic tool), meaning that it has been strongly affected by the economic crisis of 2008, where there have been significant cutbacks. This too has a large bearing on society and the quality of buildings produced. It does not go unnoticed that this too offers worthwhile potential for growth, if properly adopted.

However, in relation to this research, how it affects management regarding its implementation, sees four emerging dimensions;

- An integrated environment
- Distributed information
- Up-to-date information
- New derivatives of the information

He concludes that:

> *'Various information technologies can facilitate this new focus such as cloud computing, sensor networks, stateless web services and semantic webs. '*

These issues will be dealt with later in this work, but in the first instance, there are the practicalities of adoption and implementation. The significance of this is that while it is slowly being accepted by the professionals, there is reluctance towards it.

4. Methodology

In his foreword to *'Advanced Research Methods in the Built Environment'* Prof Peter Barrett acknowledges the complexity of the built environment research domain (Knight, Ruddock 2008). However, Andrew Knight (co-editor) notes that, many *'built environment researchers'* have been academically trained in professional areas, and not in traditional postgraduate research, suggesting that it is still a relatively new and diverse field of study.

These two points of view make for an interesting discourse, on the one hand there is much happening, but on the other there is no well established body on work bedded in the built environment from which to draw the very foundations on which to build. Equally, a subject such as digitalisation is very new within the built environment; meaning new approaches might need to be divined in order to support it and understand it. Finally, architectural technologists' assimilation into the sphere of management is not formally recognised just now. Traditionally, a technologist wanting further education usually became an architect (Barrett 2010).

In building a case, much of the empirical evidence comes from obtaining and verifying data. Traditionally, *'a characteristic purpose of a methodology is to show not such and such appeared to be the best method for the given purposes of the study, but how and why this way of doing it was unavoidable - was required by - the context and purpose of this particular enquiry'* (Clough, Nutbrown 2012).

Likewise, *'Pragmatic researchers are more likely to be cognisant of all available research techniques and to elect methods with respect to their value for addressing the underlying research question, rather than with regard to some preconceived bias about which paradigm is a hegemony in social science research'* (Onwuegbuzie, Leech 2002)

From these standpoints, Comte would say; *'from science comes prediction; from prediction comes action'* (Pickering 1993), but in complex situations as outlined here such clarity can be difficult to isolate. Thus the quantitative approach, which tends to lead to positivism, needs further insights and an understanding of various perceptions to unravel the situation leading to a qualified understanding. The qualitative approach enlists beliefs, opinions and views to gather data, which while being rich in content and scope is open to interpretation (Fellows, Liu 2003).

This situation lends itself better to inter-supportive goals and objectives. There is a need for the mixing of methods to gain a developmental position. The overall perspective to this research was more one of enquiry rather than hypothesis. This suggested a qualitative approach to the research since one of the chief reasons for taking such an approach is if the subject is relatively unexplored.

'This means that not much has written about the topic... being studied, and that the research seeks to listen to the participants and build an understanding based on their ideas' (Creswell 2008).

Denscombe presents a pragmatic approach case for a qualitative approach, pointing out the various advantages and disadvantages associated with qualitative research. He says that while qualitative research has a richness and detail to the data, there is nevertheless *'tolerance of ambiguity and contradictions leading to the prospect of alternative explanations during the process of analysis'*. Furthermore, the often less wide ranging breadth of qualitative research means the data may be less representative and the interpretation may be *'bound up with the self of the researcher'* (Denscombe 2007)

4.1 The Qualitative Quantitative Continuum

'The claim that qualitative research uses words while quantitative research uses numbers is overly simplistic. A further claim that qualitative studies focus on meanings while quantitative research is concerned with behaviour is also not fully supported since both may be concerned with people's views and actions. The association of qualitative research with an inductive logic of enquiry and quantitative research with hypothetic-induction can often be reversed in practice; both types of research may employ both forms of logic (Brannen 2005).

When we combine methods, there are a number of possible outcomes, Brannen tells us, where corroboration of results is only one of at least four possibilities (Morgan, 1998, cited in Bryman, 2001; Hammersley, 1996):

- Corroboration: the *'same results'* are derived from both qualitative and quantitative methods.
- Elaboration: the qualitative data analysis exemplifies how the quantitative findings apply in particular cases.
- Complementarily: the qualitative and quantitative results differ but together they generate insights.
- Contradiction: where qualitative data and quantitative findings conflict.

Creswell comments that qualitative and quantitative research *'are not mutually exclusive. Most research will exist somewhere on the continuum between the two'* (Creswell 2008). This interaction of methods is further expanded upon when Miles proposed:

'(...that such studies) can help sequentially and can expand the scope and breath of a study by using different methods in different components' (Miles, Huberman 1984).

4.2 The Use of Interviews in Case Studies

The use of interviews in case studies allows the researcher to get to the heart of the issue, allowing pertinent issues to come forth naturally in a free flowing environment. It also provides a rich source of data (Kvale 1996), which can be utilised in the design of the subsequent stages of data collection (Hakim 2000).

The inevitable biases that can occur due to the interviewers own background and experience (Denscombe 2007) (Clough, Nutbrown 2012) can *'rather than attempt to eliminate the personal interaction and interviewee can regard the person of the interviewer as the primary methodological tool'* (Kvale 1996). Further, the familiarity with the environment, in which the interviews are to take place, is essential.

Interviews were... made easier, due to establishing mutual respect and because interviewees were able to use jargon... in the knowledge that the interviewees would recognise these references. In this respect, the researcher can be viewed as a *'methodological tool'* as prior knowledge and experience has enabled the smoother operation of certain parts of the data collection (Laing 2008).

4.3 Research Questions & Research Objectives in General

Research design generally describes how data will be collected and analysed in order to address and answer the research question. This all-encompassing picture provides the framework for undertaking the research (Bryman, Bell 2011). However, there are also claims that different types of research need a diversity of methods to be employed:

'In broad terms, construction management research either adopts an objective 'engineering orientation', where the focus is on discovering something factual about the world it focuses on, or a subjective approach, where the objective is to understand how different realities are constituted (Harty, Leiringer 2007). *Whilst the former emphasises causality and generalisability, the latter focuses on localised subjective meaning'* (Dainty 2008).

This claim for a broad church is particularly relevant for the construction sector because it is largely a new field of research (Knight, Ruddock 2008). Knight concentrates on the role of theory or epistemology within the built environment. However, despite the many philosophical debates in the field of construction management, there has been a reluctance by researchers to fully embrace alternatives to the dominant quantitative paradigm (Dainty 2007, Dainty, Green et al. 2007). By this is meant, it appears that they are still firmly rooted in the positivist tradition. He argues that to understand why the construction process is so fragmented, a more holistic and adventurous approach is required.

Dainty therefore argues for a *'mixed method'*, combining both inductive and deductive methods, in order to justify the qualitative methods used by authors who normally would use interview, observation, documentation or other textual and visual data analysis. An issue that can arise from this is the apparent reliance on open-ended interviewing. This is exactly how contemporary qualitative research can be characterised; it is called diversity (Punch 2005).

This mixed method amounts to a pluralism, where previously Hanson, Kuhn and Popper demonstrated flaws in the purely inducted and theory-based independent observer's observations (Mingers, Gill 1997). He also noted similar trends in soft approaches supporting the emergence of these mixed methods, where the use of multiple theoretical models and multiple methodological approaches is both legitimate and desirable if established models and understandings are to be questioned and inherent knowledge extended.

In accepting that Construction Management is a relatively new field and without established practices (Dainty 2008), a fundamental question arises when establishing a philosophical position. While positivism and quantitative methods have been in the ascendency (Fellows, Liu 2003) a contrasting method, interpretivism espouses the importance of understanding human behaviour (Bryman, Bell 2011). This provides complimentary insights, which can ultimately enrich the understanding of those who work in construction.

Furthermore, arguing for an alternative method, David Seymore and John Rooke say:

'It is concluded that the dominant rationalist paradigm tacitly endorses existing attitudes and that if researchers are to have a role in changing the culture of the industry, then the culture of research must change also.'

This questioning of accepted methods (Seymore, Rooke 1995) and their dominance brought accusations of promoting an approach more akin to consultancy than research. Their response (Seymore, Crook et al. 1997) was:

'Our suggested alternative is to concentrate upon the interpretative methods which researchers and managers use to make sense of the world. This approach yields an investigation, which is primarily concerned with meaning, rather than causality and produces an account, which recognises the respective viewpoints of practitioners in the process.

It is our belief that such an account better reflects the realities of construction management as a practice. It is our perception that investigation into the nature of construction management, as a practice, has not taken place.

Construction management, as a discipline, has simply accepted without significant question one particular meaning of 'theory,' and one particular method for arriving at that theory.'

On a different tact, Dainty examines an alternative perspective of multi-strategy called 'multi-methodology' where there is a combination of methods to enrich insights into relationships and their interconnectivities within organisations. In this context, something called loose pluralism alludes to the encouragement of a variety of paradigms and a range of methods without prescribing how they should be used or applied. Elsewhere, complementarism holds differing paradigms as being internally consistent, while ultimately, strong pluralism suggests that most situations are best dealt with by a blend of various methodologies originating from different paradigms.

He claims that this is consistent with interpretivism, specifically with regard to the practitioners' perspective, and therefore contrary to positivism. He further suggests that paradigm sub-cultures exist within management science disciplines. Finally, he says:

'Adopting a particular paradigm is like viewing the world through a particular instrument such as a telescope, an X-ray machine or an electron microscope. Each reveals certain aspects but is completely blind to others... each instrument produces a totally different, and seemingly incompatible, representation. Thus, in adopting only one paradigm one is invariably gaining only a limited view of a particular intervention or research situation... it is always wise to utilise a variety of approaches.'

4.4 Grounded Theory

Grounded Theory is a method in which theory is derived from a structured data set either with or without a preliminary research question. This involves a systematic process of gathering and analysing a finite set of data to involve a theory based upon the data. This is then used to predict or explain phenomena (Glaser, Strauss 2009). Glaser and Strauss state that this is derived from data and then illustrated by characteristic examples of data.

This process is at the interpretivist, post-positivist end of the philosophical continuum (Scott, Davidson et al. 2002). Sources for generating these theories vary, and they including case studies, interviews, historical accounts, field observations and documents which ultimately produce theory development (Denzin, Lincoln 2005).

This opening up of the interplay between the researcher and the data (Strauss, Corbin 2007) is further supported by the fact that it is highly unlikely that new theories can be built from first base (Whetten 1989). In this situation, the use of case studies is considered most appropriate in new areas of research in order to provide different perspectives (Wacker 1998). The advantage of this approach is that it builds closer links with reality, so that the theory is more likely to be novel, testable and be empirically valid (Eisenhardt 1989).

Interviews will be conducted with architects, designers, managers and technologists in semi-structured dependant on disciplines to reflect on their processes and procedures. Questionnaires will be conducted primarily with students to gauge their impressions in the controlled environment of a school. This distinction arises due to the poor penetration of digitalisation into the daily work of the industry, compared to the successful adoption within teaching establishments (meaning The Copenhagen School of Design & Technology in this instance). Observation will be exercised on the case studies to establish their methods and the extent of their impact. Differing degrees of adoption and various methods of implementation offer the reader a plateau to analyse the scope and success of these studies. Analysis of procurement methods will chart the differences that are happening as a result of digitalisation. Open-ended problems tend to be complex requiring, in some circumstances, fuzzy logic. Often their classification is difficult because of working in a continuum. It is intended that the range of case studies is varied and progressive, allowing the reader to compare and contrast as they see fit.

The case studies will range through inexperienced or new firms that are implementing BIM on singular projects, to collaborations and larger firms driving projects that are benefitting hugely from BIM. The research methods aim to gather information about people, processes and projects through interviews, questionnaires, observation and analysis of procurement.

4.5 Research Rationale

The derivation of research questions comes about from the development of the research aim & research objectives. This evolves from the following:

- Exploration
- Underlying Strategy
- Analysis of Techniques

The reflection of the core interests that result in the adoption of the objectives are in response of the following:

- Behaviours
- Influencing Factors
- Response
- Success Criteria

These can then lead to further questions, where questioning can emerge fuelling a new cycle:

- Why
- More complexity

Finally, in trying to deal with something, as diverse and as complex as construction, it is natural to develop simplified versions of reality in the form of models (Crotty 2012).

> *'A discipline or profession is established by developing a body of knowledge, which is unique - that body of knowledge is produced through research' (Fellows, Liu 2003).*
>
> *'Only by use of appropriate methodologies and methods of research, applied with rigour, can the body of knowledge for construction be established and advanced with confidence.'*
>
> *'Although a number of texts are available discussing research methodologies and methods generally, there is a notable lack of such books in construction.'*

This work will be divided into three parts, the first concerns the development of a proposal, the next the execution of the research and finally the drawing of conclusions. In producing a proposal, the concept of research must be defined. It is a careful search, or an investigation, which systematically increases the sum of knowledge. This original contribution to knowledge cannot happen in a vacuum but rather is an open system, which allows for adaptability (Mayo 1949, Popper 1989).

5. Aims & Objectives

The aims of this work are to develop an awareness of the changes that digitalisation is having on the construction industry. Four objectives are advanced, which study and investigate the impact that digitalisation is having, and in particular building information modelling, especially with regard to how the industry is managed. Digitalisation is changing many facets of life and influencing everything from fingertip data, to gadgets and applications that seamlessly appear in everyday scenes, (typically, smartphones come to mind).

A major aspect of this change is the adoption of new technologies, and traditionally this process has been the domain of the technologist. It will be important for this study to examine this process and report on the practicalities of these operations and processes. A new role emerges here with regard to the management of these practicalities, chief among them responsibility, training, reliability and risk.

5.1 Objective I

The impact of digitalisation on the management role of architectural technology is rich with research possibilities. By definition, has digitalisation an impact, what is management's role and where does architectural technology find asylum through these rough seas? Has architectural technology changed? Who is best placed to implement it, to integrate it and deliver it? What roles are impacted, is the work just an automation of the traditional methods, or what roles do databases bring to the table?

As these things influence the industry, many issues arise. Prime among them is how they will be implemented and what practicalities their integration will have on both traditional procurement methods and ultimately how we design our environment. In this research, I have examined the roles of the various disciplines and assessed how they interact. Generally, how the industry performed before was not seen as ideal and many improvements have been called for, from clients to the environment, from governments to legislators and latently from contractors and the supply chain. Jason Underwood (Underwood, Isikdag 2011) goes as far as to call it, the *'traditional'*, *'archaic'* and *'draconian'* heritage.

'What are the practicalities of integrating drawing operations?'

To answer this question, will require an in-depth study of current practices with an assessment of their shortcomings especially in an historical perspective of how the architect's office functioned, together with the role of the architect within the design team.

While assessing the status quo there is also a need to evaluate the potential and scope of the new digital process. This includes looking at databases, the new programmes and how they can be integrated into current processes. This has an impact too on contracts and the whole legal basis for the construction industry.

> *'What are the practicalities of design processes within database controlled programmes?'*

Once again, this is of a very practical orientation, but as with all new ideas and procedures there has to be a benchmarking of how things are so that there can be a surgical operation to introduce the new elements into the mix.

This introduction to the complexities and the practicalities of the operations and processes, leads fittingly to the first objective for my work. Essentially, it is the laying of the table bare, so that the matrix of the workings of the industry can be seen and critically appraised. It is the foundation for the work and it identifies the niche that is to be addressed in the remainder of the work. The form of words is such:

> *'To study the practicalities of integrating drawing operations and design processes within database controlled programmes, including a mapping of overall process against individual responsibility, training, data reliability and risk.'*

The aim of this part of the work is to mark the territory of where digitalisation is impacting the industry and to draw attention to both the barriers and incentives to initiate and implement change. There is often resistance to change, especially in an industry as fragmented as construction, and in the words of author Robert Heinlein (1985):

> *'The hardest part of gaining any new idea is sweeping out the false idea occupying that niche.'*

Using BIM to design a project opens many new avenues towards improving procurement practices with even better communication and co-ordination across the whole building-sector. These new opportunities need to be investigated and reported. Because once digital data is produced, it makes sense to use it, reuse it and exchange it with others. It is pointless developing the same or similar data many times independently or in parallel.

The corollary of this is the reliability of the data. Stemming from this is the validity and more so, the trustworthiness of what is distributed or available, and this raises even more issues. Accountability enters the equation and the condition or state of the data is questioned. This ranges from conceptual and generic, through to production and as-built, so that others can appraise and accept what is both distributed and available. Metadata is required to manage this situation and *'levels of detail'* quantify the quality of the exchanged data.

This data then begins to extend beyond the procurement package, affecting the financial set-up and the life cycle analysis. Suddenly BIM has a life span before, during and after project completion, all the way until decommissioning and demolition (cradle to cradle).

This expansion of the project will influence design strategies and even more so, how to manage across this enlargened scope. Transverse collaboration is required to ensure the data is available and readable to the various parties and stakeholders. Whilst it is embedded deep in technology, it begins to impinge methods and procedures, and the associated management processes.

5.2 Objective II

Once the various roles and responsibilities are identified, the next step is to study the opportunities that can accrue from them. This requires considering how the design team operates and how the initial decisions are made. Critical here is the entrenchment of the disciplines in their current work practices, with an overview to current distribution of deliverables (typically drawings) within the design team, and the limited sharing of same. So, what are these new opportunities and how will they be implemented brings us to the next research question:

'How are BIM opportunities impacting on design strategies?'

In order to study and test these changes, it is necessary to look at some seminal projects and celebrity architects (from TeleNor in Fornebu and Terminal 5 in Heathrow, to Frank Gehry and Gehry Technologies) in order to examine the showcase work that initially highlighted the way forward. It could be claimed this has the potential to culminate positively with the re-empowerment of architects.

Following these studies, it will be necessary to align the findings with projects and mainstream practices to check how pervasive this modelling is becoming. Parallel to this is how it is being adopted and by whom. This includes the impact on management, on the process, an analysis of the depth of the problem and the changing role towards digitalisation. If it is not changing then there will be a need to examine from where the apathy and malaise stems. This questions:

'How are BIM opportunities impacting associated management structures?'

This is a significant milestone in the work because if at this point it can be demonstrated to be beneficial, then it beggars belief if it is not being deployed in larger numbers. Critically the role players come under scrutiny and the research must widen to others areas, which might bring better returns.

This objective begins to turn attention away from the technology itself, to focus on the management structures that the industry traditionally imposed. It also deliberates at large about the opportunities afforded by it. The pervasiveness of it has a big role to play here, demonstrating the gathering of momentum and the need for changes, both strategically in a vertical sense of the silos that the disciplines occupy, while driving down right through the supply chain across the whole construction sector. The second objective can be stated as follows:

> *'To investigate how the opportunities afforded by a pervasive use of IT within construction, are impacting on design strategies and associated management structures.'*

The master builder and apprenticeship system served society well until it outgrew its usefulness. The industrial revolution together with new building materials (such as steel and concrete) and new building types created new tasks requiring new solutions. In this new scenario more drawings, specification, schedules and quantities saw the design team grow and the architectural technologist shine. Whereas previously drawings of intent could be read and translated by the construction team in time honoured fashion, now all had to be delivered describing how, where and what was to be completed.

The architectural technologist has a unique perspective over the other design team members, in that they have the ability to engage with the architect, engineer and contractor as well as all the other participants in the supply chain of making a project real. The natural next step in such a position is to capitalise on the opportunity and assume the mantle of management of the building information model. The study need to analyse this evolution and consider its deeper meaning.

There ought to be a fine balance at this point in favour of the adoption of this new process but as with all new things there are those, who find it nigh well impossible or impractical initially, moving on later to a situation where it might be possible or expected, leading finally to where it becomes requisite. This brings us into the next phase where the technologist moves centre stage.

5.3 Objective III

Having studied the possibilities and their implementation brings me to the consequences of such an upheaval. Just as the microscope changed medicine, digitalisation will change construction. The ability to author and test before building will change how we build, what we build and where we build. A further question would be to see if the evolution will lead to a change in how the construction team is formed, how the work stages are remunerated and what impact Life Cycle Assessment will have on building stock. Therefore:

> *'Will Information Management Technologies (IMT) lead to an evolution of the manner in which the construction design team is structured?'*

This will require looking at the set-up of the team and the changing roles within the team and prime among these will be the new roles that are needed to oil the mechanisms therein realised. What needs to be examined is the stature of the stakeholders and their newfound activities and this will lead to a further corollary:

> *'Is a deeper analysis of the changing role of the architectural technologist needed?'*

If so, then two further outcomes are raised which lead to the final objective. The first addresses education and how we meet the expected talent shortage to implement the enterprise, and the other is how certainty is quantified so that implementation happens. This touches on who will drive the changes, whether it will be legislation, climatic imperatives or stakeholders in the supply chain.

Taking these last two questions forms the text for the third objective:

> *'To study the manner in which emerging Information Management Technologies (IMT) will lead to an evolution of the manner in which the construction design team is structured, including a deep analysis of the changing role of the architectural technologist as a direct result.*

It is the intention to explore the extent to which the best-placed team member in all of this is the technologist, both because of their all-round ability within the industry, and precisely because they know what each discipline expects and provides positively to the mix. There are rewards for these trimmings and this includes professional status and prestige, which has been lacking previously.

There is a need to look at the interplay between the architect and the technician. From this, it can be seen that the technician has consistently and quietly been promoting their role to a new ideal of technologist. This is significant and the changing role will be examined in this context.

Not alone can this afford a great opportunity, for the architectural technologist to take the initiative, it can elevate their role to that of a professional body. This can be a bridging step to change the discipline significantly. It requires defining the management roles, and how they can be implemented, this leads to the final objective.

5.4 Objective IV

'To make a significant contribution to an understanding of how IMT's will drive changes within the discipline of Architectural Technology in the next decade'

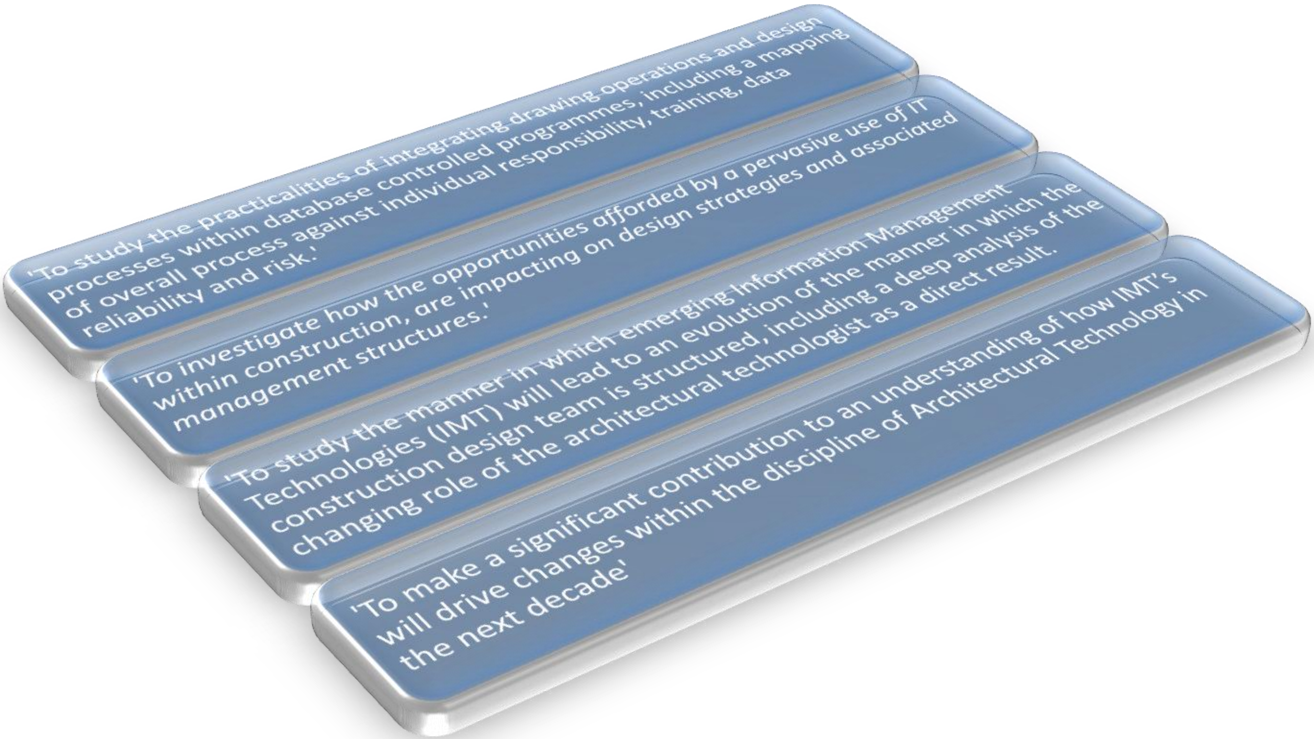
This fundamental transformation of the organisation of the design process impacts the technologist irrevocably. IMT's change how we communicate, how we share across the disciplinary platforms, how we bridge design, analysis, manage, cost and model across the building sector.

In order to pull down the professional silos that have grown up in the construction industry, without dismantling the professional roles, requires a new professional who can augment and supplement those spaces between the traditional pillars of the construction industry. It requires someone who understands the architects, engineers and construction people, and who can work with each discipline harmoniously. That role falls naturally to the technologist, who fills that role effortlessly and consummately given the opportunity.

What is new and will be addressed in this thesis is the adoption of the role and the ascension into management of the architectural technologist, in a fitting and rewarding manner. But let us start with the architect.

Text Box 1 Summary of Objectives

'To study the practicalities of integrating drawing operations and design processes within database controlled programmes, including a mapping of overall process against individual responsibility, training, data reliability and risk.'
'To investigate how the opportunities afforded by a pervasive use of IT within construction, are impacting on design strategies and associated management structures.'
'To study the manner in which emerging Information Management Technologies (IMT) will lead to an evolution of the manner in which the construction design team is structured, including a deep analysis of the changing role of the architectural technologist as a direct result.
'To make a significant contribution to an understanding of how IMT’s will drive changes within the discipline of Architectural Technology in the next decade'


'To study the practicalities of integrating drawing operations and design processes within database controlled programmes, including a mapping of overall process against individual responsibility, training, data reliability and risk.'
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'To make a significant contribution to an understanding of how IMT's will drive changes within the discipline of Architectural Technology in the next decade'

6. Historical Perspective

In Anthony Vidler's book on Claude Nicolas Ledoux (Vidler 1990), architectural education in the eighteenth century is broadly described as having little or no standards, or any uniform regulatory codes. The profession unbounded by the apprenticeship system of the Middle Ages and Renaissance had a variety of roles, leading with the *'Architecte du Roi'* to the general practitioner and the *'entrepreneur des batiments'*. Most of them would speculate and invest, engaging in both design and construction but membership of the First Class in the *'Academie'* forbid mixing the roles of architect and contractor to preserve the distinction between commerce and the liberal art of architecture.

This small difference could be said to be critical in one of the architectural profession's difficulties today, namely in delivering projects on time and to budget. This separation is also significant of the construction team and the differing roles to be played. The erosion is also compounded by the fact that architects are increasingly finding that they are in fact sub-contractors to the prime supplier as client (Worthington 2005).

Furthermore, sharing data and collaboration does not sit well with the disciplines involved in the building industry. There are well defined protocols and contractual expectations for each of the members of a construction team, ranging from and typically the Royal Institute of British Architect's (RIBA) Plan of Work or The Joint Contracts Tribunal (JCT) standard forms of building contracts in the United Kingdom. It traditionally creates an adversarial and litigious atmosphere and given that the building industry is one of the most fragmented, there is little interagency cooperation. Many alternatives has been tabled and tried and the whole process is in a state of flux. Design and Build is replacing Design, Bid, Build and new methods are continually presenting themselves. Lean design is also addressing waste in the industry.

However, as Sigurðsson says:

> *'Ever since I first started studying in 2006 there has been a little voice inside my head saying 'there is an easier way of doing this' (by) means of this then I am referring to drawings, quantity takeoff, scheduling and presenting.'*

This is a reference to a technologist's course where traditionally these things are taught in parallel, in reference to the construction industry's differing professions and their inbuilt intransigence to each other (Sigurðsson 2009).

It also concludes that Building Information Modelling is here to stay and that it will not be replaced by another method or practice, and this is a very strong statement. But when analysed there is much to be gleaned from it. All planning in its theoretical sense is essentially modelling in its practical sense of one sort or another, and when making a virtual model whether it is in a financial setting or a building context, the better the model the better the resulting project. So, it is claimed that the virtual model will continue to assimilate and absorb all the characteristics of the real project becoming closer and closer to the real thing.

There are a number of issues in this process and one is the entrenchment of the different professionals and their methodologies. While it is absolutely right for an architect to control aesthetics and space, nobody questions that it is equally right for the engineer to control the structure and/or services. What is questionable is their mindset and language, if there is to be the real possibility of shared data, and genuine cross-discipline collaboration.

Sadly, while T5 was collaborative, it was not a virtually modelled project and when the first satellite building was recently commissioned this method was abandoned for a traditional method of procurement. Questions must be asked as to how much sway the various disciplines and the entrenched methods had in this change of mind. Or was the management chain of command too onerous. The team structure had a hierarchy of several layers of management; the development team, the project management team, delivery teams and task teams.

When there was no common model to reference the level of comfort of the construction manager was not too cosy. In general construction managers have the lowest level of comfort, working with other professionals (under 20%), while owners, architects and engineers have nearly twice that level (Eckblad, Rubel et al. 2007), meaning that while the traditional demarcations have a good bonhomie, issues arise whether the industry can afford this luxury anymore.

Processes need to change and furthermore there has to be what many are calling a cultural change in the way we make buildings. Life Cycle Assessments (LCA) and sustainability are bringing the facilities manager more and more into the procurement process, instead of the traditional method where both were divorced from each other.

This widening of the scope of procurement brings with it an increase in responsibility and adds more layers of complexity. How it can be integrated broadens the role of the model in both how it performs before a design brief is in place and how its legacy could behave after project handover.

The work can be divided into two parts, one where authorship is to the fore and the other where analysis is primo (Hardin 2009). Authoring involves building the model and developing it through the various work stages of the project. Analysis allows the model to be checked and controlled so that certainty is achieved, bringing projects on time and to budget (Eastman et al. 2008). Allowing the data generated to be mined and tested is not new, it is in fact an integral part of the planning process and of great concern to the client.

While this can be described as the kernel part of the process, there is increasing concern for the lead up and post practical completion stages, essentially outside the procurement part, where Facilities Management (FM) holds sway. FM is becoming a critical player in the process now that LCA casts a critical eye on the initial design decisions where most influence is placed. In the design business, it is often said that 80% of the costs are determined in the first 20% of the design process (Smith and Tardif 2009). LCA is increasingly growing in its stature beyond the building procurement phase (Sapp 2010).

FM plays a major role in this initial dialogue where the 80/20 imbalance still figures large and even more so after practical completion with operations and maintenance issues accounting for up to 80% of the building life time costs. FM'ers regularly complain that the procurement model is unsuited to their modelling regimes, (being harvested by AEC people only) meaning that they wait until the building is complete before moving in to begin their maintenance models (AECO). Their initial models are to date also separate and indifferent to the procurement model (Sørensen 2010).

Sustainability tells us that there is an inefficient and excessive use of materials and energy today, which needs to be addressed. FM'ers are primarily interested in alphanumeric data rather than geometry and methods need to be found to allow them an input in the early stages as well as handing over a model that can be used by them instead of them having to drive parallel models.

Theoretical Diagram of the Objectives

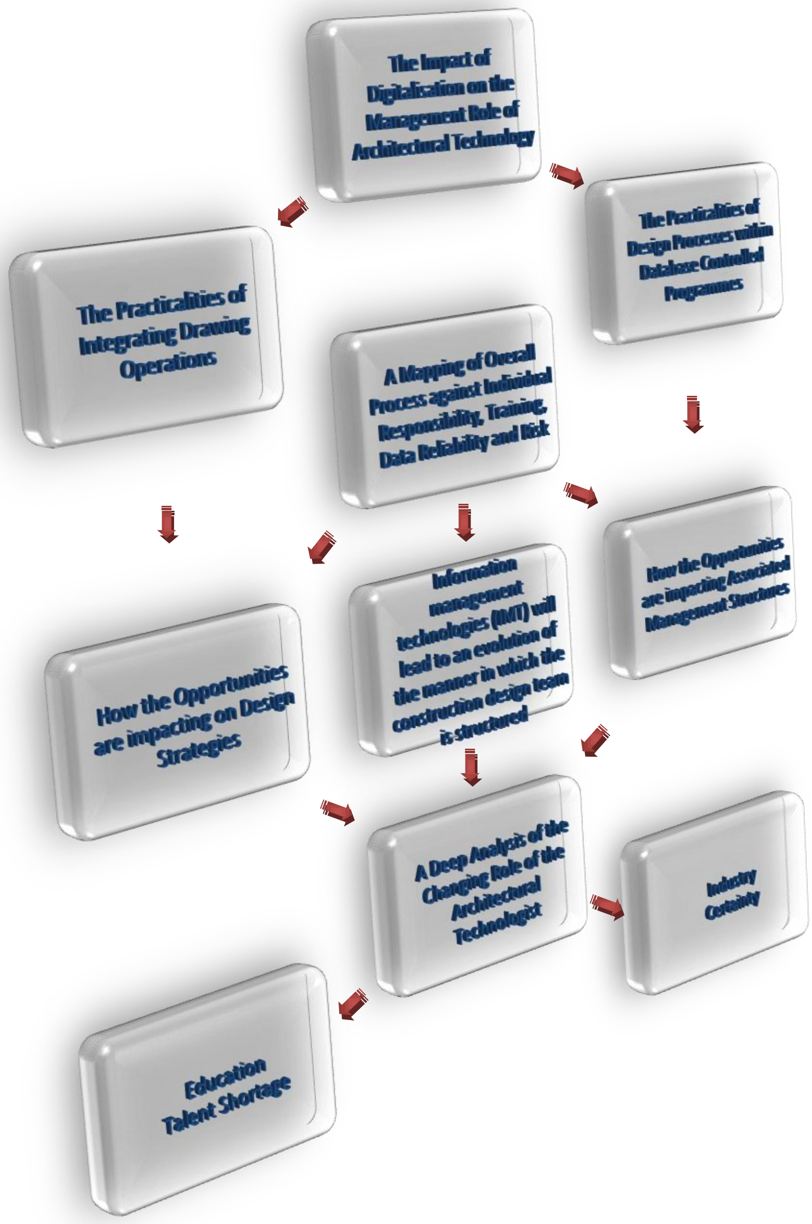


Table 1 A Layout of the Process where the central sequence shows the development, while the left-hand impacts education and the right-hand impacts industry.

7. Literature Review

7.1 Definitions:

In order to build a body of work, the foundation documents need to be identified. Essentially this involves defining what is meant by the terms used and to describe the major roles, which affect digitalisation. There are many subjects involved here ranging from architectural technologists to the scope of their work, from BIM to IPD, from FM to LCA and many subsidiary classifications and related fields, all the way down to the sub-contractor.

7.1.1 Architectural Technology:

'Technology has its root in a Greek word teche referring to art and skill; the art of making. From this architectural technology is the art of building, a discipline that aims to bring together artistic, practical and procedural skills, the fusion of three separate worlds. (Merricam-Webster 2012)

...of paramount importance are the joints between the selected materials and the synergy between the design and production - the domain of the architectural technologist, individuals with an eye for detail and the ability to take the conceptual design through to practical completion on site.'

7.1.1.1 Constructing Architect (Copenhagen School of Design & Technology)

'A constructing architect (student), deriving from the Danish word konstruktør, learns above all to design, plan and manage building and civil engineering projects regarding:

Production

- *Methods of production & quality management*
- *Design*
- *Control the design process in accordance with the phase model*
- *Business Economics, Administration & Law*
- *Financial, management & development-related assignments*
- *Surveying*
- *Conducting & recording surveys*

Supported by:

- *Correspondence involved in building projects*

Taught by:

Architects

Structural Engineers

Construction Managers

Constructing Architects

Project Managers

Mechanical/Electrical Engineers

Lawyers

Communication Consultants

Facilities Managers

…and others as required'. (Møller, 2012)

7.1.1.2 Constructing Architects (Konstruktørforeningen, KF)

'Constructing Architects are a profession in Denmark according to the Constructing Architects Institute (Konstruktørforeningen). They are employed in the construction industry, where they construct, manage and plan buildings. Their role is to bridge between design and execution'. (Ravn 2012)

'They wear the many hats.'

'They make the impossible possible.'

'They hold the overview between complex contexts and attention to detail.'

'They are generalists who can easily specialise.'

'They are helping to better lead construction.'

7.1.1.3 Architectural Technology (Dublin Institute of Technology, DIT)

'Architectural Technology is the technical design and expertise used in the application and integration of construction technologies in the building design process.

The Architectural Technologist is a highly skilled technical professional trained to play a leading role in the increasingly complex technical design process, which drives contemporary architecture and building.

As a technical designer, the Architectural Technologist plays a co-ordinating technical design role at the centre of the building design process. S/he should have an appreciation of the conceptual nature of the architectural design process, and should be able to work alongside the architect in applying technical design principles in the development of an architectural design. S/he will play a lead role in overseeing and co-ordinating the input to the design process of consultant structural and services engineers, and of specialist sub contractors.' (Allen 2012)

7.1.1.4 Architectural Technology (Stephen Emmitt)

'Over the past 50 years a succession of (British) government reports and an enormous volume of research have urged all those involved in building to work together towards a joined-up industry. Paradoxically, the trend has been towards greater specialisation and increasingly more complex relationships, which has led to greater barriers to effective communication between the project participants. As information has become easier to access through information technology, it too has become more specialised and hence more compartmentalised further supporting

specialism and fragmentation. More recently, the separation of technology from architecture, both in education and in practice has resulted in the growth of a relatively new professional discipline, architectural technology.

(His book) aims to bring together philosophical, technical, legal and social issues often thought as separate subjects, to provide a constructive link between manufacturer, designer and builder.' (Emmitt 2002)

7.1.1.5 Architectural Technologists (Chartered Institute of Architectural Technologists - CIAT)

'...Architectural Technologists... are experts concerned primarily with the sound technical performance of buildings. They are specialists in building design and construction and can initiate and complete a building project from conception through to final certification. They undertake a wide range of work including domestic, commercial and industrial projects. (CIAT 2012)

Architectural Technology is the science and technical aspects of architecture primarily based upon the twin concepts of designing for performance and production through the use and integration of technology.

Architectural Technology is the technical side of design - it can be about how things look but mainly it is about how buildings work. It's all about problem solving and turning conceptual drawings into reality. It's (about) understanding design and the buildability of buildings.

Chartered Architectural Technologists and architects are qualified and competent to lead construction projects from design through to completion. The difference is within the specialisms that they will bring to a project. Chartered Architectural Technologists' training and emphasis is the science and technology of architecture and architects' training and emphasis is the design and philosophy of architecture. Whilst both disciplines have their own distinct training and specialism, there is considerable overlap between the two professions'.

7.1.1.6 Architectural Technology (International Conference of Architectural Technology - ICAT)

'Architectural Technology in this context is not mainly about the many techniques used by the architect to produce the documents, drawings and models, but rather the techniques of how to put the building together that are to be embedded in the documents produced by the firm of architects. It is about how to master the 'coherent' technical design of buildings in the drawing offices today and in the future' (Barrett 2011).

7.1.2 BIM Handbook, Charles Eastman

'Building Information Modelling (BIM) is the process of generating and managing building data during its life cycle (Eastman 2008). BIM involves representing a design as objects – vague and undefined, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. BIM design tools allow for extracting different views from a building model for drawing production and other uses. These different views are automatically consistent – in the sense that the objects are all of a consistent size, location, specification – since each object instance is defined only once, just as in reality. Drawing consistency eliminates many errors. Typically, it uses three-

dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction. The process produces the Building Information Model (also abbreviated BIM), which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components. Pieces can carry attributes for selecting and ordering them automatically, providing cost estimates and well as material tracking and ordering. This method of management is more practical and efficient. It eliminates many of the uncertainties found during the construction phase since they can be found during the design phase of the project and fixed so they do not occur during the actual construction phase. Also, any changes during construction will be automatically updated to BIM and those changes will be made in the model. Modern BIM design tools go further. They define objects parametrically. That is, the objects are defined as parameters and relations to other objects, so that if a related object changes, this one will also'.

7.1.2.1 Building Information Modelling (AIA)

'Building information modeling covers geometry, spatial relationships, light analysis, geographic information, quantities and properties of building components (for example manufacturers' details). BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. Quantities and shared properties of materials can be extracted easily. Scopes of work can be isolated and defined. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities. Dynamic information of the building, such as sensor measurements and control signals from the building systems, can also be incorporated within BIM to support analysis of building operation and maintenance (AIA 2012).

Under the guidance of a virtual design and construction project manager (VDC) BIM can be seen as a companion to Product Lifecycle Management (PLM), since it goes beyond geometry and addresses issues such as cost management, Project Management and provides a way to work concurrently on most aspects of building life cycle processes.

The American Institute of Architects has further defined BIM as 'a model-based technology linked with a database of project information', (AIA 2012) and this reflects the general reliance on database technology as the foundation. In the future, structured text documents such as specifications may be able to be searched and linked to regional, national, and international standards'.

7.1.2.2 BuildingSMART Alliance

'A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward.'

http://www.buildingsmartalliance.org/index.php/nbims/about/

7.1.2.3 National BIM Standard (USA)

A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge *resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward.*

Creating the National Industry Standards, Building Information Modeling Deke Smith, FAIA, Executive Director, BuildingSMART Alliance October 2010

7.1.2.4 Deke Smith's Vision for BIM

'If, the following are true, that:

BIM is a true as-built, meaning the virtual model is an exact copy of the built project

BIM is used for pre-fabrication, meaning that the components and elements are sophisticated representing the building components and elements

BIM drives CNC equipment, meaning that machine code can drive the production

BIM will feed FM tools, meaning that there are life cycle elements included in the model

Codes' bodies accept models, meaning that the model can be digitally uploaded to the municipality, where it can be deciphered and accepted or rejected with related generated reports

Then:

Drawings will no longer be the media of choice' (QED - ed.).

Deke Smith, FAIA, Executive Director, BuildingSMART Alliance October 2010.

7.1.2.5 Demise of Paper as a Media

Ray Crotty similarly attacks the media of paper (Crotty 2012a) with invective, where he says:

'...with drawings, no matter how detailed you get, you can only say approximately what you mean or intend. You depend upon the person at the other end of the conversation to complete the picture, to read your drawing correctly, and to understand it fully. And no matter how much effort you put into it, your drawings will never be unambiguously clear, fully complete, correct, internally consistent, and coordinated with other people's related documentation. With drawings, this is simply not possible. So huge numbers of people throughout the industry spend inordinate amounts of their time checking information, guessing the true intent, getting it wrong, correcting things, making mistakes, cutting stuff out … kango hammers. All because the only way we have of designing buildings is with drawings - which produce inherently untrustworthy, unintelligent, un-computable information'.

7.1.2.6 Association of General Contractors Policy (USA):

'…Any trade that does not want to be included in the model goes last, after all else is complete…'

7.1.2.7 Metadata

The label printed on a tinned can is in fact metadata, showing: brand, type of product, flavour, ingredients, expiration date, etc. This has an importance to BIM where the data can condition and rate the handed-over model, so that the receiver has an idea of what is being received (like reading the tin can before buying it at the supermarket). This:

- Improving confidence in information
- Knowing who, what, when, why, info quality, etc.
- Identifying level of detail
- Identifying authoritative source
- Reduces redundant data collection
- Facilitates flow of information
- Identifies intellectual property
- Reduces litigation

Information Assurance is critical in order for Metadata to work

7.1.2.8 How much does it cost not to do BIM?

- Recollecting data, means double work amassing the data in parallel, a second time
- Unavailable data, means break downs in communication
- Lost operations time spent tending to the first two items
- Premature mechanical failure due to not testing or analysing operations first
- Performance inconsistencies between design and operations (saw tooth knowledge drops at hand-over).

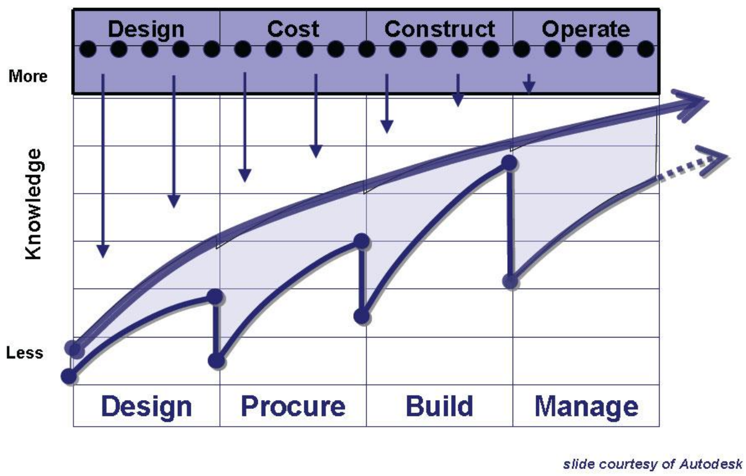


Figure 1. Saw Tooth Knowledge Drop. Courtesy of Autodesk

- Change orders due to conflicts due to not resolving the issues earlier in the design process
- Owner disillusionment can arise that requires modifications, due to misunderstandings about their expectations and anticipations.

7.1.2.9 Open Standards, AIA (USA)

AIA Policy Statement:

'The AIA believes that all industry-supporting software must facilitate, not inhibit, project planning, design, construction, commissioning and lifecycle management. This software must support non-proprietary, open standards for auditable information exchange and allow for confident information exchanges across applications and across time. This is best accomplished through professional, public- and private sector adoption of open standards. The AIA encourages its members and other industry organizations to assume a leadership role in the ongoing development of open standards.' (Approved December 2009)

7.1.3 International Facility Management Association

'The integration of processes, within an organization, to maintain and develop the agreed services, which support and improve the effectiveness of its primary activities.

Facilities Management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology' (IFMA 2012).

7.1.3.1 Construction Operations Building Information Exchange (COBie)

'With regard to BIM & FM, the objective of the Construction Operations Building Information Exchange (COBie) project is to create an open standard through which information created during design and construction can be transferred directly to facility operators, maintainers and managers in useable electronic format.'

Kurt Maldovan - Jacobs Architecture & Engineering.

7.1.3.2 Whole Building Design Guide (WBDG)

The Whole Building Design Guide states that:

'Today, most contracts require the handover of paper documents containing equipment lists, product data sheets, warranties, spare part lists, preventive maintenance schedules, and other information. This information is essential to support the operations, maintenance, and the management of the facilities assets by the owner and/or property manager.'

Rather appropriately, it then cites that:

'Gathering this information at the end of the job, (today's standard practice), is expensive, since most of the information has to be recreated from information created earlier. COBie simplifies the work required to capture and record project-handover data.'

COBie's approach is to harvest this data when it is being created, during design, construction, and commissioning. Given that different parties, use different kinds of software, and differing methods of presentation means that it can be a laborious process collating the many formats. This means that COBie is very versatile and simple in that it held in a spreadsheet. (East 2010).

7.1.4 Construction Delivery Systems

'The advantages of BIM over the traditional design and construction process are significant (Slutzky 2008). BIM single data entry into one model avoids the opportunity for inconsistency and error of repeated input of identical data in multiple media. Data once entered or altered is available in the single current model available to all.

- *BIM design efficiency reduces the cost of design and preparing contract documents.*
- *BIM base information is uniform and shared with all participants.*
- *BIM three dimensionality and software identify physical conflicts between elements reducing significant construction delay, and extraordinary additional expense. Where modifications are suggested, the impact of the proposed changes is immediately apparent, subject to evaluation and reconsideration.*
- *BIM three dimensionality assists in sequencing and constructability reviews.*
- *Confidence in shop drawing and fabrication accuracy is improved by BIM because the model can provide construction details and fabrication information. More materials can be fabricated more economically off site under optimal conditions due to the confidence in the accuracy of the fabrication.*
- *BIM can link information to quantify materials, size and area estimates, productivity, material costs and related cost information.*
- *Overall, the BIM digital model becomes a rehearsal of construction and can help identify conflicts and their resolution before actual construction dollars are spent.'*

7.1.5 COBie Process Mapping

'Identify Submittal Requirements

- *Create Submittal Log*
- *Update Submittal Log*

Define Submittal Schedule

- *Add scheduled dates to submittal log*

Transmit Submittal

- *Prepare Contractor submittal*
- *Prepare and transmit 'tiered' submittal*

Approve Submittal

- *Owner Review/Selection*
- *Designer Approval*

Install Equipment

- *Commission Equipment*
- *Commission System*

Provide Warranty

- *Provide Spare Parts Sources*
- *Transmit Handover Information'*

(COBie)

While some of these definitions might seem irrelevant now, there purpose will become apparent in the following discourse. What they provide here is a continuity through the many changing developments that both the scope and very kernel of the industry is going through. But first, there must be a return to the source of this upheaval.

7.2 A Driving Desire for Change

Two major reports from the nineties in the UK set the scene, which began the reforms and mapped the process to change the construction industry both nationally and with increasing influence across the globe. The first, *'Constructing the Team'* by Latham, a former Conservative MP, recommended a need for better standards in construction contracts at a time when there was little or no cross platform uniformity. He called for better guidance on best practices and legislative changes towards arbitration in an attempt to change industry practices, '*to increase efficiency and to replace the bureaucratic, wasteful, adversarial atmosphere prevalent in most construction projects at the time'* (Latham 1994).

The report wished to delight clients (Latham's words) by promoting *openness, co-operation, trust, honesty, commitment and mutual understanding among team members*. Incredibly all of these aspirations have remained on the agenda right up until and including today. Finally, he identified and determined that efficiencies, especially in savings of the order of 30%, were possible over five years. In the report, he condemned existing industry practices as being *'ineffective, adversarial, fragmented, incapable of delivering for its customers'* and *'lacking respect for its employees'*. Even at this early stage, he urged reform in the industry and advocated partnering and collaboration by construction companies. He went on to say:

'Partnering includes the concepts of teamwork between supplier and client, and of total continuous improvement. It requires openness between the parties, ready acceptance of new ideas, trust and perceived mutual benefit' and *'Partnering arrangements are also beneficial between firms'* without becoming *'cosy' (sic).*

Of the recommendations in the report, the two most notable with reference to this research include:

'The use of co-ordinated project information should be a contractual requirement'.

'The role and duties of project managers requires to be more clearly defined'.

Following on from this seminal report came the Egan (former chief of Jaguar) Report, *'Rethinking Construction'* (Egan 1998), which identified five *'drivers'* to improve in construction practices:

- Committed leadership
- A focus on the customer
- Integrated processes and teams
- A quality driven agenda
- Commitment to people

A further four processes were identified where it was recommended that they should be significantly improved:

- Product development
- Project implementation
- Partnering the supply chain
- Production of components

Finally, there was a call for a set of targets to be improved with respective quantities for the improvements:

- Capital cost were to be reduced by 10%
- Construction time was to be reduced by 10%
- Predictability was to be increased by 20%
- Defects were to be reduced by 20%
- Accidents were to be reduced by 20%
- Productivity was to be increased by 10%
- Turnover and profits were to be increased by 10%

There was also a call for decent and safe working conditions, whilst improving management and supervisory skills. This was coupled together with long-term relationships based on clear measurement of performance and sustained improvements in quality and efficiency. That this has been so successfully undertaken with regard to health and safety shows that with the right legislation it is achievable. The best embodiment of these works and the culmination of Egan's work could be said to be encapsulated in the new Terminal 5 at Heathrow, opened on 27th March 2008. Egan, chief executive of BAA, commissioned the terminal and implemented the *'Terminal 5 Agreement and the Delivery Team Handbook'* (Haste 2002).

Otherwise the SPICE project (Structured Process Improvement for Construction Enterprises) in trying to meet the challenges of the Latham and Egan reports, looked at addressing the issues that the industry has poor methods on which to base improvement. Because of the absence of guidelines, benefits cannot be adopted across the board. For any work that has been done in these areas, it is difficult to assess the improvements or resources appropriately. This ultimately means it is not possible to benchmark or measure performance across organisations.

'BIM and Construction Management' by Hardin is a very practical oriented book (Hardin 2009). The sub title *'Proven Tools, Methods and Workflows'* is essentially, what it delivers. It presents an array of practical information, aimed at the user. It has tried and tested methods of binding the 3D *geometry* with the fourth dimension (*time*) together with the fifth dimension (identified as *resources*), which can be assembled together in programmes such as NavisWorks. Here clashes and collisions, as well as timeline monitoring can be mapped and resolved before becoming an on-site problem, as was the case traditionally.

Hardin discusses the parameters of management, preconstruction, construction, administration, sustainability and Facilities Management. Indeed, this is one of the first publications where FM is seen in practice as an intrinsic part of the building process (life cycle assessment), which now is a critical part of the whole process. The total integration is also well documented, where he shows that he is indeed on top of where the whole process is going. As can well be imagined, the integration of these differing technologies into the traditional work phases is new and can be daunting. Hardin gives step-by-step guidance in a straightforward manner.

A complementary publication *'BIM Handbook, a Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors'* by Eastman, Teicholz, Sacks and Liston covers all aspects of BIM, from theory to practice, for all stakeholders, including a look at the future together with a selection of case studies to illustrate the work and identify good practices (Eastman, Teicholz et al. 2008). It can be read from cover to cover or dipped into for relevant chapters or sections. It is a comprehensive collection of knowledge on this relatively new approach to design, construction and Facilities Management.

While strong in areas of life cycle assessment and contractor involvement, it is weak in that it fails to identify just how the collaboration that is critical to the process is achieved and maintained. But it does correctly identify the two main drivers of client demand and productivity gains that we can see becoming mainstream in the next few years. It also sees the lack of trained personnel as the biggest barrier to adoption.

Following Eastman, Smith's book *'Building Information Modeling, A Strategic Implementation Guide for Architects, Engineers, Constructors and Real Estate Asset Managers'* (Smith, Tardif 2009) provides a more strategic coverage of the implementation of BIM. These cultural changes include building trust and mitigating risk, which Eastman does not address as comprehensively. Also, FM and LCA feature more prominently giving the book more purpose, it also is not afraid to name names such as BuildingSMART and FIATTECH to make its point.

In the seminal publication *'BIG BIM little bim, The Practical Approach to Building Information Modeling'* by Jernigan, great emphasis is placed of the process and culture rather than the technology and software (Jernigan 2007). That said, it stresses the importance of the guidance aspect associated with BIM and how the process is actually delivered. It identifies four phases for integration, *initiate*, *design*, *construct* and *manage*, with *certainty* as its mantra. It is firmly based in the design team issues, rather than the wider contractor and sub-contractor benefits or the life cycle issues for owners.

Life Cycle Assessment (LCA) and sustainability are addressed by Krygiel and Nies in *'Green BIM, The Successful Sustainable Design with Building Information Modeling'* (Krygiel, Nies 2008). Notwithstanding the focus on sustainability, it goes deeply into the underlying issues of BIM, IPD and methodologies before delving into sustainable forms and systems. These are addressed with orientation, massing and daylighting for the questions of form, with water harvesting, energy modelling, renewal energy and sustainable materials for the systematic side of things.

In conclusion, they call for:

- more interoperability between software packages which is seen as a great drawback (currently)
- more input from the designer in the modelling
- a call for a carbon counting method in the form of a dashboard on the fly through the design phase

- more immediate responses to calculations of rain water to roof areas, window to wall ratios, and
- better interactivity with climate data, all of which is eminently available now and possible because BIM is essentially a database

Taking perhaps a more managerial approach, Elvin places the emphasis on the benefits and cultural change required to effect collaboration, in *'Integrated Practice in Architecture, Mastering Design-Build, Fast-Track, and Building Information Modeling'* (Elvin 2007). The book remains solely in the architectural domain and does not venture into the whole supple chain. Its ethos can be seen in the American Institute of Architects' (AIA) stance where architects see integration as belonging in their function as the natural team leader.

This is also taken up with *'Design Management for Architects'* by Emmitt, who looks at the broader picture and makes the case for architects retaking the role as the managers (Emmitt 2007). Coupled with this is *'Architectural Management'* by Emmitt, Prins and den Otter, which documents the added value from good management, both in design, communication, integrity, practice and education (Emmitt, Prins et al. 2009). Critically Emmitt laments the level of management undertaken at schools of architecture and comments on the knock on effects such will have. This is dealt with later in the chapter on education and its impact.

Predating digitalisation, in its scope presented here, Winch provided some useful insights into the politics (small *'p'*), of collaboration and large project consortia in his book, *'Managing Construction Projects'* (Winch 2002). There is good account of the roles and how they dovetail with each other. Vignettes are drawn of how real projects developed through the roller coaster modes of management back then, in a matter of fact documentary style, highlighting, for want of a better word, the need for the change that the industry is now experiencing.

Finally, collaborative relationships, both in contractual frameworks, conceptual frameworks and through networking, are well covered in *'Collaborative Relationships in Construction, developing frameworks & networks'* by Smyth and Pryke. Smyth starts by saying value is added to projects through people, and this drives the remainder of the work. While acknowledging *traditional methods*, as well as *information processing* and *functional management* the basis of the book explores relationship approaches. This opens a socio-psychological perspective, which drew me beyond my first boundaries for this research. It takes partnering further than before laying the groundwork for longer-term relationships. It takes the roles further than being project delimited, meaning that people are beginning to look beyond single project handovers, wishing to build relationships where there is trust, and where they use each other for what they best suited, while sharing and reaping the many benefits of such illicit affaires (Smyth, Pryke 2008).

The book refers back to Terminal 5 and much of the work draws from what happened there. It explores new ways of collaboration, with emphasis on the trusting element that is necessary in any relationship. Indeed, it is like a formalised speed dating session where both, or all parties, need to establish their credentials, together with a method of finding how compatible they are with each other and also finding ways of linking like-with-like so that there is not an imbalance in the relationships formed.

In terms of papers, reports and other research numerous texts come to mind. I have grouped them under phases. The first phase happened when BIM first formalised itself broadly speaking with Jerry Laiserin first coining the term in his letters column *'Comparing Pommes and Naranjas'* (Laiserin 2002a). He notes having lengthy discussions in getting the two top weights, Autodesk and Bentley to agree on the common term BIM as a generic term similar to CAD. The same series notes the development and strategy of Autodesk viewing Revit as the obvious platform for the building Industry, saying: *'...Revit is Autodesk's strategic authoring application and platform going forward for building information modeling and the building industry'* (Laiserin 2002b).

As the software houses developed their programmes one of the first major pushes outside their remit saw the American Institute of Architects (AIA) devote a whole conference to BIM and its impact on the profession in 2006. They gathered the researchers of the intervening years and presented a new pan-cultural view of changes in the architectural profession. The previous year Norman Strong chaired an Integrated Practice Strategic Working Group which lead the charge for the adoption of integrated practice as the primary emerging issue for the AIA board in 2006 (Broshar, Strong et al. 2006).

Notably they wrote:

> *'Imagine a world where all communications throughout the process are clear, concise, open, transparent, and trusting; where designers have full understanding of the ramifications of their decisions at the time the decisions are made; where facilities managers, end users, contractors and suppliers are all involved at the start of the design process; where processes are outcome driven and decisions are not made solely on first cost basis; where risk and reward are value-based, appropriately balanced among all team members over the life of a project; and where the profession delivers higher quality design that is sustainable and responsive. This is the future perfect vision of Integrated Practice'.*

They pointed to the shift from a linear perspective to virtual modeling and they sought to define its impact on the relation between the logic of representation and the logic of construction. Thom Mayne was even more forthright or damning with his paper *'Change or Perish'* (Mayne 2006) where he starkly stated to the delegates to prepare for a profession that they would not recognise in ten years time.

Eastman pointed to two enabling technologies *parametric modelling* and *building data models* in *'University and Industry Research in Support of BIM'* (Eastman 2006). Significantly, Jonassen in *'Changing Business Models in BIM-driven Integrated Practice'* foresaw the need for a new role, a model manager (Jonassen 2006). He addressed owner discontent, cost over runs and improvements in building information modelling. He saw a new approach to building delivery *(note: the term 'integrated practice' was to become 'integrated project delivery')* integrating design and construction, while entertaining enterprise operations to improve quality, productivity and safety, to reduce the cost and time of project delivery.

In *'Roadmap for Integration'* the ever increasing consumption of water, raw materials, fossil fuels and other non-renewables was tackled as eroding the global environment faster than it could be replenished (Lesniewski, Krygiel et al. 2006). In *'Suggestions for an Integrative Education'*, a call was made for radically changing education *'to shape the trajectory of exploration after graduation'*.

Kimon Onuma painted a picture of the architect in the 21st century being transformed by process rather than software (Onuma 2006) and so improving value to clients in *'The twenty-first Century Practitioner'*. Joseph Burns saw standardisation opening the door to allow analysis of designs at an early stage reducing re-work, and enabling sharing (Burns 2006).

'Technology, Process Improvement, and Culture Change' stressed BIM is not a new drafting tool (Bedrick, Rinella 2006), as well as noting the need for cultural change. *'International Developments'* drew attention to the global nature of architecture (Howell 2006) whether it is sourcing materials, or working across borders either physically with worldwide offices or global commissions.

Finally, life cycle assessment is dealt with in *'Information for the Facility Life Cycle'* by establishing an overall facility lifecycle information strategy as well as methods to determine the handover, develop the handover and implement the handover (Fallon, Hagan 2006) in a way that uses the metadata that is now being generated.

These ten papers plus the introduction were to drive the AIA's focus substantially in the future, the following year the terminology changed or developed slightly giving us today what is called Integrated Project Delivery (IPD). Their 2007 conference in

California began addressing methods with *'what, why and how'* and great stress was placed on achieving IPD (Eckblad, Rubel et al. 2007).

Figure 2 10 Reports on Integrated Practice, at the AIA Convention Las Vegas 2006

7.3 The Practicalities of Integrating Drawing Operations

The practicalities of integrating drawing operations are instrumental in adopting BIM. Initially, of the three objectives in this work this was seen as the embodiment of the thesis:

> *'To study the practicalities of integrating drawing operations and design processes within database-controlled programmes, including a mapping of overall process against individual responsibility, training, data reliability and risk'.*

Now the sands of time have moved and the focus is not so much on the drawing per se as modelling. *'Sadly, pencil and paper is no longer centre in the creative act'* but *'computer generated imagery goes beyond the image on paper; (with) its ability to be displayed and distributed ad infinitum...'* (Dunlop, Scott 2010). Both are a form of abstraction and in that, there is relevance, but it is interesting to map this progression in such a short space of time.

Traditionally the drawing office produced the drawings from which the building was made along with specifications, schedules and quantities. The management, leadership and/or project co-ordinator, usually an architect, integrated these tasks and administered the contract to procure the building. The drawing process would be executed along the lines of work stages, resulting in remuneration packages for reaching milestones along the process.

The work stages also reflected the movement from the conceptual sketches through to the specific details required to screw the building together, as demonstrated in the use of levels of scale across the drawing set, starting with large scales to capture the overall drawings right down to the small scale (even one to one) to represent the tiny details. Parallel to this the written documentation would follow similar lines, and a package would be produced for tendering which would provide the basis for delivering the building.

7.4 Historical Context of Design Content & Form

Christopher Alexander, in *'Notes on the Synthesis of Form'*, describes three scenarios of designing content and form (Alexander 1964). The first occurs in unselfconscious societies where the building process has remained unchanged through many generations. In this situation the content relates directly to the form, since the person building it lives in it. This invariably means that the community has established fixed workable solutions. The situation requires no formal plans or abstracted sets of codified instructions, because methods are handed down from generation to generation without change or development.

Examples of this can readily be seen in primitive tribes and even in traditional vernacular regionalism.

The second scenario happens when artisans or craftsmen emerge to do specific tasks within the community. Since it is not *their house,* repairs and chances for mistakes become possible. This is because there is a distinction between *the doer* and *the user*. Now that there are two or more parties there has to be a chain of command resulting in a handover of requirements. Depending on the competences of those involved there has to be a set of codified instructions, even if at a primitive level. The formal nature of this situation opens up the possibility of mistakes or errors. This is not due to any lack of quality in the work but largely because of the increase in the magnitude and complexity of the work. Alexander sees this as a semi-conscious state where the way the work is done is through an image of the content required together with an image of the form delivered. It is akin to the movement from word of mouth to the written word.

The last scenario is a formalisation of this process where the images are formalised (a formal image of content and a formal image of form) so that they can be better recognised and controlled. This is the fully conscious state and the building industry essentially endorses this method with formal procedures for checking and controlling the work that procures a house or whatever.

Once the act of *'drawing'* was formalised, its growth possibly blossomed with the Renaissance where there is complete separation between the drawing and the project on site. But unlike the Gothic era, just previous to this, the drawings began to be instances rather than types of the projects, and this abstraction saw developments in proportion and perspective. Even the term Gothic is seen as derogative with Banister Fletcher citing Giorgio Vasari using the term as rude and barbaric back in the 1530's (Wikipedia contributors 2010c). This discourse continues right up to the modern movement where there is a close dialogue, and stark delimitation, between the architect and the craftsman through defined boundaries and clear expectations, culminating with nineteenth century *catalogue-type* building parts.

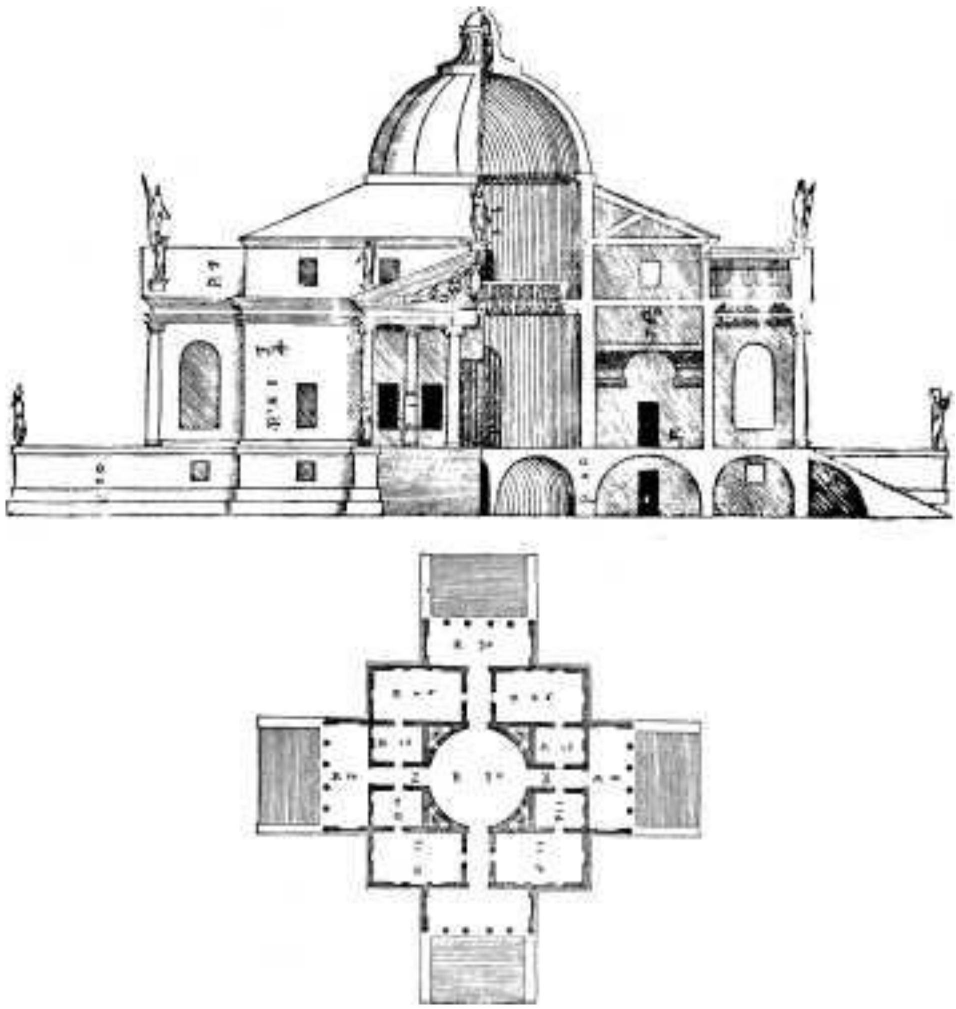


Figure 3 Villa Capra "La Rotonda", by Palladio 1591

With the Modern Movement, and new materials like reinforced concrete and steel, this lineage was broken. Increasingly the know-how that was part of the apprenticeship served by all craftsmen moved from the building site into the drawing office where the draughtsmen began defining what, and how they wanted buildings made (Barrett 2010).

Another twist happened with the introduction of CAD into the drawing office after the first oil crisis of the seventies, a fission occurred between the management and the technical staff where there was no appreciation of how digital draughting was being applied, and the seeds of mistrust were sown. There was also a challenge for senior design team members in implementing new design technologies and adopting new practices (Eastman, Teicholz et al. 2008). It took nearly a generation to heal this gulf but arguably, now it is being usurped by BIM (Eastman, Teicholz et al. 2008, Tse, Wong et al. 2008).

This can be seen with the various parties working together to produce a building. Previously light tables would be used to correlate the various tasks, or more recently, overlays of digital drawings could provide a method for formalising the process being undertaken. Both methods involved the checking and cross checking of other disciplines work, with the appropriate action being taken to harmonise and synchronise the work.

But the light table does not even feature in the cartoon industry today and like the balls of twine that quantity surveyors used to take-off measurements are long consigned to the trashcan. More common is the emergence of technical meetings now occurring on site, often in parallel with the architect’s site visit, but chaired and run by technologists. These usually comprise of the sub-contractor and the technologist who puts the work into its context, as well as the sequencing and first/second fixes required to complete the work.

This situation means that much of the problem solving and rectifications occurred on site with the ramifications of architects' instructions, change orders and/or requests for information (AI's, CO's & RFI's) ensuring that the project was both late and over budget. Indeed, there festered a culture of bidding low, with aggressive litigation to drive costs up and delay handover, which goes beyond the scope of this work.

7.4.1 The Abolition of Mandatory Fee Scales

As long ago as the 1980's Philip Bennett writing on *'Architectural Practice and Procedure'* for (Bennett 1981) painted a wholesome picture of the architect in full command at the helm of building procurement. If you wanted a building, you appointed an architect. The architect established the design team, tendered the work and administered the contract.

At that time most architectural institutional codes of professional practice (RIBA for example) forbid competition between architects for work. This had the professional ethic of presenting a solid front to the public that upon becoming a member, professional capabilities were guaranteed and certain standards assured through a code of conduct or similar. The market (in the mid eighties) in challenging this alleged monopoly forced the introduction of competitive fee tendering for appointments.

While appearing straightforward in its consequences it also had the effect of polarising practices into specialisation and niche markets. For example if a firm had several hospital designs under its belt, it had earned a reputation that it could use to its advantage when fighting for the next contract. The image of a pipe smoking man on a high stool behind a mechanical draughting board, being able to switch from a house extension to a hypermarket master plan was over.

Ray Cecil in *'Professional Liability'* of about the same period bemoans the carving up of the architect's cake by the *'proliferation of consultants, each of whom has created an institute of association to protect and promote their interests'* (Cecil 1989). At that time these included quantity surveyors, various engineers, landscape architects, town planners, differing designers, as well as sanitary, security, fire, space, acoustic traffic lobbies etc… not to mention energy, environmental health and safety that we have today. He ends his work shrouded in gloom as to the prospect of the depleted architect's role in the future. Parallel to these developments has seen the emergence of project, construction, design managers and technologists (as distinct from technicians) who have also identified a wedge of this architect's rich fruitcake as being fair game.

Differing forms of contract from Design and Build to Partnering have also reinforced this situation. A traditional contract is becoming rarer and some would go so far as to say that architects might become marginalised, being hired in a sub-contractual role for a limited design package, removing or managing them as a perceived risk. So where has this shift come from and where is it going?

Partnering has existed in Denmark internationally since the 1990's and domestically since the millennium with about a hundred companies having first-hand experience. It is largely based on trust, dialogue and openness creating a shared culture with trust relationships having common goals, expectations, values, efficiency, innovation and quality. The biggest difference between partnering and IPD is that partnering works typically with short term alliances while IPD is for the longer term.

But that aside, large general contractors are increasingly taking the lead role in larger projects, assembling the procurement team and running the contract. Interesting too, many multinationals and branded companies are not buying and building their property portfolios, but rather they are commissioning space and leasing it so that they are not responsible for the maintenance and operations for which they otherwise would be liable. This means that there is a *de facto* inferred life cycle assessment being implemented, where the onus is back with the large contractor to provide a total enterprise solution. Here the market rather than legislation is driving the situation (Erkessousi 2010).

7.4.2 Pseudo Collaboration

There has often been lip service to collaboration and readily too (Smith D. K. 2009). There have also been very successful procurement teams with very successful building projects. But there has never been a repeatable mechanism to propagate and develop these relationships. The industry is noted for its fragmentation and even if the same disciplines or practices work together on subsequent or continued work, often the personnel can be switched out for whatever reasons meaning that the learning curve is jagged with drops in the acquired knowledge accumulated over the course of the project.

Furthermore, when requested to collaborate by the client (or out of good common sense) often there is no device to allow this to happen, meaning the adversarial nature of traditional contract and appointments hinder such co-operation. Sometimes it is seen as correct procedure to nay say and remain aloof from the proceedings, divorcing the commerce and the liberal art of building as mentioned earlier.

Cicmil and Marshall elaborate and clearly elucidate a scenario of pseudo collaboration, where a two-stage tender is hopelessly inadequate due to the intransience of the quantity surveyor (QS) in their perceived role of advisor to the client, and not a deliverer of the project. There is no mechanism in place to allow the QS to enter into a collaborative state with the main contractor and no desire to either (Cicmil 2005). In an earlier study Cartlidge probably summed it up best in a condemnation of the then relationship of QS's with clients, recommending *'...quantity surveyors must get inside the head of their clients'* (Cartlidge 2002).

In mapping new methods with a view to collaboration the AIA in their *'Integrated Project Delivery (IPD), What, Why and How'* (Eckblad, Rubel et al. 2007), draw attention to that in 2007 46% architects were unsure about improving current design and construction processes. Furthermore, there was a 27% misalignment between owners (88%) and architects (61%) concerning inflation in construction costs.

Later they presented a chart showing approximately two thirds of architects, engineers and owners had high or good levels of comfort working with each other, but that construction managers dropped to under 50% and were worse than contractors or sub-contractors. The inference here points to the comfort zone that the design team had nurtured for itself, leaving the construction manager to clean up after them, and be saddled with the blame.

7.4.3 Reducing Double Entry Work

For as long as deliverables remain in a printed-paper format (or even PDF) then the consequence and bottom line is double work. By this, I mean that when design team meetings, contractor site meetings and all in between happen with each participant providing paper copy then the recipe is for disaster. There are tendencies for open collaboration today, but there is also strong resistance too, with copyright and ownership being the main issues, along with payment and limitations to use (Williams 2009).

Traditionally the architect would sketch and scheme a design where the main disciplines would attend initial design review meetings and by and large reserve space in the grand order of things, so that when the dust settled on the architect's design they could be activated and slot into their respective roles (Shiratuddin 2003). This meant that when the architect had set the building out with grids, main arrangements and general form, the other consultants would take the drawing release set and set their own in-house draughting team to prepare a set of drawings reflecting their concerns. After due course another meeting would be held where all sets were co-ordinated, checking and cross checking each other's work.

Where a building type was well known or common this strategy had a strong possibility of success, but where some of the roles were new, risks would invariably arise. Also given that there are only so many plans, sections and elevations that can reasonably be taken of a building project, blind spots had a higher chance of occurrence. But also as the design progressed it was not uncommon that small changes due to building regulations or developments in the brief, that the engineers would delay or forego updating each amendment out of a sense of propriety.

Often these sets of drawings could be out of synchronisation for long periods, but this was largely acceptable by the team members, so long as they all remained on board. Projects often go through periods of inactivity due to the client, the authorities or any number of things and typically, when they become active again the jagged learning curve raises its head meaning that the collective memory was not as crisp as would be desirable.

Alternately, the scope of the building project might be beyond the competence of some of the team members giving rise to problems on site. Most notoriously, these are clashes and collisions of building elements or components occupying the same space. Less obvious are the sequencing and time-line, or order in which the building elements or components, are constructed. The logistics of when things arrive on site and are installed requires careful planning to avoid rework.

Boeing, the aviation company, is known to have commissioned a virtual robotic figure of human proportions in order to check accessibility for all assemblies in their planes (Gehry 2008). Finally, if a building was not rectangular then the risk of cramped spaces or changes in the behaviour of components was not tested. In general, all of these scenarios result from the abstraction of the building project to two-dimensional media. The virtual robotic figure was an attempt to address the geometrical issues but nothing more. The third dimension's impact was largely visualisation and as such treated poorly, and often outsourced as an extra.

7.4.4 Reducing Cross Referencing within Practices

The implementation of BIM, it is claimed, reduces the proportion of hours spent on construction documentation on any project. A skilled designer can realise the intent and detailing required, which results in much less third party support than previously sought (Eastman, Teicholz et al. 2008). *'Details, material selection and layouts need only defined once and can be propagated to all drawings...'*, where for example the biggest saving was in billable project hours for an intern architect from 320 hours to 96 resulting, resulting in a -233% change in demand.

Reverse engineering this statement, it is arguable that the development and production of a project consumed many hours in cross-referencing work. It is something that is continually being addressed within firms, usually by building teams that comprise of people that are good at a particular role or thing, and keeping them locked in that role or process.

To reduce the cross referencing in practice several issues need to be resolved, some are to use the carrot and offer professional services compensation, to offer project delivery performance incentives and/or business enterprise performance optimisation incentives. By doing this mutual respect and trust can be nurtured, benefits and reward can be encouraged, more collaboration comes into the innovations and decision-making.

Once primed and underway there can be earlier involvement of key participants, earlier goal definitions, intensified by early planning, more open communication opening the way for appropriate technologies and better informed leadership. In a survey (conducted by the AIA in 2008), respondents were asked to prioritise issues seen as barriers to adoption of IPD. The *'experienced'* in IPD methodologies compared to those categorised simply as *'knowledgeable'* expressed less concern about the barriers to adoption. These findings suggests that the *'actual risks'* associated with IPD are less significant than the *'perceived risks'* expressed by those who are not fully committed.

Finally, George Miller argues that to reduce these barriers, one should consider a facilitator or an outside catalyst. If it is difficult to break away from the historically adversarial behaviours typically found in the design and construction industry then such an adjunct consultant might smooth the transition over. Such a facilitator might be of great use to teams, trying to ease away traditional boundaries and enhance collaboration (Miller, Suehiro et al. 2008).

7.4.5 Reducing Checking and Rechecking of other Consultant's Work

Once your own house is in order, the next step is to find likeminded neighbours. Much the same process that was described in the previous section applies equally here and even more so, because between practices it is more difficult to enforce or encourage adherence or coherence. The risk factor is considerably higher because all parties are working at risk, meaning ultimately they inextricably depend on each other. If the whole portfolio of a firm was so exposed, it could jeopardise the firm’s existence, in a weakest link scenario.

Traditionally tendering for work, or prequalification, meant setting manpower and resources against the job in hand. In splendid isolation with disregard to the other teams, a conservative estimate was usually put forward. This meant that if changes occurred during procurement, with a model being initiated and passed around, then clearly the same manning was not required and the project is consequently over manned. Rather than reducing the commitment pro-rata often there was an attempt to bully or bluff the client into accepting the agreed manning levels and paying out on the pre-planned mobilisation. Such a situation was usually sold with guarantees of compliance and cohesion, and the extra manning was then set to checking and cross checking as per usual.

This is a self-perpetuating vicious circle, which encourages the project architect, or engineer to repeat the exercise next time there is a bidding process. It provides work for the firm and meets in-house manning targets and expectations. It will only be when the client demands a BIM model and collaboration that these tendencies will die out. A point I shall return to, is that the professions in these situations are happy with the status quo, and do not necessarily see the need for change.

Text Box 2 Acceptable Levels of Engagement in Architectural Competitions

Recently one of my students returned from his internship where one of his assignments was to pull a competition project together from various sources and media. Being a competition, one condition was the submission of an IFC model so that they could be compared with the assessors' own criteria. Incidentally, this is appearing more regularly in architectural competition briefs, precisely because the assessor panel can now check for complex briefing requirements and do so with confidence of compliance.

The work had involved two architects working on the CAD plan layouts in Autocad, and another two working on the facades in another programme, Rhino. It was quickly discovered that nothing matched up. The floor plans on each floor did not line up. The facades did not relate to the floor plans meaning a best estimate had to be made. Once completed the project architect was informed that the overall area was closer to 40,000 m² rather than the specified 35,000 m².

This was greeted with *'...we thought that we were a little over...'* followed by *'...are you sure…'* and *'...how did you get that so quick?'*

In the student's own words:

> *'...And I did what was possible to reduce the areas in the model by maximising cut-outs for stairs and atriums and the facade was only drawn showing the first layer of the double skin. They then spent a day or two trimming and reshaping the design, which I then updated in a couple hours and gave them new numbers, which were finally trimmed down to just under 38,000 m².*
>
> *After showing the head architect what they could extract from the IFC model, he told me that up to 5% over was acceptable and in the old days they would just lie about it and the real areas would get updated in the next phase if they won the competition but because of this IFC they would have to justify the excess area in the text, which was done very eloquently explaining that the client was actually getting extra m² for free as the overall budget was still being held.*
>
> *I was also able to point out that the facades the architects were working on in Rhino didn't related at all to the programmed floor plans and the building was also over the height limit by a couple of meters, the height thing we could worry about later which we did by me removing 1.5 meters from one of the levels in the model.*
>
> *After giving up trying to get the Revit model to match the Rhino model with the stepped and angled facade and trying to convince them that there was a problem with the facades, a model in solid Perspex was ordered using the Rhino model when it arrived it turned out to be missing 1 floor which explained why I couldn't get it to match and a new model was promptly ordered...oops.'*

This starkly demonstrates how multiple models from several sources can compound a complex situation. It also shows entrenched attitudes and a lackadaisical regard for the brief and deliverables. During the design process there were among other things many meetings with the different engineering companies, responsible for energy calculation, structural analysis, cost estimation and service installations. During one such meeting, the discussion expanded a little, where the student incredulously questions the methods being used. There followed a frank discussion of the situation. He continues:

> *'I questioned one of the engineers, how they could do the Be06 (Danish Building Regulation for Energy Frame 2006) energy calculation when the final form, facade construction and much more was still unknown, to which he replied that Be06 was such a simplified calculation compared to LEED or BREEM that they could at almost any stage in the design do the calculation and get whatever result was wanted and document it convincingly.*
>
> *I was convinced of this as after sending all the area schedules of the facades, roofs and floors to the engineer for them to do the energy calculation. She called early the next morning asking if I had time to check through some of the areas with her against my model, which I did and found they were all correct. She then began asking if I was sure that the entire exterior was double glass and how many m² of solar panels she could place, as she was "still a long way from Class 1", and didn't*

know how to make this work. The head architect later spoke to the engineering company and I didn't hear from her again but the building came in just below Class 1 energy rated.

(There was) a similar situation with the cost estimation, again after sending all the schedules of walls, floors, doors, roofs etc to the company to make the cost calculation, I then had the engineer on the phone the next day checking if I was sure about all the amounts, as he was having serious problems holding the price with this amount of glass facade etc, and again the building came in just under the programmed budget.

Another interesting situation was after a very long meeting with the service engineers they expressed their opinion that a building of this complexity with labs and auditoriums and canteens and more would need at least double the amount of space for technical services as was specified in the programme, this area (around 2000 m²) was then distributed throughout the building which I then also placed accordingly and pointed out again that we were well over the max gross area, and after some long discussions with the lead architect most of the area was removed to bring us back to approx. 5% over, justified by the fact that it wasn't in the programme and the client has good advisors that are well aware that there will probably come large increases in the technical area required to make the building work and that could be worked out in the next phase.'

Reading between the lines it is very obvious that there is a protocol at work, where the design process is seen as learning curve or a familiarisation process as the players come to terms with the project. It is almost expected that it will cost more, be delayed and that the client will pick up the tab. The student then sums his experience up of the delivered project with:

'The IFC model was an approximation of the delivered floor plans and drawn as a gross area model but only to the first skin of a double facade with many differences to the delivered facade renderings and section drawings.

'The building was delivered with large shortfall in the technical services required to run it.'

'The building would require major work to meet the energy calculation that it was submitted with.'

'The building was well over budget but adjusted to work.'

'...And everyone seemed aware and comfortable with all of this – get the project first "there is always some redesign in the following phases"'

Admittedly, this is only my personal experience from one project that was particularly complex and pressed for time but I also had similar experiences later and heard similar stories from classmates so am sure it is not unusual. And in a market that is tight with a lot of pressure to win contracts clients are able to squeeze more than before but I believe they are only setting themselves up for large cost overruns.'

7.4.6 Reducing Human Errors

There are many ways of reducing human errors and prime among these is experience. But expecting clients to foot the bill for gaining experience is becoming a contentious topic (Barrett 2010). Actuaries mean that it would take fifteen years to train an architect with the resulting uproar of this being too long and unpalatable. Compromise is important as there will always be continuing practice development and so forth but another avenue is available, namely employing the same model. This reduces the double work, which is critical to addressing the shortcomings mentioned earlier, but a new mindset is required to implement it.

Collaboration not only reduces errors, but it also improves communication and understanding of the other roles in the procurement process (Ribeiro 2010). Traditionally this was achieved through light tables with tracing paper and overlays in CAD digital formats. Again only the material presented could be checked, meaning a more meaningful method was required. This is also reminiscent of the saw tooth knowledge drops incurred through a project when there are several handovers of information at design, procure, build and manage (Eckblad 2007).

7.4.7 Students & Practical Training

An allegorical tale is of a student, returning from practical training, at a young practice that had recently won a provincial town competition for a new public building in the town square. Essentially the project had no right angles, being an organic form, and the municipality made it a priority that there was complete disabled access in the winning scheme. In the first instance, it was modelled in Sketch-Up to satisfy the architects that the new situation met with their design criteria. This demonstrated a good knowledge of the relevant building regulations and their application.

Then it was modelled in ADT in order to demonstrate to the structural engineers that their A4 key junctions worked precisely and only where the section line had been chosen, but failed when it was moved a mere meter up or down from where it was taken. Close collaboration with the engineer ensured a pin-jointed solution could be employed resolving key parts of the building in the studio and not on site had the errors not been highlighted when they were.

This was one of the reasons for the school’s change to a modelling basis soon afterwards, in an attempt to minimise the number of programmes students’ needed to master. It is also an example of the technologist understanding both disciplines' modes of working and responding appropriately to both. Finally, it illustrated client requirements being assimilated and the solution being fittingly presented, by the technologist (student) none-the-less.

What this clearly demonstrates is the monolithic stance of the differing professions and the ability of the technologist to both understand and meet the professionals' stand-offs, while integrating their methods into a workable solution. This was pre-Revit days and involved geometry-based solutions only, the project indeed was complex. But it shows the interaction of the parties and their abject inability to work in 3D. Had the intern not highlighted the patent fault in the engineer's design so early in the project it would have caused bigger problems later. It shows also the engineer's non-committal stance at this stage of proceedings (waiting for the architect to table a more complete proposal).

7.4.8 Resolving Issues Earlier in the Design Process

The classic situation on a building site is the service person installing an air duct on the third floor that needs to go through a concrete beam. He calls the site hut and the site architect comes up to see for himself. He goes back to the site hut, resurrects the drawings for architect, engineer and services to see if this is indeed the case and if there is something to be answered. If there is a fault or blame to be apportioned the necessary paper work is set in train. If it is an oversight, all relevant parties are summoned either to an ad hoc meeting or it goes on the agenda of the next site meeting.

Either way the situation has to be resolved which means new work, a lot of paperwork with added costs and time delays. By the time a meeting can be arranged with all parties concerned a week can go by, by the time the blame is apportioned and the costs are distributed thousands can be added to the job. Something has got to give.

Architect's Instructions are mechanisms to issue further drawings, details and instructions beyond the documentation included in contract to cover unforeseen things during the building phase. They are conditions laid down to typically correct discrepancies in documents; comply with statutory requirements; correct setting out work; make good work, materials or goods not in accordance with the contract; exclude people from the site and so on (Bagnall, Brett-Jones et al. 1990).

The obvious antidote here would be to have better and more complete documentation before going on site. To resolve these issues a better way of finding and correcting mistakes is required. This takes us back to the minimalising double work and reducing human error. In one of the case studies (mentioned later) all the site excavations, foundations and basement work resulted in one AI being issued for one borehole that was missed. This was achieved with better tools and better collaboration earlier in the procurement phase. All parties have moved to better co-ordination of work with standardised methods of measurement and common classification systems, giving better schedules and specifications. But sharing the data, as is now possible with building information modelling, is not happening as quickly as it should given the tacit improvements it provides, and this raises many concerns.

7.4.9 New Interdisciplinary Collaborations

It is not unheard of for firms to amalgamate two or more disciplines in an effort to gain an advantage in bidding and delivering work. This could be architects and quantity surveyors or the many types of consulting engineers that we find, where the purpose is to remove potential barriers or internal conflicts to the procurement process (Smyth 2006, Smyth 2008). With new methods of tendering and partnering differing consortia often find it advantageous to come together on a project for project basis too. Prequalification means building up a track record in predefined core competences. There are many strategies at play and many responses.

Looking at RIBA's work stages and Plan of Work (RIBA 2007) many combinations of procurement are mentioned including; fully designed project with single stage tender or with design by contractor or specialist; design and build with single or two stage tender; partnering contracts; management contracts; public private partnerships and private finance initiatives. Within these options there are appointments and selections, input and output packages with requirements and proposals.

Depending on the size and complexity of the project there are a number of ways that its design and construction can be undertaken (Müller 1997). First, there is the traditional contract, using a standard form. It usually requires the contractor to carry out the construction according to the drawings and specification drawn up by the design team, where the work is supervised by the architect. Digitalisation in this context is a simple translation to the new media with little or no new input. All parties maintain their independence and retain their core competences.

With a fixed price contract the contractor agrees to construct the building as specified in the drawings and bills of quantities for an agreed sum, by an agreed date. It allows the contractor to claim additional costs for any variations to the specification. The allowance can also be claimed for an extension of time for delays beyond his control. It can be for the whole contract, a section of work or it can be applied to a unit rate, where the price is fixed but the amount of work is unknown. This is an area where contractors are fast becoming the drivers of the digitalisation process, with the Association of

General Contractors (AGC) in America recommending to their members not to bid on non-BIM work, or in the worst case to build their own model before bidding in order to have better control on estimates and processes (Young, Jones et al. 2008). This is a significant paradigm and a move that is changing the drivers of BIM adoption.

In AGC's own guide to BIM implementation, they blast the first two myths that BIM is only for large projects and large contracts (Ernstrom, Hanson et al. 2010). They identify the benefits in a no nonsense style mentioning collisions detection, visual communication, fewer errors, higher reliability, better *'what-if'* scenarios, better end product for clients and users and fewer call-backs meaning lower warranty costs.

A reimbursement contract is usually used in refurbishment work where it might be difficult to assess the cost of work, in which case it can be used to reimburse the contractor for the costs, plus a fee to cover overheads and profit. Digitalisation here beyond the previous method would be a checks and balance means to justify the costs. But laser scanning is also beginning to appear in this niche as a means of control, either at commencement of the works to record the existing work, or more dynamically as a regular or daily method to track the progress of the work against the virtual model. This is very advanced but with the development of GIS technologies this will push the augmented reality aspect of things, which will be mentioned later.

In design and build contracts, the contractor is responsible for the design, specification and the construction. It may be on a fixed price or cost reimbursement basis, which is either negotiated, or subject to tender. It is normally used for standard or repetitive building types, where the contractor has previous experience resulting in savings for the client. This is very appealing to digitalisation especially where there is duplicity of the building type with serial clients. The benefits and return on investment makes this very attractive for all involved.

Develop and construct contracts are similar where a design team is appointed to produce concept drawings prior to going out to tender. The advantage is that the developer is only dealing with one source who has sole responsibility for the project's design and construction. This means that there is an awareness of the financial commitment prior to the commencement of construction.

In management contracting, the design team specifies the building requirements and specialist sub-contractors are supervised and co-ordinated by the management contractor to carry out the construction. For this the management contractor receives a fee, which may be fixed or a percentage of the contract cost. It is generally used on complex projects that require a short contract period, which must have flexibility for modifications during construction. Digitalisation has a huge benefit in this fast track method but requires a highly motivated personnel and digitally competent team.

Sub-contractors can enter into contracts with the management contractor to carry out specific work, where it is the management contractor who has a contractual relationship, not the client. If any problems arise, it is the management contractor who must pursue for a remedy. Sub-contractors are normally appointed by competitive tendering based on the drawings and bills of quantities. For the contractor the biggest advantage here is that there are very few risks, as they are guaranteed a return of costs and they do not have the problems associated with the employment of labour. It is important for the project manager and quantity surveyor to control costs, since the management contractor has no incentive to control costs within the cost budget, although incentives can be introduced. For the developer work can begin as soon as the first few work packages are produced, so allowing design and construction to overlap.

The interesting part here is where the model is made available to the sub-contractor meaning the contractor has been given the model. This is rare at the time of writing but in isolated cases and pilot studies, sub-contractors were at first most reluctant to engage a model, citing all kinds of excuses ranging from beyond their scope to tried and trusted traditional methods. But having complied there was an watershed moment of *'how had they not been doing this sooner'*. I will return to this with reference to methods and programmes that are both relevant and applicable to their needs and capabilities.

Construction management is similar in most respects to management contracting except that the contracts are made with the client. The construction manager is employed to manage the construction work. This system is used mostly on large, specialist technical projects. The payback here is that the on-site phase can be carefully monitored and fine-tuned in the model, meaning that the model is as near as the built reality as possible, and is ready for hand over to the facilities managers upon completion. The real bonus here is project certainty both in terms of time and budget, and the continued relevance of the model under operations and maintenance.

Project management is also normally used on larger developments. It is becoming increasingly popular but more importantly it is reducing the architect's influence within the construction industry. The project manager can be an organisation or an individual, who guides the client through the procurement system, appointing the construction team and controlling the project. Usually appointed on a fee basis, it means he is not dependent on the cost of the contract. This tends to ensure that the project manager works solely in the client's interest, as he earns no commission. The potential here is that the divorcing of the architect and control of the job leaves the door open for a manager of sorts.

Whether the role is filled by someone from the construction industry or comes into the industry with pure management skills is up for debate but interestingly with regard to the building information model for which there is a need for the management of sharing, integrating, tracking, and maintaining data-sets, this offers the opportunity of a new and awesome task. This in a nutshell is one of the hypotheses of this work.

Partnering covers both Public Private Partnerships (PPP) and Private Finance Initiatives (PFI), which are special relationships between contracting parties in the design/construction industry (Erkessousi 2010). They positively encourage changes to traditional adversarial relationships to more co-operative, team based approaches. By this, they promote the achievement of mutually beneficial goals while also preventing major disputes.

Private Finance Initiative (PFI) is an arrangement where public sector assets and services are acquired through private sector funding, thus reducing government/public sector borrowing. It is a procedure where the public sector sponsors or establishes a business case strategy. In Europe, the project is then advertised in the Official Journal of European Union (OJEU). Through a prequalification process the bidders are then short-listed, a consortium is usually set-up specifically for the project, forming a Special Purpose Company (SPC). The contract can then be awarded.

It is usually financed by 10% from the company, with the remainder coming from the financial institutions. This is then recouped over the next 25-30 years from tolls or service charges upon completion. There is good potential for high returns, it gives continuity of work and offers involvement in the design phase. It means that it is highly buildable, because of the makeup of the stakeholders, and it offers more control over the programme than might be possible under traditional methods. On the down side are the initial bidding costs, which can also be long. It is a very competitive market tying up many resources initially, being also quite complex and demanding. Contract terms can also be very onerous and penalising, and it usually comes at a fixed price for the contractor.

Their main features require firm commitment from top management, encouraging continual improvement while also allowing time for the benefits to emerge. The basis for these mechanisms is to break the traditional mould, which engulfs the industry, and to provide a forum where new talent can showcase their worth. They are also based on the equality of all partners with an interest in mutual profitability. In total contrast from the traditional contract, they have free and open exchanges of information. This lends itself well to BIM and opens a bigger scenario called Integrated Project Delivery (IPD).

Not so obvious is that it tries to keep project teams together, which is done with well thought out incentive schemes. The top reason for this is that it reduces the learning curves that are otherwise necessary, while eliminating the saw tooth information drops through work phase handovers or similar. Great value is therefore placed on long-term relationships, and an environment for long-term profitability exists where overall performance can be improved.

With all parties seeking a win-win solution everyone understands that no one benefits from exploiting each other. Crucial to this process is the problem-resolving ethos that it engenders. By having mutual objectives, the door is open to consideration, as a concept, of each other's worth. Ironically, this was missing previously. Trust and openness is encouraged to openly address problems, so that innovation is embraced positively. Each partner becomes aware of the other’s needs, concerns, and objectives and is interested in helping to achieve this.

Prime in its objectives are improved efficiency, coupled with a reduction in costs. Dependable production quality then leads to speedier construction and more certain completion time. Longer-term benefits include better continuity of workload and a more reliable flow of design information.

The shared risk has both positive and negative connotations, to which I will return. In short, the team works much better together, but in contrast, one bad apple can turn the whole barrel. With the reduction in litigation, there is the knock on effect of lower legal costs and exposure. There is also a lessening or removal of large contingency sums, with better decision and problem solving systems. This in turn can equate to savings of approximately five percent on project costs, six percent for clients with profits of up to nine percent accruing according to Construct Site (Construction Site 2010).

Where problems do occur, derives largely from the fragmented nature of the construction industry, typically the low bid mentality or from corruption. At the other end of the scale are issues of intellectual property and complacency (Williams 2009).

7.5 The Practicalities of Design Processes within Database Controlled Programmes

7.5.1 Introduction

Donald Schön describes design as a problem resolving process, saying:

'Designers juggle variables, reconcile conflicting values, and manoeuvre around constraints: a process in which, although some design products may be superior to others, there are no unique right answers'.

He also has the classic line:

'I can tell you that there is something you need to know... But I cannot tell you what it is in a way you can now understand' (Schön 1987).

Basically, he is alluding to a nebulistic process where it is difficult to chart linearly what happens in order to design something, or that there are no two ways, which are the same.

For some it has a fuzzy logic, for others it can be a far crisper method, but most designers like the indefinable nature of design and the process, contributing to the elusiveness of the beast. I know this might be a generalism, but it is not within the scope of this work to establish design methods. But rather that in this situation it can be difficult to produce tools to expedite this special process. For some it can begin with a squiggle or an abstract form, for others it can be the rigour of an algorithm or the persistence or an algebraic formula.

But speaking as an architect, it is a process that needs a broad church as the initial concept needs to grow and encapsulate many foreign ideas, protocols and disciplines before it materialises into a finished building, while still retaining the guiding light or *raision d'être* of the spark that ignited the process. The ubiquitous pencil filled the role admirably as long as the two dimensional drawing was the standard method of media transfer.

As long as CAD remained the digitalisation of the pencil, (in that the lines that a pencil could draw became the lines that the program could replicate), there was little or no expansion of the process. But with the advent of BIM, the goal posts were effectively moved and a new criteria presented itself. This new paradigm is the introduction of the database.

A database is essentially an organised collection of information. It is usually digital, (since the arrival of computers), which are programmable devices that can store, manipulate and present output in a useful manner. It is this number crunching effect that is of interest, in that there is potential for great computations. Finith Jernigan quotes Denis Diderot (1713 - 1784): *'There are three principle means of acquiring knowledge;*

observation of nature, reflection and experimentation. Observation collects fact; reflection combines them and experimentation verifies the result of that combination' (Jernigan 2007).

So here we have a link from Daniel Schön's thoughts on the reflective nature and the ability to combine and/or experiment and that link is the ability to handle data, which should open a whole new panacea to the designer. Kimon Onuma is one who has embraced this exciting situation with his *'BIMstorms'* (a play on Brainstorms), where his motto is Keeping It Simple (Stupid) where data is taken and used (/reused) in various formats (Onuma 2010).

This is achievable using *'Cloud'* technology. The term cloud relates back to telephony where up until the 1990's telephone companies offered point to point connections. Then came Virtual Private Networks (VPN), which utilised the latent bandwidth more effectively and opened up new possibilities. The term is derived from the cloud diagrams that were used to fence the differing tasks and entities that were grouped together, showing that they could interact on a platform or network level.

The subsequent persuasiveness of the internet brought computing into this mix, which was first noted in 1997 by Ramnath Chellappa (Wikipedia contributors 2010a), where data could be centralised and equally important access controlled. While all this may sound daunting and even tangential to the design process, Onuma makes one compelling argument. One aspect of design is about *programme* and this is usually entails a long process of gathering information, setting out requirements and fulfilling demands. This can result in briefing documents of imposing size, (depending on the project) which need reading, interpreting and actioning. Often clients can have huge sets of demands, depending on branding, function or standards. The processing of this data can cause errors (human or whatever) through distribution and handling.

For example, think of the penetration or comprehensiveness of MacDonald's restaurants, Marriott Hotels or any other global brand. There are stated requirements for the chip fryers, the width around a king size bed, the colour of the ceramic tiles. Centralising the process removes many opportunities for mistakes and makes access much easier. It also makes revisions and improvements incredibly easier (compared with the longhand method, which could occupy whole divisions and incur militaristic rollout dates and timetabling).

A definition of *'Cloud'* could be:

> *'The storing and accessing of applications and computer data often through a Web browser rather than running installed software on your personal computer or office server*

> *Internet-based computing whereby information, IT resources, and software applications are provided to computers and mobile devices on-demand*
>
> *Using the Internet to access web-based applications, web services, and IT infrastructure as a service'*

In cloud computing, data and software are stored on servers; devices are then used to gain access to them through the internet. This has two huge impacts; the first is that files reside in one place and in one version. This has vast implications. The other is that the applications to run these files can also be run remotely, meaning that they do not need to be on the device and that they might only be leased on a need to use basis, and not licensed or paid for, whether used or not.

There are many similarities to what has happened in the music industry with Digital Rights Management (DRM). Here the major players initially tried to lock users in, first with location limits, so that releases could be controlled, and secondly with how many copies could be downloaded. Both these limitations seemed to reinforce the traditional market forces but what they failed to appreciate was the new wave of downloading, illegal or otherwise which just stymied the whole system. A new approach was needed and eventually arrived where today some mobile telephone contracts include a license to download, and the cost is inbuilt into the whole scenario. This was in response to the new generation, which does not want to pay for anything, or so we are led to believe.

What this shows is that a solution could be found and was found to appreciate the new times while acknowledging market forces. But this too has a remarkable impact on listeners of music today. Where is your collection, do you have the whole album, can you transfer it to other media, is it accessible beyond today's media? It also moves us a step closer to a situation where if the internet was shut off tomorrow, where is your music?

There are the old brigade who would relish such a situation, coming out on to the streets with their old gramophones and pieces of vinyl, to inveigle us with rasping grainy scratched versions of songs which are played analogically and not digitally. I recently bought a turntable with a USB stick with the idea of transferring all my golden oldies to digital par excellence. It was not pretty and the result was not acceptable, and I wondered how we put up with analogue’s shortcomings so long. We have moved on.

Such a regime can only occur with the upcoming cloud; very soon, people will wonder how they tolerated the old methods and will demand the ubiquitous service of the cloud. It will transform how we collate and record all of which we do. It will also have the legacy of being the most up-to-date and the single source of information. This means that it will be dependable and trustworthy, meaning people will become reliant on it and that it will be reliable.

There is an argument here where the cynical, spy an exposure and corrupting influence, which can be exploited and abused to others' benefit. But remember that the internet's existence is found on that very corner stone that means nobody is bigger than the internet and nobody can control or pervert the internet as it is. Or course there are viruses and phishing, which can con people, but the overall system is designed to survive man's best efforts.

Furthermore, according to the BBC, the days of the PC are numbered and this comes from one of the founding fathers of the IBM 5150, Dr Mark Dean, who sees it being replaced by the cloud (BBC News Tech 2011). PCs will go the way of typewriters, vinyl and vacuum tubes (valves), he says.

7.5.2 Databases and their Overwhelming Impact

The ancient Chinese proverb: *'Tell me, I forget. Show me, I remember. Involve me, I understand'* is still relevant today and when coupled with databases opens a whole new plethora of possibilities. Knowledge Management Systems (KMS) differ from other management systems in that the latter only stores and processes the information, whereas the former assists and elevates information to knowledge. This is done by collecting, processing, interpreting and distributing data in pertinent forms. In the right hands, this becomes intelligence. At this level, there is the *'explicit'* knowledge that can be extracted from the data, and the *'tacit'* knowledge that comes from the *'what-if'* scenarios that can be generated from the juxtaposing of these complex sets of data. This data can be interrogated and analysed in reports where the consequences of certain actions can be seen before they are committed (West 2001).

The relevance of these thoughts is that, drop a report on my desk and, I can forget its modus operandi. Furthermore, I am likely to not appreciate the procedure that generated it. Come with three options and I begin to see the ballpark and its parameters, which better informs my decision process. Give me the tools to generate these outcomes for myself and the best solution is guaranteed through this immersive process. Essentially, this is what databases bring to modelling. Having a beautiful drawing, and I have many, is a wonderful thing, but it stops there where the outcome of that drawing is the media itself. If it is to inspire or contribute to a process, it starts a new process, the continuity is broken and some of its intentions might be lost.

It has been formalised into many competence level descriptions with three levels of knowledge:

- Level 1: Knowledge and Understanding

- Level 2: Application of Knowledge
- Level 3: Reasoned Application of Knowledge

The synergy here is the combined effect of two or more forces, working together to create something better, than could have been achieved individually. Initially this argument was difficult to comprehend, largely because of its reach and scale. But with many things happening despite it, our everyday is being influenced more and more, day to day. We no longer use telephone directories, we do not remember telephone numbers. When someone rings us, his or her face appears on the screen not the number. The telephone number is gradually becoming a latent part of the communication process.

7.5.3 New Developments in Software and their Integration

Software houses are now producing programmes that are more intuitive and more interactive to the environment in which they find themselves. BIM opens new avenues before inception and long after completion of projects. A virtual model can help enormously with marketing and raising capital, it can aid leasing and renting or allay fears to relocated workforces, it can pacify worried neighbours and it can placate civil servants about densities and volumes. All this is long before the project enters the main development and design phases. In addition, it represents a good image of the proposed building.

As mentioned and as fully accepted it aids the procurement process but after completion, a relatively new professional body has emerged in the guise of Facilities Managers (FM). This is essentially operations and maintenance, but as any FM'er will go to great lengths to point out; it is not about changing light bulbs, but about managing the whole enterprise right up until decommissioning.

Even in decommissioning the virtual model will help in identifying how the building has been constructed and so how it can be deconstructed. So the humble virtual model has a life expectancy long before and long after the building procurement phase for which it is created. I should add at this point that cost check take-offs and other simulations (acoustics, lighting etc...) are possible allowing continual assessment throughout the process.

Clients are commissioning projects, which rely on a single building model (BIM) which holds all the data in one place and through which all modifications are made. Authorities are also making demands in this regard with the emergence of automatic building control systems. Facilities Management's input is to broaden the scope and influence of the design documentation to provide add-ons such as *'as-built'* drawings, fire documentation, furniture, fittings and equipment (FF & E) strategies, rental and leasing plans as well as running and maintenance calculations.

Building component producers are beginning to make smart building elements that adapt themselves to their situation (2D entities, 3D entities or spreadsheet data as required). Local authorities are asking pre-emptive questions (for example building heights in relation to other buildings; can the buildings be seen from a certain viewpoint; are they eyesores in the landscape, etc?). End-users are being allowed to view their new environs before they are built and are consulted in the design process so that their fears and demands are taken on board, and not for granted.

7.5.4 Overview of Integration of the Process

Integration of the design process can take many forms, but overall the critical path can be best demonstrated with the integration of an authoring tool, with a quantities extraction tool and a Gantt chart tool. One scenario would be (Autodesk) Revit Architecture with (Code Group) Sigma and (Microsoft) Project. This provides the 3D (geometry), the 5D (resources) and the 4D (time) that can be brought into a monitoring package like (Autodesk) Navisworks Manage. This allows control, certainty and confidence (Fong 2007) to develop right through the procurement process of the construction project (Hardin 2009).

Regarding the wider issues of Facilities Management (FM) and Life Cycle Assessments (LCA), which are predicted to be more critical to the design (Eastman, Teicholz et al. 2008), and which traditionally have fallen outside the procurement model, it is interesting to explore their inclusion within a BIM model. This is achieved using the potentially powerful *phase property* in the BIM software.

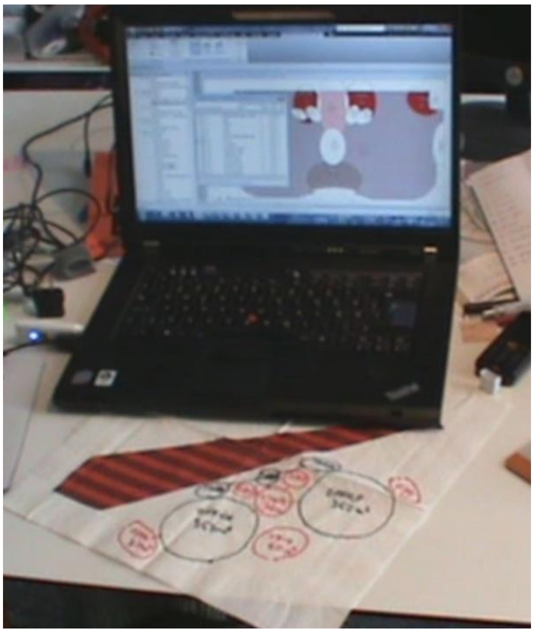


Figure 4 Transferring a bubble diagram into BIM

So starting with a functional bubble diagram sketched as an adjacency diagram, these notional forms can be entered into the model in the Appraisal stage. In theory, they are entered as *spaces* with *names* and *area tags* added, so that schedules can be extracted. They can then be measured against price books or other forms of cost calculations, for example incorporating high quality retail/commercial against a low weighted back of house services/storage areas or whatever, so that a balanced costed proposal can be prepared and delivered before any major decisions, architectural or otherwise, are taken.

This is achieved by placing a mass equivalent to the length, breadth and permissible height of the proposal, derived from client wishes, site restrictions or outline planning permission. The mass can accommodate levels, which will later become the floor plates. On to these the bubbles are placed. This is done by using *'Room Separation Lines'*, which can be drawn as circles and ovals. These shapes can then hold data, namely *'Room Names'* and *'Areas'*. Enlarging or decreasing the shapes allows approximate sizing so that a schedule can be extracted listing all the shapes with room names and areas. At this point, they can be exported to another programme like Sigma where the data can be manipulated with price books (like Spons) or reality norms to give an outline costing for approval by developers or stakeholders before the design is progressed.

Figure 5 RIBA Outline Plan of Work 2007

A feature under *'Manage'* called *'Phases'* allows this exercise to be archived into a work stage like RIBA's Plan of Work; Preparation, (A) Appraisal or (B) Design Brief (RIBA 2007). Because the phases are sequenced one after the other the model can hold them as separate entities, in real time and this is important. Moving into work stages (C) Concept, (D) Design Development and (E) Technical Design the project can be progressed where the first can be filtered using *'Views'* to highlight areas of interest for the client (C), the second can be the internal document of how the building is screwed together (D), and the last is filtered to show statutory fulfilments (E) (Conover 2006).

As the building takes form the bubbles created in the Appraisal phase can be brought over into the next phase. This is done by now replacing each space with a rectilinear separator, in the more conventional room manner and when the bubble is replaced the data jumps into the new data holder. More schedules can be extracted and exported to check that the previous work is still being adhered to and when ready each separator can have its properties upgraded first with generic walls and later with fully developed standard constructions.

It is at this point in the process that *'Type Codes'* must be introduced. There is a plug-in that links Sigma with Revit and under this *'Add-in'* there are *'Element Properties'*, which allows a code to be attached to each element in the model. These type codes can be generated from a classification system, such CI-SfB, Omnicodes, NBS or generated in-house depending on which price book is being used or how the estimate is to be prepared. It is these *'Type Codes'* that drive the integration and tag the data during the process.

Later at the tendering phase the main and sub-contractors may be given this bill of quantities, unpriced, as well as the model, in order to make their own bid. Free programmes such as Navisworks Freedom, Tekla viewer or Solibri reader allow the bidding parties access to the model without having to have the expensive authoring software such as Revit.

As more becomes known about the spaces, new fields and values can be added to their properties as per FM requirements or client demands. Typically, this could relate to occupancy or tenure with details of contacts or contracts being added. The walls and other building parts can have suppliers' details or maintenance intervals added in a similar fashion. Sustainable reports can be generated to check that air changes, wall constructions, thermal line losses and cold bridges can be monitored and adjusted as required.

When each element or building part has been coded, it is possible to export the model to Sigma. For an estimator or quantity surveyor this is where price books like Spons (UK price book) or independently worked calculations or materials and resources can be applied to the data. A price can now be generated and the data past back to the objects in the Revit model. They are intertwined by the type code, making them bidirectional. Any changes in either programme will have an impact in the other. The updated objects now have material costs with fixed and quantified resources added. So if Spons has one man taking one day to build a certain amount of masonry, the contractor might have two men taking half a day with fixed overheads and a profit margin added.

This priced bill can now be exported to Microsoft Project. All the data is again passed over to the new programme where everything comes in with the current day's date. The sequencing and critical path has not been plotted yet. All the bars appear in the Gantt chart with their resources displayed but unconnected. Either the critical path can now be started or the work set after their progress on site. When this work is finished, a practical completion date becomes known. It is a living document so delays or improvements can be entered, and their effects be seen, using the *baseline* feature.

Once the (MS) Project file is adjusted, the fourth and fifth dimensions are in place. Navisworks can be opened and the 3D model can be exported from Revit. It comes in with all its objects identifiable either through the 3D view or from the 'Selection Tree' like a project browser at the side. Adding the MS Project file allows the timeline playback feature to be run where the week numbers proceed to show the progress of the project at each point in time. A Construction Manager (CM) can see and match the virtual model with reality as the job is built. Adjustments and changes can be applied to either to reflect what is happening.

It does not end there either, other work and other consultants can add their models or analyse the model for different tasks. Typically, the structural model and the services models can be added. In refurbishment work, the existing model can be placed first or a point cloud laser file could be placed so that clash detection and good fit can be checked. Sustainable reports can be generated, looking at daylighting or the energy frame, climate and regional data can be used to test the model's parameters early in the design phase to help and better inform design decisions. Digital architecture as a style is also endorsed by the complex geometries that can be created as seen in the work of Libeskind, Hadid or Gehry, to name a few (Gehry 2008).

At its most fundamental level, it can be said that the model is a representation of something else (Bandurevskaja 2010). Scientifically, models are made for logical reasoning and this applies as much to finance and banking as architecture. The power of the model can be clearly seen in two anecdotes from two totally different eras. Ross King (a faction writer) in his book *'Brunelleschi's Dome: The Story of the Great Cathedral in Florence'* (2000), recounts how on the patron saints day of Florence every year, that all those involved with the cathedral's construction, had to swear an oath to faithfully undertake the work exactly as portrayed in the cathedral's brick scaled model measuring 4.6 metres high and 9.2 metres long (King 2000).

Bear in mind that even though it was designed by Arnolfo di Cambio back in 1294, work only started on the dome itself in 1420. Cryptically, no one knew how to deliver the unique structure, putting it off until another day, as they say. It called for an octagonal form higher and wider than any that had ever been built without buttressing to prevent it from spreading or collapsing. In sequence the church was worked on by di Cambio, Giotto, Pisano, Talenti, di Lapo Ghini Arnoldi, d'Ambrogio, di Fioravante, Orcagna and Ghiberti, before Brunelleschi came on board (Wikipedia contributors 2010b).

So, it can easily be seen that the city fathers (the client) who had bought the concept of this fabulous church, needed a quality control mechanism to insist on getting the church built as designed and this happened through the model. It was duly consecrated as per the model on 25th March 1436, showing patently the longevity of the model.

Figure 6 Basilica di Santa Maria del Fiore, Cathedral of Florence, (1296 - 1436)

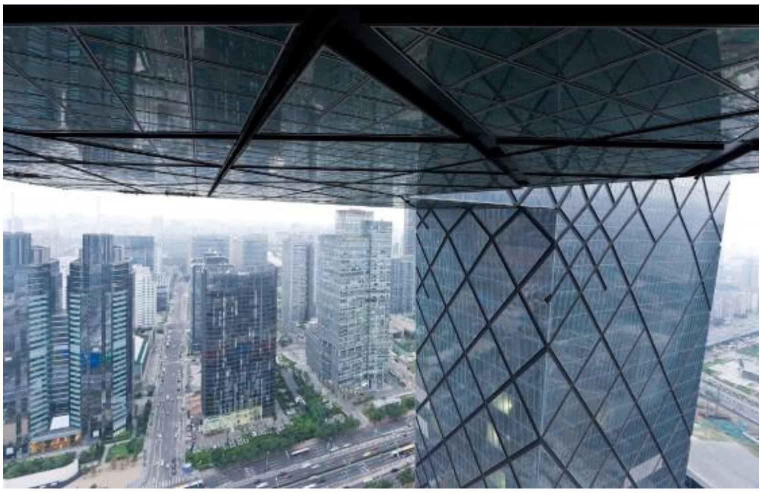
9

Figure 7 CCTV HQ building in Beijing OMA & ARUP (2002)

Contrast this with the CCTV HQ building in Beijing, China by the Office of Metropolitan Architecture (OMA) (Koolhaus 2002) with ARUP as engineers. It is a 234m tall building with a highly unusual shape, described as a *'three-dimensional cranked loop'*. The building is formed by two leaning towers, bent 90° at the top and bottom to form what ARUP call a continuous tube. This means the building has a gravity defying cantilevered section soaring above the skyline, making it also a unique design.

One of the project architects, Chris van Duijn of OMA, tells of the client demanding a scaled model (1:50) with matching components in both strength and performance, to satisfy their concerns about the cantilever being safe. Here again is the model supplying the quality control mechanism to a client who does not totally trust the designers.

To a design professional, this may seem incidental but clearly, to the layperson the model has an incredible role to play. Within building information modelling this analogy can also be applied in many ways, from the multitude of simulations to the depth of analysis that are becoming available to allay the client's fears and build confidence to deliver a degree of certainty that has been lacking at times.



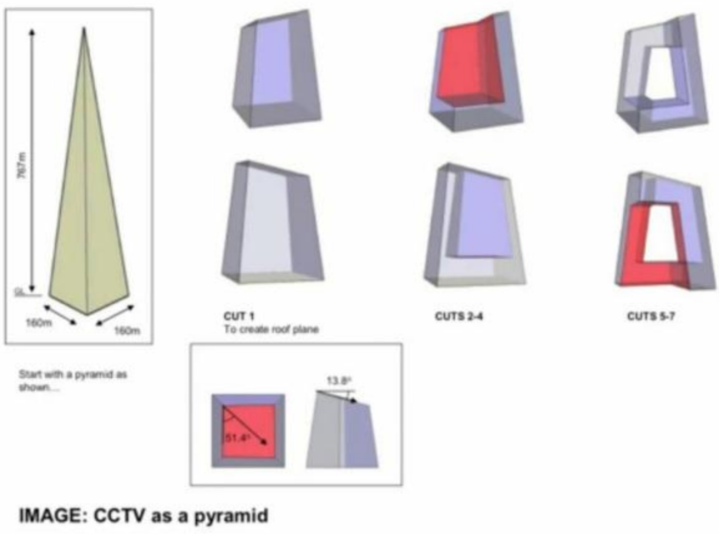


Figure 8 Underside of CCTV cantilever & development of form, courtesy of OMA

7.6 A Mapping of Overall Process against Individual Responsibility, Training, Data Reliability & Risk

7.6.1 Introduction

The momentum of implementation takes on many aspects, ranging from new comers for whom it can be a giant step forward, to converts who exponentially adopt it and see its influence ever grow in areas not initially within their scope. Whether or not the changeover is planned and targeted, there are latent things that surprise rather than hinder the process. This is most notably illustrated where experts are three to four times more likely than beginners to see a higher level of benefit (Young, Jones et al. 2008).

This clearly demonstrates that there is a perceived resistance to adopting a new technology, being more secure in the status quo, as it were. It also related to the fragmented nature of the industry as stated elsewhere. Brad Hardin's book (Hardin 2009) and a raft of similar publications (Eckblad, Rubel et al. 2007, Eastman, Teicholz et al. 2008, Smith, Tardif 2009, Elvin 2007, Strong 2005) recommend bringing management and leadership on board at the earliest with their unreserved backing in such endeavours.

Largely this hankers back to the CAD adoption days where a schism occurred with management and the technology, resulting in misunderstandings and a lack of communication. Glenn Birx of Ayers/Saint/Gross in addition says it is more than the changeover to a computerised drafting tool, adding *'that it will cause many cultural changes that will pervade almost all aspects of practice'* (Birx 2005). These changes relate to individual responsibility, training, the reliability of data produced and the risks involved, when sharing.

According to Hardin, the responsibility for implementation should be identified in a role of someone as BIM Manager. This should be someone who can be trusted to realise project workflows, understands the needs of the delivery team, has sufficient technical knowledge of the programmes used, communicates well and appreciates the skills required, has an appreciation of appropriate training needs, while having good teaching skills and an overriding ability to coach. Such a person needs to be a technocratic evangelist but retains objectivity in crises while at all times being flexible and mobile.

The role is further complicated by issues of *'in-house'* and *'out-of-house'* domains of territory. In-house is fairly straightforward with a clearly identifiable chain of command and ring-fenced personnel. But out-of-house and across the divide raises many difficult situations if trust and social relationships are not present or cherished.

If there is a start-up phase, (a new BIM seat/workstation) a budget needs to be established together with a time span of incremental deadlines for both software and hardware, together with training and support leading to achievable expectations. This can be done in many ways, for instance the IT department can respond to the unique requests and requirements of each unit and their resources (as is a global multinational company). Conversely, at the other end of the spectrum, while feeling the need not-to-left-behind (a successful tradition practice) can employ internship students (practical placement) to parallel their established processes in what is essentially double work, until they have the expertise to make the step up (ie two paths; CAD and BIM).

In between is the more expected response where the client, another stakeholder, or the municipality require or demand it for a project, making it mandatory. This then becomes the pilot or test case in which to tinker and assess the project. This is generally the most recommended method. Two outcomes are possible; where catalysers emerge and become drivers of the new operation or independent groups are formed and become new entities within the firm growing and initiating the change over a longer period through a method of assimilation.

Either way, this is related to the integration plan that needs to be adopted or developed. For the office, this is a type of benchmarking which can be assessed and costed. Usually a Return of Investment (ROI) can be determined from this, meaning metrics are in place to track the success or otherwise of the venture. These would include:

- *Improving the project outcomes, with fewer requests for architects' instructions, change orders or requests for information (AI's, CO's & RFI's),*
- *Better communication or visualisation for the team*
- *Improved productivity of personnel*
- *A positive impact on both the project and the interaction between stakeholders*
- *Life cycle assessment can be impacted and evaluated*
- *Staff training costs and lead-in times*

According to the Smart Market Report from McGraw Hill Construction in 2008 the following featured as being the most valuable aspects to result in ROI:

- *'Easier co-ordination'*
- *'Improved efficiency'*
- *'Better communication'*
- *'Improved quality control and accuracy'*
- *'Competitive advantage for early adopters'*
- *'Clash detection and avoidance'*

In an extreme cases the ROI was claimed to be over 1000% but average figures of around 300% - 500% were more common (Young, Jones et al. 2008).

Because Integrated Project Delivery is based on collaboration, then it must be built on trust. This trust must be effective and its structure must encourage the stakeholders to focus on the job at hand and devote their time and energies to the project outcomes rather than individual goals. Otherwise adversity and antagonism remain, which has dogged the industry using traditional methods.

The major project outcome must be that the project is delivered to the client's satisfaction. In order to achieve this there must be mutual respect and trust between all team members and stakeholders. Just how this equilibrium is accomplished I will return to later. From a technical viewpoint, the new methodologies employed require changes in the allocation of resources and efforts. This in turn requires an appropriate compensation model for all involved, reflecting what they have done and how they have done it. This further breaks down into two parts, balancing fairness to all to remove the antagonism, with proper motivation to the required actions to encourage initiative. This ensures that there is mutual benefit and reward for all their endeavours and this too is essentially a paradigm shift.

Suddenly there is an environment where there is an incentive to get the job done and to do it right. Arguably, all contracts strive to do this but all too often, there has been a tendency or a milieu to do the opposite. In *'Partnering in Construction'* two forms of tendering are described, the first *'lowest bid'* illustrates the evil cycle where the lowest bid has no optimised products or pricing, leading to low productivity and insufficient communication, where claims, no trust and a poor working atmosphere leads to conflicts, low profit which only start the spiral again.

By contrast the *'correct pricing'* method ensures that product and pricing is optimised, that there is higher productivity, higher communication, better trust, better dialogue, more collaboration with no conflicts, leading to higher profits and further investment, propagating a healthier bidding cycle (Høgsted, Olsen et al. 2006).

Traditionally there was individual responsibility where professional conduct ensured the competence, of the disciplines involved, with clearly defined terms of engagement. Dismantling these barriers in a sense could result in a greying or blurring of the roles defined, with the knock on effect of ensuing chaos, but if the incentives are in place then the situation is ostensibly the opposite.

These incentives typically can include professional services, so that the stakeholders can be sure of their services being recognised and duly compensated. This basically would cover costs plus profit (optional). A Project Delivery Performance Incentive introduces the concept of *'everybody gets paid or nobody gets paid'*, which fosters positive effects while neutralising negative behaviours. This is by and large short term relating to handover only where the main issues are; scheduling, costs, savings, waste (reduction), quality, safety etc. But a additional incentive can be the Business Enterprise Performance Optimisation Incentive (BEPOI), which draws attention to the longer life span of the building and allows the procurement team access to funds for the consideration of energy performance, operating costs, tenant/user satisfaction and general sustainability.

Incentives of this kind are more closely aligned to the client's long-term motivations and need clear articulation to establish the metrics and methods of measurement to trigger pay-outs. Miscellaneous considerations might include cash flows reflecting the MacLeamy curves where the money might need to follow the effort meaning a larger percentage of fees being associated with earlier parts of the project.

Group compensations generally accommodate or promote *'best for project practices'* providing a mechanism that encourages and supports collaborative behaviours. The notion of pain/gain sharing should broaden the idea of risk and reward, which in turn should uphold the strong focus on project outcomes. Where some of the goals cannot be readily realised (longer term rather than shorter) methods need to be in place to ring fence these outcomes so that they remain critical and to the fore so that they do not fall to the wayside or disappear off the radar.

All in all these changes build a stronger foundation, which need evaluation and feedback so that the experiences can be banked. This warrants compensation too! In many ways the report by the AIA Integrated Practice Discussion Group; *'On Compensation'* (Miller, Suehiro et al. 2008) mirrors many of the things found in the Heathrow's *'Terminal 5 Handbook'* (Haste 2002).

With this set-up Miller describes *'Collaborative Innovation'* as a means to earn endorsement, because individuals feel unshackled in coming forward with ideas and improvements for two reasons; the first being the obvious better practice issues but also the latent empowering process where there is worth in the contribution with added value to the closed community. As simple as it may sound, sadly this was missing in the bad old days. Closely related to this innovative process is the management trait of *'Decision Making'* where there is a liberalising of the structures previously in place. The decision goes with the man best placed to take it rather than the earlier situation of rank pulling rank.

Bringing *'Key Participants'* into the project earlier and involving them in the decision making process is also something that has not gone unnoticed in other project models like Partnering, Design & Build, PPP and PFI. This is something contractors have been seeking and getting for some time now. I deal with this more thoroughly in my assessment of Frank Gehry and his evaluation of the new methods.

In order to keep a track of things, bringing all stakeholders in earlier means defining targets and goals long before traditional methods, so that time is not wasted or effort stifled. The *'Early Goal Definition'* requires *'Intensified Planning'* if so much is to be documented and known at this early stage, or at the very least, signposted. For this to happen *'Open Communication'* means that things can be easily tabled and access to the relevant data is both encouraged and supported. Part of this process demands the *'Appropriate Technology'* is in place and can be employed or deployed as necessary.

Finally, this holistic approach could without difficulty get side-tracked by stakeholders that introduce red-herrings or go off on tangents unrelated or unnecessary to the task in hand. This is where there must be appropriate *'Organisation & Leadership'*. Intrinsic in this are personnel who understand all the strands mentioned above, with both the overview and perspective, as well as being able to drive down to the attention to detail level.

Critical here too is that the differing disciplines need to have their own house in order, but to also have an awareness of the others with a sympathetic ear and a level of synergy to compete at this higher plain. All this effort moves much of the process earlier in the procurement and this needs attention if the money is to be followed. It challenges the Plan of Work model (as per se; RIBA), and even here variants are proposed and structured. These can be seen Office of Government Commerce (OGC) and Smart PFI variations at the end of their three-page outline document (RIBA 2007). OGC is a body set-up to get the best value for the UK government's £30bn estate as well as generally delivering projects they are involved with on time and to budget (Salmon 2010).

7.6.2 Individual Responsibility of Data Input

Traditionally the responsibility of all input was traceable, through authorship (with the trefoil of *'drawn'*, *'checked'* and *'approved'*), clearly defined in the disciplinary silos of the professions and their hierarchies. The deliverables format was two dimensional, meaning habitually in a paper format. This meant that the front line and point of engagement happened at meetings and through distribution of drawings and their drawing lists with their ever-changing record of revisions.

The *'distribution drawing list'* was a kingpin in the management of the data flow where reworked sections of the project could accumulate many revisions demarked by a running capital letter appended to the drawing number, accompanied by many telephone calls ratifying the current set-up. This is largely because the sequence of changes often would become mangled where one discipline would linger with their alterations, fearing double work should the work become abortive, through additional tweaking. It could also happen due to the reworking or the development of a difficult piece of the design or the changing requirements by the client or the authorities.

The necessity of this elaborate set-up was to ring fence the discussion because these situations were precisely where the discussion was needed, and to ensure that both parties were comparing apples with apples and not pears. Often misunderstandings could occur where the incorrect drawings were being discussed over the phone. Merely digitalising the process brought many benefits, notably with overlaying work. But the quantum leap comes with the *sharing* of work, digitally.

As innocent as it sounds, for one party to give their work to another is in fact fraught with complications. Quality management, copyright and indemnity insurance only scratch the surface. Branding and expertise can also readily be heard as arguments against such inane practices. Reimbursement features too. Beside this, the biggest hurdles lie in the practicalities. First is the need to protect the work and disable any risk of interference to its authorship. Next is the fidelity of the work, and the successive effect for other users of it. Finally how the work is presented so that it is relevant to the recipient through appropriate filters with differing viewers.

These three practicalities relate directly to the role of responsibility for the data and the model. While ownership might be collective or hierarchical (ultimately to the client) management is a mechanism which is a catalyst to allowing it a place to both happen and a process to be executed successfully.

Management can be nurturing and/or prescriptive, with either a milieu mentality or an acceptable set of standards implemented and properly administered. But the question is can it cross the boundaries of the respective disciplines? Either the lead stakeholder can appoint a manager from within or there can be an external consultant appointed from without. This is discussed elsewhere, most importantly in the latter chapters leading to the conclusion. Here its relevance is the responsibility together with the respect and power to infiltrate and solicit change to working practices and methods in the other professions.

The best-case scenario is where there is an accepted shortfall in the other stakeholders' abilities and the offer or existence of a competent authority is most welcomed and deployed. The worst-case scenario is where there is resentment or tardiness in the development or where there are cross-purposes or misunderstandings. In these situations there is no mechanism to enforce the new methodology (if this is not a too strong a word for it), and this becomes the bottleneck in the procurement process.

Either way, there is a distillation process, where the best or most competent person or organisation is earmarked for the role and this can be seen as grooming for the role as BIM manager. This has not existed in the CAD world where the nearest could be seen as outsourcing CAD work to bureaus or overseas, or with the hiring of contract staff to complete projects on a project-by-project basis. CAD consultancies rarely if ever came in on a management role to deliver projects, at best, they could be on the fly as bespoke hardware and software suppliers customising the package for a prestige project as in Terminal 5 at Heathrow (Lion 2004).

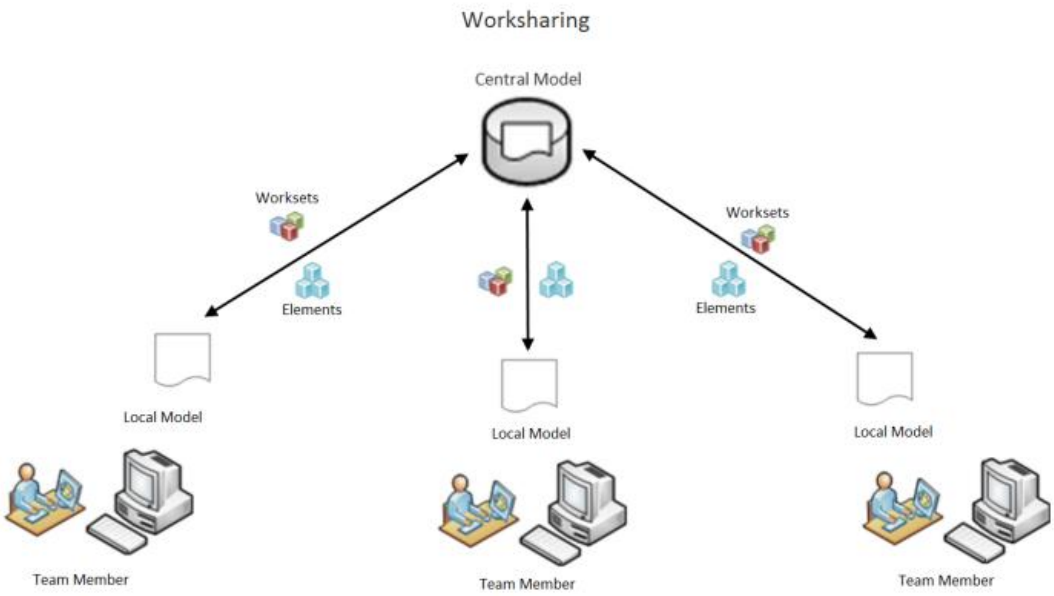


Figure 9 Diagram of Central file and Worksets, courtesy Autodesk WikiHelp

But in taking the protection, fidelity and filtering mentioned above, there is a mountain of work involved. Protection and security can be found at a micro and macro level. If the file (model) is shared, methods are necessary to make the work available but not editable. The reasons are obvious so as not to invalidate or undermine the stakeholder's input. Within programmes such as *'Revit'* where there is a *'central file'*, a feature known as *'Worksets'* allows for the division of the work within the model.

A *'central file'* can be enabled in the project (it is not by default) which creates a new management level in the file. Without a *'central file'*, there is a one-on-one interaction between the operator and programme. Work is developed and saved to the project as might be expected. The *'central file'* removes the *'saved file'* from everyday use, making it a holding file, tracking the many users who divide the workload. Its job now is to spawn numerous *'local files'*, which become the *'worker bees'* where the work is done.

A *'local file'* is a subset of the *'central file'* where a subdivision of the work is defined. It is arbitrary which can often be misleading but this too is its brilliance. Ownership is now given to the user of the local file and permission is assigned where they and only they can work on the borrowed subset, until it is returned and relinquished. The complete file is available and viewable with restrictions. This temporary dismemberment of the holistic entity takes part of the file and gives it to the user to work on and develop. While they have ownership of the part it is exclusive to them and cannot be edited by others until returned.

But through frequent saving and regular updating to and from central, their work can be distributed to the others so that the latest model is always only a click away. The central file becomes a repository for the bit work being done by the others and manages the status of the model for everyone, keeping it up to date. Issues arise when ownerships and permissions get entangled usually where an element might need to be borrowed or its host might require moving or changing. A secondary system of borrowing and flagging requests comes into operation so that the knuckle is highlighted and can easily be toned down rather than becoming a monster.

Upon conclusion of the subset, the workset can be relinquished, meaning it is returned to the model, free without ownership, unless the owner decrees otherwise. This could mean the owner is not finished or does not want to make the work available to another party for editing. The workset here acts as a locking mechanism making it non-editable and closing it out, while leaving it viewable and fully integrated within the complete model. This situation could be implemented where the model is shared across disciplines, although other options are available and these too will be discussed.

The next level where protection can be portrayed is where differing variants of Revit are used, as in Revit MEP and Revit Structure (as distinct from Revit Architecture) to reflect the differing disciplines in the procurement team (namely *'mechanical, electrical and plumbing'* and *'structures'* and of course *'architecture'*). Bringing the work of one discipline into another enables a protocol of *'copy and monitor'*. This means that certain common parts of the project are benchmarked such as levels, grids and volumes, which are defined for all stakeholders.

Each stakeholder can then go about their expert role and the product can be seen in unison, when the other two plug in their parts into the third disciplines effort. The status of the single model is reinforced while the differing disciplines contribute to the whole. The underlying mechanism is the workset idea developed on to a bigger tapestry. This can happen because the toolsets for each stakeholder are inherently different. The architect works broadly with the spaces, the engineer with structures and the installers with services. Where conflicts occur the same borrowing or flagging mechanisms can be deployed.

The next level is the where differing platforms are involved and here special programmes known as viewers are involved where they present each model in 3D space together, allowing clashes, collisions and time lining to be checked on the respective models. These include Navisworks, Tekla Viewer and Solibri. This means that the conflicts arising are noted, and marked for attention so that they are dealt with at the early design phase and not on-site as previously. There, by default, can be no editing in a viewer, which removes that level of risk.

The last level is where there is a common format for delivery as in Industry Foundation Classes (IFC), which introduces a deliverable format, which is not editable, unless translated back or imported into another programme. This is also an open source solution, which has many important repercussions, not least in not tying public bodies to *off-the-shelf* solutions, or tying them into licensed products or monopolies.

However, tests have confirmed that the IFC interfaces do not work as expected. Both simple and complex demonstrations have revealed cases of information distortion and information loss. This proves very unsatisfying where guardianship is not in place. If the purpose of the IFC model is *'to provide means of passing a complete, thorough and accurate building data model from computer application used by one participant to another; with no loss of information to the arranged level of precision'* then unfortunately, the end users cannot blindly trust the mapping process (Pazlar, Turk 2008). This shows that there is a need to passively as well as actively to protect data and its fidelity.

New developments are also afoot, with cloud technologies looming largest (Wikipedia contributors 2010a). Cloud as the name implies means that the data is held up there on the airwaves on accessible servers (Cloudcomputingdefined 2011). This means that the data is centralised and available on demand. It reduces the risk of multiple copies and the ensuing problems of current up-to-date files. In terms of scalability, it too needs a management structure so that it remains robust so that it cannot be inadvertently compromised by wrong or incorrect data. Essentially data is held centrally and not locally and, as far as Revit is concerned, *extensions* have recently become available to place the central file on a Wide Area Network (WAN) rather than the Local Area Network (LAN) that currently exists.

Although this is a subtle development, the implications are enormous. It moves the whole enterprise into a domain where BIM can blossom and claim its rightful pedigree. *'Greater than the tread of mighty armies is an idea whose time has come'* said Victor Hugo. While it will increase the risk, it will also reduce the scrutinising and cross-referencing of others data. It demands that there is transparency in all dealings and this brings the issue of trust back to the fore.

7.6.3 Data Reliability

Beyond the trust that must exist between stakeholders, there are obvious shortfalls where the differing disciplines either do not have the expertise or the right to exercise an expertise, which plunges unverified temporal work into a *limbo* stage. First, there is a need to define some work or flag the area for the correct person to deal with so that it is not missed, but there can also be unclear divisions of work where ownership might be disputed.

Next is the transforming of data. By this, I mean its development and growth. For example in life cycle assessment, there are many metamorphoses that entities go through and there is much latency where pockets or holders of data lie empty, waiting, if appropriate, to be filled at some point with relevant facts, by the qualified authority. At the strategic or financial stage of a project, before a line has been drawn, objects could be formed with names, functions and interactions.

This could be a function diagram, an adjacency plan or a humble bubble diagram to establish the projects aims or needs. To these names can area requirements be added, which can be rated and ranked, before being costed in square meter prices to reach a budget sum. This can then be conveyed around to attract sponsors, developers or satisfy clients.

These areas can then be morphed into space objects, still containing the data, but still having no form. From here the round spaces can become rectilinear (if that is the form pursued), which then can become generic building components such as walls in the first instance. Needless to say, the data is still available. The walls can then become classified as external or internal, go through analyses to ascertain new properties such as their elemental composition, their performance criteria and their resource payload.

As new things about the wall become known new fields are opened for further quarrying or mining of the data. As the project develops, new stakeholders require different information or add different information, until it is built and the building becomes operational. At this point, the virtual element should be an as-near-as-possible replica of the (real) built element.

Data relevant to the facilities manager is either there or can be added so that the virtual model can exist in parallel to the real facility until decommissioning or demolition where the data is again available to aid and abet sustainable procedures to either reuse or redeploy all the parts in a meaningful manner. In this relay race, the baton has passed through many hands and has accumulated much data.

The architect was concerned with the wall's aesthetics, the engineer with its load bearing ability, the service engineer with it thermal properties, the contractor with its composition, the sub-contractor with its hosting capabilities, continuing with the user, occupier, municipality, facilities manager and all in the supply chain to realise the object. Each has a vested interest in particular data that may or may not impact or effect someone else but the holders are encapsulated in the object overflowing with data.

At the concept phase the architect does not know or define the supplier but at the production phase these things have been added and at the operational phase manufacturers details, life expectancy and maintenance notes are embedded into the humble object. But along this journey at the concept phase, the composition is not known. Therefore, if it is modelled with a thickness of 400mm, then during design development and technical design it might transpire to be 390mm or even 720mm.

The architect cannot be held responsible for this discrepancy, and such a situation, as this is part of the development. This means that there has to be an acceptance of the data as found and a responsibility to correct the data as it becomes better informed. It harks back to the old adage *'whoever finds the problem, owns it'*, but here it has to be seen in a positive light where the project is being developed.

Text Box 3 Spearin Doctrine, USA

This is fine where there is lineage and competence in the data flow, but what about where there is a time bomb waiting to explode, meaning there is disinformation loose in the project. How does this relate to the natural law of tort, or more particularly to law cases, which spawned the *'Spearin Doctrine'* in the USA (Mitchell 1999). The case concerned a naval dock in Brooklyn where a sewer was rerouted according to owner-approved drawings and specifications, only for a damn not mentioned or included in the documentation set to subsequently burst and flood the dry dock. Two points of law arose from the case: *'the first implied warranty in that the plans and specifications are accurate* *and the second is that they are suitable for their intended use'.*

Collaboration contracts specifically state that stakeholders will not sue each other meaning that in such a case as above the solution would be mutually found and executed. In the event of it happening under operations a mechanism would have to be in place for a procurement part of the consortium to come back and rectify the situation. To date I have no knowledge of this ever happening.

7.6.4 Risks and Their Associated Benefits

'...But the benefits by far outweigh the risks' (Eastman, Teicholz et al. 2008). This integrated approach requires open standards and a shared model. The standards can even be localised and the model only partly shared. Different parties will require different views of the model, some will require holistic approaches, and some will require extremely filtered portions. For some it will be graphical data, others numerical, and for others it will be time based, while the remaining stakeholders will look at performance and behaviour.

With each having their own agenda, it becomes a difficult playing field to get all to perform to equally trustworthy standards. In the few IPD case studies to date, there has been unique collaboration contracts drawn up, but also intrinsically important to the success of the project, there has been *'gentlemen's agreements'* to be open and transparent in all dealings, and this has helped the procurement process through virgin waters. Where it has been successful, there has been bonding of the teams from top management down to grassroots' execution. There has been give and take in the interests of a successful completion to the venture.

Likewise, this requires equally committed partners in the collaborative process, and this is a high-risk situation. If you cannot control, or if some parameters in the contract are outside your control then you are working at risk, and to quote one of the big players, you cannot totally immerse a business in such a fashion to such a business model, it would be suicidal.

So evidently, the makeup of the building industry is challenged. By this, I mean that it is very disparate or disjointed. Not only are there many stakeholders, but size-wise they tend to be small operators and even when they work together, on subsequent projects often the personnel change, meaning that there is little continuity and less chance for improved teamwork.

7.6.5 Technological Evolution, Ability to Change and Adapt to New Materials and Construction Practices

Where the technological evolution will help the disparate and disjointed stakeholders, is through its ability to offer centralised points of contact, centralised pools of data and centralised up-to-date versions of all documents and drawings. This makes it imperative to be linked to this source, and this ultimately brings the peripheral figures, who either resist the technology or protect their own worlds to be part of the enterprise.

At this point not being involved is tantamount to conspiracy or even espionage. While sounding daunting this can be the case, because as more become reliant on the central source, so too does the responsibility and authority. If someone does not upload or place correctly documents or drawings then officially they are not in the system, and while initially this argument might hold water, as the momentum of the beast grows then a critical point can be reached where not to do so is counter-productive and damaging to the enterprise.

Where the system is difficult to implement, unfriendly or not streamlined to its purpose then new issues arise. Often in the past, these have been legitimate excuses or reasons for failure. But increasingly better and more user-friendly applications are emerging, and more importantly the technology is learning and improving too through versioning and development.

Previously, clients would commission IT projects and budgets (here, expressly not construction projects) to bespoke tailor-made solutions. Usually, this resulted in poorly built, single perspective, inflexible solutions that usually ran over budget or got canned through over-spends. The next generation resorted to off-the-shelf solutions and duly became embroiled in tied-in contracts and legacy programmes. By this, I mean that they became subordinate to the programme and vendor, and overtime (or after signing the contract) became disillusioned or unheard with regard to performance and wish lists for desirable features.

Quietly in the background, a growing number of disenchanted people resorted to open source software as the only way forward. This makes mergers and buyouts nigh impossible because of the sheer number of individuals who have written lines of code leading to entanglement and interdependency. It also means that there is a body of work, which remains, fresh and relevant, because those involved are involved out of a desire and aspiration to do something worthwhile.

It also acts as a tempering body toward the software houses, offering an alternative to the out of the box solutions. More importantly, it empowers the commissioning group by usually being driven by crystal-clear aims without the tarnished ambitions of selling more licensing seats or subdividing the programmes to increase sales.

Another aspect is the uptake of digital devices, especially Smartphones and the number of extra things they can do. Apple Inc. became the most valuable company in the United States, surpassing Exxon Mobil Corp. on Wednesday 10th August (Ortutay 2011)(Ortutay 2011). This is largely because of its ease of use and feel good factor. It also shows that if done properly that it can be a success.

With regard to construction practices, many of the benefits have or will be mentioned elsewhere in this work. But critical, and worth mentioning here, is that many of the tangential applications being delivered to Smartphones, have a bearing in the industry. For example, the ability to photograph a room or place and have the application match them together to form a 3D continuum. This means that buildings can easily (or can shortly) record and archive spaces as we experience them. Already Google sees this building up in their Google Earth, where just like users upload photos from their GIS savvy phones, so too will people upload the spaces they encounter, embroidering the experience for others.

7.7 How the Opportunities, afforded by the pervasive use of IT within construction, are Impacting on Design Strategies

7.7.1 Introduction

BIM can contain graphic and non-graphic data, contractual information and even risk registers. It is, in general, a pool of coordinated information with the keywords being it should be shared and structured. If it is shared then the maximum value may be extracted out of it and if it is structured then as many different processes as possible can use the information in as many different ways as possible.

To recap, as mentioned in the last chapter, a feature of BIM modelling software is that it allows for the notion of phasing in the building process, and it is important to stress that it is a process. If phasing is employed then a pre-model (FM) can be hosted, the procurement model can developed as currently understood, and a post-model can be prepared for future deployment after handover. Crucially too the use of tags (whether type or instance) allows fields to be generated but only deployed when appropriate to do so. A good example of this is in tendering where all specifications and data should be generic unless entered as prime costs sums.

Post-tender, as each object becomes defined, it is important to populate these fields so that stem data and maintenance schedules can be developed. Typically, this can be seen when the contractor takes over the model and begins describing just how it will be built. This allows the contractor and project/construction manager control to administer the procurement process in earnest.

Strategically this means that objects can occur in the same 3D space of the model without interfering with the geometry but being able to share common data. This is a 4D feature. By extension, having differing phases allows for differing scenarios. This feature is what is called open architecture (in terms of information technology) which can be expanded and utilised to allow flexible non-defined objects to be placed non-intrusively in the model. The model now has an architectural filter retaining the architects conceptual design, together with a detailed contractor filter showing a living organic development which can lead to the *as-builts* upon completion.

This allows an entity to be a data holder. The paradigm though is that data, when entered, can be filtered and viewed as appropriately by others. This manipulation means that BIM can host FM data, and present it to the appropriate stakeholders. Generally a major problem at the start of a project is that showing a client, or a developer drawings with line-defined spaces, however well unintended, equates to bounding walls in their perception. This means that most FM protocols tend to use bubble diagrams/function diagrams to avoid the obvious misinterpretation or at best largely misleading information.

The architect's role later is to look at the agreed areas and convert them into rooms. In this phase, the architect can look at the bubbles, which have had data added, and begins to consign rectangular spaces over these formless bubbles to begin the form-making process that is the architect's role.

This is the first seamless transition of collaborative integration of the life cycle assessment. Later using a proprietary viewer the other phases can be added as well as other model types allowing a host of differing files to co-exist, which provides generative options for various reports regarding clash collision, resources and manpower to be compared and contrasted.

7.7.2 Design Strategies

One of the design strategies is to try and avoid problematic situations, which require reworking. This can be, as I have seen, a bracing structural member, which ends up one meter offset from a realigned external wall, because nobody communicated the changes to the rest of the team. Moreover, the perpetrator probably did it, knowing full well that there would be extra costs later to rectify it. In another instance, complete facade panels were delivered on site and mounted so that the openable lights clashed with the position of the stepped back columns. This meant that they could not be opened. Both of these were first unearthed on site, where a model would have resolved them earlier in the studio.

This has now moved the debate further in that the stakeholdings (of ownership) in a model have a requirement for overall co-ordination. There is a need for the management of the sharing, integration and tracking as well as maintaining the datasets, which Jonassen sees as a rather overwhelming endeavour (Jonassen 2006). The situation is poised for the introduction of the BIM manager. There will be a need for overall management and leadership but where it will come from is now the major issue for all concerned. If the model is to be hawked from one discipline to the other, then where is the co-ordination? Who ensures that it is kept functional, or merely operational, for want of a better word?

Under traditional project procurement, other disciplines in the design team could be reluctant to get involved above and beyond basic and initial observations before the architect had substantially formed the building. Generally, the other team members were there at this stage to ensure that space was allocated for when they got involved at a less turbulent stage. Typically, this would mean a structural engineer staking a need for a certain size-ceiling void for the placement of structural members together with a service engineer who would place all ducting and pipework in the same void.

There is a professional language and protocol at work. Traditionally too this led to exactly where problems occurred on site when there had not been thorough cross checking of the various disciplines' work to avoid such errors. The effect of this initial approach meant that it could occupy much of the remaining (project) time being resolved.

This applies equally to more straightforward parts, where the fault was not so obvious. Generally, the experienced practitioner learnt this through hard won knowledge from previous projects; it was a *'learn-as-you-go'* scenario that came at a price the industry has been happy to pay to date. Also it could only be tolerated on projects following a similar vein. New ground heralded a new battlefield, with all that entailed.

Young, Jones and Bernstein see the value in BIM being the integration of the tools and the process. The AGC BIM Forum (BIMForum.org - home) sees this as a dichotomy where the individual users are identified as *'lonely BIM'* as opposed to the IPD practitioners, which it calls *'social BIM'*.

BIM has intelligent objects and distributing them makes sense. Authoring tools allows design to be embedded, construction to be sequenced, and scheduling to be broken down into elemental works; while a costing model can be implemented, fabrication can soon replace traditional shop drawings and ultimately an operational model can be handed over to the client. While Young et al (Young, Jones et al. 2008) see architects rejuvenating themselves as the main drivers of BIM with 40%, contract managers and general contractors come in at second on 18% with a combination of both at 14%. Owners are next at 13%. However, this is the current situation. It remains to be seen if architects can remain at the controls.

7.7.3 A Broadening of the Scope of IT

Software houses are now producing programmes that are more intuitive and more interactive to the environment in which they find themselves. BIM opens new avenues before inception and long after completion of projects. A virtual model can help enormously with marketing and raising capital, it can aid leasing and renting or allay fears to relocated workforces, it can pacify worried neighbours and it can placate civil servants about urban densities and massing. All this is long before the project enters the main development and design phases. In addition, it represents a good image of the proposed building.

As mentioned and as fully accepted it aids the procurement process but after completion, a relatively new professional body has emerged in the guise of Facilities Managers (FM), managing the whole enterprise right up until decommissioning. Even in decommissioning the virtual model will help in identifying how the building has been constructed and so how it can be deconstructed. So the humble virtual model has a life expectancy long before and long after the building procurement phase for which it is created.

Clients are commissioning projects, which rely on a single building model (BIM) which holds all the data in one place and through which all modifications are made. Authorities are also making demands in this regard with the emergence of automatic building control systems. Facilities Management's input is to broaden the scope and influence of the design documentation to provide add-ons such as *'as-built'* drawings, fire documentation, furniture, fittings and equipment (FF & E) strategies, rental and leasing plans as well as running and maintenance calculations.

Time can be incorporated into the process, often called the fourth dimension. Conceptually this would mean a slider control would allow the viewer to see the building being built up in sequence so that the process is controlled. This can work in two scenarios; the first is to appraise the proposal, where the project can, via GIS, be correctly placed into its context. The other is during construction where the project architect can select a point in time in the model and the model can then be superimposed on the reality. Using a viewer, it can very quickly be seen that the project is up to date, behind or possibly ahead of schedule.

Add to this the fifth dimension; called resources and the various tasks can be measured against material costs and manpower. The whole science of estimating works on defining the work to be done and setting it against known cost parameters so that a reasonably confident sum can be presented for the work in hand. Usually there are price books, which tabulate similar work so that formally, like can be compared to like and with a degree of authority an estimate made. Indexes then keep this data up to date, until new data updates the process.

7.7.4 Frank Gehry

Computers are now providing a means of building previously unbuildable works for architects like Frank Gehry (DIGITAL PROJECT - Frank Gehry.). He set up Gehry Technologies (GT) to realise his unique forms. Two sequential projects were the Walt Disney Concert Hall in Los Angeles and the Guggenheim Museum in Bilbao. With regard to the concert hall, Gehry found himself beset with cost overruns and the project was shelved for a period due to lack of funding. It finally cost an estimated $274 m., which is more than five times the $50 m. budget at the start of the job.

In this situation, Gehry has said that his position went from having the parental role at the start of the project where he was in control, to an infantile one when cost overruns threatened to scupper it. The focus moves from the architect to the contractor. The architect has lost face in the eyes of the owner and the contractor is now seen as the saviour, if the building is to be realised. Conversely, when tendering came about for their next commission, Guggenheim Museum in Bilbao, GT sent a member of staff over to Bilbao to train the bidders in the software prior to tender, which was pretty unique in 2004. The result was they came in under budget seeing more than a fifth being knocked of the estimate.

Figure 10 Walt Disney Concert Hall in Los Angeles (Photo Credit Michael L Maggat ©2003)

How can one project with conventional tendering end up five times over budget and arguably the other with a common model come nearly one-fifth under budget? The upshot is that subsequently people who wish to work with Gehry must adopt his processes and prequalify for collaborative work. It has put Gehry firmly back in the parental role at the helm of the ship and one where he is in control. It heralded a new dawn for Gehry where he now uses selective tendering, and bidders learn how to extract quantities. The intelligent model (BIM) has done this for him.

From the evangelistic viewpoint, this is the clarion call, but from the practical position, there are many other issues. Primarily there is ownership. Who will own the model, who will manage the model, and who will co-ordinate the model's passage through its turbulent growth. In the Gehry case it is a star architect and in such lofty situations, those choosing or succeeding to work with him have identified this type of work and accept its challenge.

Here follows a dialogue with Frank Gehry from an exhibition presented in Copenhagen in the Spring 2007. (Gehry)

Frank Gehry has said that the culture of architecture in our time works like this;

'You do a job; - you meet a client, they hire you to do a project, and it's usually a kind of a nice love affair and so on. It's a very positive, uplifting relationship at the start, and you develop a scheme, with plans for their building and they're upbeat and happy about it'.

Figure 11 Guggenheim Museum in Bilbao (Photo Credit Gehry Partners LLP ©2004)

Of course, they have a budget, which they tell you and a time schedule or whatever. So you finish the design and you put it out to bid, and then it comes in over budget. That (happens), I'd say, 80% of the time. Then the construction people say just that: we know what to do - straighten out a few things - we'll get it on budget.

Of course, the owner finds himself very confused about this, for the most part, because they don't have the extra million dollars or whatever it is, and they're on the way or they're underway, and it's very hard to stop or be sympathetic to the architect, or to the project.

They feel betrayed, and this happens all the time, and it's an uncomfortable place to be but no matter how much work you do, an architect can't control the marketplace, or the cost in the marketplace, or the construction world; you know, it's just not possible.

Now you can be as careful as possible about working for budgets but I've always hated that moment, and my friends have always hated that moment and you sort of wonder is there some way out. In the middle ages, the architect was a master builder, they built the cathedrals, they were respected, they had a process and it was done over centuries so no one got the blame, (laughs). In our time, you have the Sydney Opera House where poor Jørn Utzon gets clobbered. It's a horrible story. It practically destroyed the man's life'.

So in setting the scene Gehry has recounted that a parental/infantile relationship occurs between the architect and contractor towards the client. Initially the architect has the parental role with the client, advising and leading the way in this new adventure to build a house.

After going out to tender the bid often comes back way over budget, and going cap-in-hand to the client a new price must be negotiated. At this point the contractor is on board, he made the bid and on hearing the situation will usually offer ways of minimising the over-spend. He now takes on the mantle of parent and the helpless architect becomes infantilised, taking a back seat and losing control.

Below, Gehry tells in more detail about the two commissions his firm had for two major clients. The earlier building is the Disney Hall in Los Angeles, which falls into the infantile arena. Here the tender sum came back sky high but luckily, in having a client as big as Disney the project was completed. But the new scenario is told in his next commission for the Guggenheim Museum in Bilbao where the technology restored the architect to the parental role. He continues:

'And so, on Bilbao, for the steel bidding, and there is not one piece of steel that's the same if you look at the steel frame, we used CATIA. We sent a team to Bilbao and spent a week training the Sub-contractors and those people bid on the construction the steel frame. They came in 18% under budget on just the steel alone. There were six bidders and the spread between them was 1%. Now that is knockout, rare, you don't ever get that.

Which means, when you show a model of a building which looks like Disney Hall to a contractor (which we did, way back), they give you a price that's out of this world. Until you say to them 'Here's a wall that we built with it, here's the drawings. Here's like how you can do it.' The guy said 'Oh, OK!' And then you get real.

And that's what happened with Bilbao and that's what happened with all our projects since then. It's not that you control the market but that you can more *precisely control the process and the things that can be controlled, you control, and it has worked beautifully'*

Figure 12 Shell of Guggenheim Museum in Bilbao (© Photo Credit Gehry Partners LLP)

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7.7.5 Local Authorities & the Planning Process

Local authorities are regulatory bodies mandated with the role of ensuring standards are met and implemented. It is a bifurcate process (Heap 1982) where on the one hand the authority is involved in the making of development plans for the foreseeable future, and on the other where there is the day-to-day control over the carrying out of development by the granting or refusing of planning permissions.

This control is administered through statute, regulation and code and is enacted through parliament, local plans and health and safety legislation. The existence of building regulations goes back more than 4,000 years ago to the Babylonian Code of Hammurabi, where among others such dictates decreed the death penalty of the builder if the house he constructed collapsed and killed the owner (Ching, Winkel 2007).

According to the Webster dictionary a building code *'is a set of rules of procedure and standards of materials designed to secure uniformity and protect the public interest in such matters as building construction and public health established by public agency* *and commonly having the force of law in a particular jurisdiction'.* When man first started to congregate in cities the environment could be quite dreadful without any form of control. It took disasters such as the Great Plague or the Great Fire of London to focus the city fathers into efforts to prevent recurrences, to ensure the health and safety of the inhabitants (Elder 1989).

The history of modern legislation in the UK for example goes back to 1845 when the first Public Health Act was passed, dealing primarily with dampness, structural stability, poor sanitation, fire risk and lack of light and ventilation. In 1877 the first model by-laws (incidentally *'by'* is the Nordic word for *'city'* as in Rugby) were produced as a guide for local authorities. By 1936 this extended to all buildings (previously it affected only new buildings), but the decentralised nature of their implementation made it a very onerous task to the execution of their intent without local knowledge and experience.

In 1952, the model by-laws became universally adopted, bar the London County Council (LCC) who had a more developed set of standards dealing with a more complex urban situation. They were revised in 1961, 1972, 1976 and 1985, by which time Inner London began to look at adoption. This led to the situation found today where there is a set of building regulations, which govern the land. This process has been mirrored more or less in most jurisdictions. Essentially, what it means is that the regulations have developed and matured over time and that there is an underlying layering, which can complicate matters.

So while there has been a growth and expansion in the regulations through the years there has also been a consolidation enabling practitioners to comply with them, as can be seen in the Building Regulations of 2000. Differences are now managed in local plans, which tailor developments with desired outcomes for local communities. Local plans typically identify where new homes, jobs and other types of development may occur. They may also stipulate related developments to be provided, and outline restrictions where certain types of development are unacceptable. They also allow third parties to see what is allowed, proposed or encouraged, while giving guidance as to what is desirable on a site and providing a basis for decisions regarding applications.

So there is now a structure where Outline Planning Permission can be sought to check the validity and legitimacy of a project meaning that there is no excessive abortive work done. This is then followed by a Full Planning Permission at stage D according to the RIBA Plan of Work (Phillips 2008), with an application for statutory approvals at stage F1, with the provision of further information at stage F2.

Such a complex system requires an equally complex civil service or bureaucracy to administer it. Again, with reference to the UK, the Town and Country Planning Act in 1947 set in motion the emergence of the town planner. The Royal Town Planning Institute (RTPI) was founded in 1914, and initially this fell within the compass of the architect but gradually the materialisation of the planner as a profession gained currency. Today urban planning has grown into a strategic enterprise and planning is a very diverse discipline.

Their role is to draw up the development plans and to both decide and advise on planning applications. This includes such matters as plot ratios, densities, car parking requirements, building lines and road widening provisions. They also co-ordinate how other bodies are consulted and involved in the process. They hold and administer a schedule of listed buildings and preservation orders and they define conservation areas, areas of outstanding beauty and green belts. There ambit may also extend to tree preservation orders, while finally they hold, as record, any previous planning decisions affecting the site.

Once a planning application has been submitted, the local authority assesses it. The decision to grant or refuse permission is made in line with their policies. These are; the core strategy, site-specific proposals, area action plans, and the development control. The decision will also take into account other issues (known as 'material considerations') which could include things like noise, design, loss of light or supplementary planning documents.

The submission in nearly all cases currently is a two dimensional paper format. A pile of drawings and documents is presented with an appropriate fee and a waiting period of eight to thirteen weeks depending on the magnitude and scope of the submission is incurred while the planning department and/or counsellors make their considered decision. Procedures for submissions are very precise as too is the procedure for viewing, contesting and appealing the process. Deadlines are also equally important as it is a legal process where there can be much venture riding on an application outcome, both for the plaintiff and defendant.

The drawings and documents are then circulated and each aspect of the application is examined and tested to see if it meets the demands set by the planning process. It can be arduous and slow and the room for human error can be large. Drawings and documents can be lost, misinterpreted or plain overlooked. Sometimes the application can be refused on a technicality or an extension can be sought on some pretext due to work overload or whatever.

There exists an alternative. It is called Code Checking and it is a digitalising of the very process outlined above. It is dealt with elsewhere in this work where how code is developed and how it is implemented, so I will not repeat myself. It requires a digital submission and the local authorities' server can then check all rules and respond with an approval, an irrelevance or a refusal. What it cannot do is negotiate planning trade-offs or massage political decisions. But it can remove eighty or ninety percent of the work from the desktop of the planner, leaving the planner more time to deal with the more contentious and delicate matters that planners might prefer to address.

Just as in banking, decisions used to come from the face-to-face meetings with bank managers. But increasingly this process is being replaced with net banking and the online facilities to test liquidity or loan potential. Such a situation is knocking on the door in planning, but something is holding the process back. Is it the political will, the lobbying of large practices, or is it from within where planners themselves are resisting change?

When I started out on this research, I thought, after seeing the Code Checking videos of David Conover that this was it, game over, adopt and accept. But this has not happened (Conover 2008a, Conover 2008b, Conover 2008c). While it might be beyond the scope of this work to analyse this failure at public office level, it seems that it will be clients and contractors that will drive the process. Whenever I raise this issue with planners, civil servants or to some extend politicians, it is met with a blank stare or ignorance toward the matter. As of today's date, a simple search of the Royal Town Planners Institute (RTPI) web site for *'BIM'* heralds: *'No pages were found containing "BIM"'* (RTPI 2011). This is the same as for RICS (surveyors) two years ago, and IEI (engineers) four years ago.

Text Box 4 Donal Blake of Scott Tallon Walker on Singapore Code Checking in 1997

But within planning parameters Code Checking has had a presence for a long time. Donal Blake, a partner at Scott Tallon Walker, a renowned architectural practice in Ireland, recounts the following that was happening in Singapore back in the 1990's:

> *'I finished up in Singapore in March 1997 to come back to Ireland. I was working for a company at the time called RDC Architects Pte Ltd. They would have been considered one of the top five companies at the time carrying out a lot of residential and commercial work, most notably condominiums.*
>
> *At the time, and it may be different now, there were very clear and prescribed guidelines for planning and building regulations. Particularly in planning where there was a very clear development control plan for the island developed by Liu Thai Ker in the Urban Redevelopment Authority (URA). Essentially, with a few exceptions if you stuck to the planning guidelines, height, plot ratio, set back, zoning etc. you would get planning. If you deviated, you negotiated a waiver with the planners, usually to get more density.*
>
> *The building control was more complicated with up to six separate submissions, Fire*

(although this was becoming self-regulating as I left), utilities (water, gas, telecoms, drainage etc.), parks and others when project specific.

The office was selected as one of a number of sample companies (we had very good computer systems for the time) to test a new electronic checking system which would entail an electronic submission and approval process. With the agreement of our client, a large developer, a condo project was selected and a team dedicated to it. This was a real project and genuine commercial considerations had to be taken on board by our client such as the reading-in time for the team on the software (Autocad 13 was the norm at the time and although the new software was similar it had many differences to be learnt) and the time taken to draw and check the scheme in house. Obviously, the hope in this instance was that this time would be made up in the anticipated rapid approval process.

The principle applied was that the scheme was designed and drawn with this software that was informed by the building regulations and essentially would self-check as design proceeded, for example stairs setting out. I am not sure if there was an alert in the system to confirm compliance when it was a work in progress. Then when the scheme was complete and checked the software ran a self-diagnostic for compliance on the scheme, highlighting areas for correction and ultimately approving the scheme in house. At this point, the scheme would then be submitted electronically to Building Control who would run their own protected identical software check. The result should concur with the in-house office result and then the scheme received immediate approval'. What this illuminates quite nicely is the scope and extent to which Code Checking was applied back then.

David Conover in his videos illustrates the huge potential of Code Checking. In the final video (Conover 2008c), the demonstration takes a model through three different parsers and shows the Code Checking in action. Nick Nesmith, who has close contact and much involvement in the method describes the process as follows:

'I've used a different Code Checking engine to the one that Richard (Richard See from Digital Alchemy, who demonstrated a US coast guard station) has been using, but we have been using the same source codes. So we are going to show you that we got the same results. We are generating a simple HGML report, which can be disseminated back to the designer. This is the schedule for problems for this building; if it were built in Duluth, which I'm told is in Minnesota. There is a summary report of some of the issues arising from moving this building type on to the Great Lakes somewhere, I think.'

The process as outlined here is intended to show that irrespective of where, or with what, that the Code Checking applies itself to the matter in hand. While this sounds self-explanatory, it was obviously seen as very important at the proceedings. He continues:

'I am going to look at a couple of the reports that have come through and the first one here is a summary, and couched in the terms of a typical plan correction notice, that an adjudicating planning officer might have generated. It cites the code section that has been violated. It names the inspector who is responsible, David, and it also provides some detailed advice on how you can pass this regulation, that you are currently failing. It is generated by simply interpreting the mark-up that is in the code. In this case it is advising me to reduce the lighting load, in just the same way that Richard's did.'

In order to show the versatility and overarching scale of this technology the same process is then implemented in yet another method. Here there is better-informed detail, but clearly, the intention is to demonstrate its ubiquity:

> *'In another viewer, this is the Octaga Viewer, and I won't demonstrate it any further, except to say, that the space there behind that window is highlighted. The other significant thing is that there is a detailed explanation and again that's generated automatically by the process of interpreting the code and so there is a full trace back on every clause and every exception that is being tested until we get to a point where we think that there is a failure.*
>
> *The other thing that is significant about the fact that we are working so closely with the source code is that there is a citation here which if I open it by following through on the hyperlink, it doesn't just take me to the document, and it takes me to the exact paragraph where the failure has been generated from. What you can see here is a section of 505.5.2 and you can see in green the text that is in the document and in red a hint of the mark up that actually making the text into something that is useful.*
>
> *In the same way, we can track down another failure, which I will just take a quick look at, which is the failure of that roof component. Again we have a detailed trace back identifying what the R value was, how it is calculated, and its dire conversion from a U value, so that all of that information is traced with a detailed explanation. Again if we follow the hyperlink, it will take us to the exact paragraph where climate zone seven and the requirements for the opaque envelop.*
>
> *So the power of interpreting the code and getting back to it and using it in lots of different ways is there. And now having shown you that I am going to hand over to our colleagues from Singapore who will show you how the same rule set has been built into the existing Singapore system'.*

At this point Steven Chan takes over:

> *'Ok, good afternoon, my name is Steven Chan from Nova City Nets from Singapore. Automated Plan Check Systems have been implemented in Singapore, so that it is no more a dream but something real. What you see over here actually is automated building plan codes, the fire safety codes and the building service codes. Basically there is close to about three or four hundred by-laws that have been automated. The current status is that we have completed the development of the automated plan check, automated Code Checking and presently we are doing a role out implementation for the industrial users. We also part of the international effort to promote BuildingSMART. We have done a demonstration or pilot system in New York, where we have converted our present Singapore code to use the ICC codes. Most of those codes that we did for New York were for fire safety, and we were also a part of the team that helps with the work for the Norwegians, a pilot for the automated plan check.*
>
> *So for this demonstration, in the next few seconds, we basically took what we have done for Singapore 'ePlanCheck' and added on the 'ICC codes' to it and we are sure that it still works in the same way. It shows internationally that we can cooperate and have this BuildingSMART. Just before I hand over my colleague Chidambaram to do the demonstration I will just explain the system overview. The automated plan check system is made for the Building Construction Authority of Singapore and this system is a web-based system and it is hosted centrally. So for any architects or engineers that want to go for this ePlanCheck they basically can submit through the internet.*

By the way, in Singapore, we also have implemented the electronic submission of all building plans and permits, and in fact in Singapore today close to 100% of the building professionals submit their applications electronically. Now, having the ePlanCheck, being web based and centrally hosted, has the advantage that the architects and engineers can submit for Code Checking 24/7. Bear in mind most building regulations make changes over months or years. So when you are a central system you can effect these changes much easier and in a more secure environment.

So after the architect or engineer has submitted to the central server, the checks are performed, and returned back to the architect or engineer as reports, which can be read through HGML, a viewer or to a report. I would like now to hand over to my colleague Mr Chidambaram to do a demonstration. Thank you'.

Chidambaram now takes centre stage and begins the demonstration:

'Thank you Steven, I am going to bring you to ePlanCheck demonstration here. I will also show you the results of the ICC Codes 505 and 502. Basically when the user logs into the ePlanCheck System they will see all the projects submitted into the system in the library. They can select checking of the project, choose the project overview, and choose the clauses inside the checker'.

(Steven Chan makes an a-side, that they will not do the demo over the internet to their Singapore system because of the time issue:

'Actually we would like to demonstrate really through the internet and log into the server in Singapore, but because of the time constraint we will do it on a laptop'.)

Chidambaram continues:

'Basically they have to select the clauses available here. Currently we have 502, 505 and 503. Basically I will show the results for 502 later. So once, they have selected checking they can go for checking. Due to the time limitation I will not do this but rather show you the results. The results can be viewed in a 3D modeller with a viewer. You can see the results over here I will hide the storey and call up where the failure is and you can see the noncompliance results over here. The space will be highlighted so that you can see it in a red colour. You can see the spaces over here which have failed for 505.

The first one is the conference room, which is again the same thing, the access wall of this because of the lighting power recommendation it failed, and similarly you can see the office also failed. So to show the pass case, we have modified the model and so in the next wee while I will show you it. So now, in this case, there is only one failure and you can see the conference room now passes.

I will show you one of the modifications we did to the model. I will zoom into the area. So in this case we have deleted some of the light fittings in there and modified the power of the light. So this particular room passes while the other one still fails. So basically the Code Checking works on this model. This next one I am going to show you the building checked against the ICC code 502. This building is placed in the location Tampa.

You can see that added to the walls' failure that Richard has shown earlier that there are a lot of window failures. You can also see the detail by going into the messages, where you can that see the fenestration fails because of the heat gain coefficient. So it depends on the location, which kind of failure comes out. You can see the details by selecting the particular window, and seeing the property of it. By going through

> *the properties available the information is available in there, which verifies why it has failed. With this I end my demo and pass back to Dave'.*

So after demonstrating the mechanisms of compliance and the climatic influence of location, elements comply in one place but not another, command is returned to the chair; David Conover:

> *'Thank you very much. (I think three, and) I am going to summarise, and then we will be done, or two, I think, of the interesting points of this are that the tag regulations that we looked at were used by three different engines, and came up literally with the same answers, but that they were presented in a lot of different fashions. The other thing was the point of the windows not complying in Tampa. What is interesting about this is that where the codes change based on climate, geographic or other provisions, one can take that building and move it from Tampa to Duluth and I will guarantee you that those windows will be all green, because there is no solar heat gain coefficient driver up in Duluth, (but there is in Tampa).*
>
> *So with that, a summary; what have we accomplished here in 2006? We have completed the initial work to demonstrate manual and automated code compliance checking, and validated the approach used. We have done that today. We need to fine-tune the process, and software for creating the code atoms, or SMARTcodes, and based on what we have done, we are going to come back and do another refinement pass. By the end of the year, we hope to be there; to finalise the energy code. Do the other sections and software and output schemes to make this a reality for the energy code; to continue and collaborate with other folks. But where does that leave us in 2007?*
>
> *Show case and beta test the energy code. Get it out there, get it on the internet, and let folks use it. Continue work on user interfaces and storefront, if you will, and make this accessible to folks. Create SMARTcodes for the remainder of the ICC Codes, plumbing, mechanical, fire, electrical etc. and the California amendments to the 2006 ICC Codes. They are the department state amendments; you really are going to search at the federal state or the local level. It starts maybe with the mode codes; they are used by the majority of federal state and local agencies, which you ultimately need to get to the municipality or specifics. ICC Standards, we need to do the same thing with other SDO's on SMARTstandards'.*

This will be raised again with reference to ongoing developments in Norway, as mentioned above.

7.7.6 BIM's need to Empower Architects/Managers

BIM has a need to empower architects and managers so that they can regain the overall command in the design process. We have already examined the opportunities afforded by large international practices, like Frank Gehry, in re-empowering their overall commanding role, but equally so these are permeating all the way down to regular practices, and will feature (if not already) in *'retro-fit'* refurbishments and *'the bread and butter'* of young firms, architectural competitions. From this, it can be seen that there is a need to empower architects, and their decision-making processes. Equally there is a need for architects to empower themselves and this rides very close to leveraging them into the new methods by showing and encouraging their adoption.

Furthermore, with regard to project deliveries, the model is and will grow to help both site architects and project managers. Augmented Reality together with GIS is transforming this sector. Viewers are also influencing their impact, making them indispensible. Levels of Detail are making the collaborative process better and the communication value of visual material cannot be underestimated, which accounts for much more than previously anticipated by this author.

This section will address the role the model can acquire to aid the initial design decisions, all the way through to the maintaining of the project on time and to budget. Essential, to these processes, is the way the model can be interrogated, analysed and simulated. This is where the model begins to take on its own responsibility in impacting design work and the processes or strategies adopted for its overall effect.

During a recent four day workshop, forty AEC professionals and students (roughly split 50/50) assembled to partake in a four-day intensive course to tackle a problematic site, whose role had dramatically changed due to a recent development on a neighbouring site, a real project. There were eight groups of five and the assignment was to analyse and programme a solution for the left over space. Initially there were presentations of the proposals from the master planners and architects, as well as presentations of the various software programmes and methods to be implemented. The organisers, in close collaboration with the architects of title, had developed a brief of functions and performances, which had to be met in our handling of the project.

This was to be achieved and closely monitored by introducing a BIM Checker, to show and advise on compliance with client requirements of correctly categorised floor areas, and parking. Coupled with this interactive reporting was another form of feedback using simulations and analysis to better inform the decision making process. These included wind simulation, solar gains, thermal performance, and daylight factor amongst others. The adjudication parameters were to be; architecture, energy frame, the environmental impact, the collaborative process, the application of software and mutual co-operation together within groups, polished off with an eye-catching presentation, good argument and strong validity.

The site was the most northerly part of Ørestad, a new urban development in Copenhagen. It marks the border of the existing city with the new and it is bounded by the refurbished campus buildings from Copenhagen University, and across the road a new very dense urban development of 124,000m² by Bjarne Ingels Group (BIG) called

'Batteriet' (or The Battery). It comprises of a plinth with up to eighteen storey buildings, including a mosque and minarets, in a cascading architectural interpretation of an Alpine landscape.

The south of the site is formed by a pedestrian street called La Rambla, which is an extension on Njalsgade coming from the harbour and Islands Brygge forming a visual vista from the old to the new. The site is then flanked by the campus buildings and the *'Metropole,'* an eight storey office building, strategically situated between the boulevard and La Rambla, beside the metro station to the university complex.

The programme required, a total area of 9,500m², of which 5,000m² was student residential accommodation, 500m² was a kindergarten, 1,000m² parking, and 3,000m² commercial floor area. It was to have an energy class for 2020, with a daylight factor of 2% for residential, 7% commercial, 5% kindergarten (with 2% for all ancillary offices), under an expected minimum 1,500 hours of sunshine per annum.

The organisers set-up a common Dropbox, (a web based file hosting service that uses cloud computing that allows users access and sharing of fully synchronised files across the internet), and a group Dropbox for each group. All information, inspiration, lectures and software links were placed here. The group box was a place to work.

Autodesk, Graphisoft and a few other software producers, with support, were at hand to help install and start up all the programmes we were to use. The list included:

• Revit Architecture	• Archicad
• Revit Structure	• Rhino
• Revit MEP	• Designbuilder
• Autocad	• Rockwool Energy
• 3DS Max Design	• Weather Tool
• Showcase	• Win Air
• Quantity Takeoff,	• Relux
• Navisworks Manage	• Radiance
• Inventor Fusion	• A+E 3D
• Ecotect Analysis	• VELUX Daylight Visualiser
• Vasari	• Code Group Sigma
• IES	• Microsoft Project

Some of the lesser-known products are niche markets, and it must be stressed, not all were used, given the short period we were engaged in, but the biggest players were Revit, Vasari and Ecotect. From these an IFC model could be uploaded to the Dalux's BIM checker, which in turn generated a report to test compliance. The eventual winners also used, Tekla, Robot and Sigma, having also knowledge of Inventor and Rhino. First prize was an evening at *'Restaurant Noma'*, (winner of *'The World's 50 Best'* in 2010), with consolation prizes of iPads and commercial software licenses.

What was learned from the workshop was that co-operation and collaboration were critical to achieving substantial results. In the groups where there was resistance to placing work on the Dropbox, there was a price to pay. While it is easy to see it now, these groups did not have trust, in a professional sense, in place. Largely this was due to architects (both practicing and students) not wishing to relinquish fledgling concepts until they were fleshed out. This was typified by one architect removing/deleting their work after the final presentations from the Dropbox, rather than letting the work be archived for later analysis.

The better performing groups had a majority of technologists, 3:2, and while it is true to say that the workshop was very orientated to the implementation of technology, those architects who attended came with an admirable purpose, but resorted to type under the intense pressure and nature of a workshop. This underlines one of the issues endemic in the industry.

Jan Søndergaard, an eminent architect and professor in Denmark, presented a lecture during the workshop where he beautifully distilled the essence out of a project for *'Dacha on the Volga'*, north of Moscow. It was reminiscent of his own summerhouse district, and drew heavily on the plot patterns and typologies ingrained there. But significantly he also stressed the need for and a mechanism to exclude other stakeholders from the design, until the essential elements were in place. He drew an implicit observation that in excluding a rack of unqualified personnel, that he kept control of the layers of the design as they unfolded. He also lamented in the aftermath discussion that the days were gone, when architects *'were best friends with the client'*.

During the follow-up debate, this exclusion was defended by architects but attacked by those who were excluded. It ended with that this is one of the reasons why it is difficult for stakeholders to work with architects. That increasingly the architect is brought in for this qualified purpose, but removed as quickly as politely possible from the supply chain afterwards. It was a very dignified debate with openness and honesty from both sides. It also redoubled everyone's efforts to build and mend the bridges in the workshop.

One area where this worked was in meeting the brief requirements. Because of the BIM Checker there had to be teamwork. Once the functions and adjacency diagrams were in place the rooms had to be *'instance coded'* in precise terms for uploading. Once the form was made there had to be testing to check shading, solar gain and energy consumption.

In our group once the quantity and form was placed on the site it was quickly agreed that the architectural devices to use were the adjacency of the mosque and its juxtaposition to La Rambla, which suggested strong ties with Moorish architecture in Andalucia, notably the Mesquite in Cordoba and its Orangerie. The green facades of the neighbouring project (KUA2) were seen as a device to tie both together and the vista from Islands Brygge to the site along La Rambla was seen as similar to the Vista stop made by the Guigenheim in Bilbao.

Once the project's programme was approved by the BIM Checker, the building's form could be tweaked and manipulated. This meant it was possible now to make architectural statements addressing these issues, backed up by a checking system and this was empowering. Essentially, we achieved in four days intensively what might pass for a whole semester's project at the school in other circumstances. Granted it only stretched over Concept and Design Development work stages, but the gist of it can be appreciated.

Had it continued into Technical Design and Production Information then programmes like Sigma and (MS) Project could have delivered more of the 4D and 5D that is happening in the classroom and increasingly in the industry. With programmes like Navisworks, Tekla and Solibri the project could be both time-lined, checked and visualised for all stakeholders.

At the other end of the process, and to address the other aspect of this chapter, I will now venture into the management end of things. Here I will use the example of 2nd Semester at the Copenhagen School of Design & Technology. The group in question comprised of one trained trade, and four matriculating students (ie direct from second level education). They came from Denmark, India, Pakistan, Kosovo and The Faroe Isles (3 male, 2 female). After only being less than one year at the school and most of them having no experience of Danish culture, building technology, or the new building regulations (especially regarding the new energy frame), they epitomise the communication value of a common model and group work, or better still, collaborative work.

In no particular order individual skills improved in modelling, detailing, visualising, another was intellectually strong and one was seriously ill (being hospitalised for a short period) during the semester. This is not to add weight or bias to any one aspect, but to put into a context the differing layers affecting them, and the need to bring each other along, and keep each other in the loop.

The scope of the assignment is a two centre project where the same brief is contrived to be built in two climatically differing places, in this case just north of Copenhagen, facing east into the Øresund (sea), and just north of the Bulgarian border in Romania facing east into the Black Sea. This also impacts the cultural differences, local materials and building techniques. By the time the assignment is complete both projects describe the journey through which they have travelled both in terms of form and programme, and the learning outcomes support an appreciation as to why they have become different.

During the semester, there were two evaluations and at the first, there was difficulty just in mapping the two projects, which was further compounded for the teachers who found it difficult to see what related to what. At the next evaluation job numbers and discipline had entered the fray and light began to emerge at the end of the tunnel. At the final exam, all five were very well versed in both projects and very confident in both questioning and presenting, with no difficulty in comparing and contrasting as well as defending decisions taken during the journey.

Once the model was broadly in place, there was more time than usual (or previously, ie prior to modelling) to spend on polishing their call outs, specifications, schedules and general documentation. One example was that a detail, which when presented at an evaluation comprised of five parallel lines (a standard construction of the flat roof). This particular drawing was so transformed that it was now deemed *publishable* in the words of the examiners.

The external examiner, who previously had been the dean (head) at another technologist school (where he had also been a teacher) and now being an examiner, chose to compliment their presentation, awarding them all top marks. He added, that in all his time as dean, teaching and as an external examiner this was the best presentation he had ever seen and while there were mistakes in the work, he felt that this work was of a graduation standard.

Furthermore at the beginning of the exam, he was worried about the amount of information technology taking over from the technological *'screwing of a building together'* as he put it. After the exam, he was impressed and converted to the idea, seeing now the value and worth of modelling. One of the key moments in the presentation was where the model was brought into a viewer (Navisworks) from where time-lining, process and interactive viewing with embedded hotspots that could link to schedules, key junctions or standard constructions. The communicative significance of this alone was immense, both to the students and the staff.

7.8 How the Opportunities, afforded by the pervasive use of IT within construction, are Impacting Associated Management Structures

7.8.1 Introduction

Associated management structures affect the whole supply chain and the maintenance programme that follows occupation of a facility. At the start of this research, my work was limited by and large to the procurement model and the application of a new technology. Very quickly, this was found to be too constricting and a new structure was sought. Increasingly the scope widened to include not only the procurement disciplines, or AEC as they are also called, but also all stakeholders from the financing institutions to the ultimate users. In between this also affected the contractors and sub-contractors to a depth not knowingly foreseen but to a degree where they cannot be excluded now, nor even conceivably so.

In this chapter, I will address this aspect and how it is impacting the industry. It is eloquently dealt with in Terminal 5 but without the FM part. It is also raised with Kimon Onuma and his BIMStorms, especially where he enters into the monitoring of facilities for optimal function and purpose. It is also intrinsic in many of the partnering projects that are increasingly happening today, where the client is closely involved with the planning and delivery of the project but does not take over the facility upon completion, preferring that the developer remains onboard and responsible. This insures better procurement practices since the risk and quality remain in the developers' domain, and are not concluded at handover.

James Woudhuysen and Ian Abley in their book; *'Why is construction so backward?'* (Woudhuysen, Abley 2004) refer among others to the slowly evolving process with reference to BAA's two new airport terminals; Stansted and Terminal 5. In the first, there is recognition for the need of better control with a common data environment, thought to deliver 10% savings. While in the latter, single supply chain savings are forecast to reach 20%. There is a nice progression here, in subsequent projects.

In Stansted, spatial co-ordination and integrity were achieved by preparing a 3D model from 2D drawings (it was the mid 1990's). It was noted then that a common area for concern was the integration of building services, were at one point 2,500 clashes were identified, astoundingly, in a mere two minutes. The result of the exchange of information over a project extranet is cited as the major cause of the ten per cent savings. As Dan Golden of NASA once said:

'We should build prototypes in the inexpensive virtual world, not the very expensive real world'.

With Terminal 5, as stated elsewhere, higher controls and standardisation were achieved using their *'T5 Agreement is the Delivery Team Handbook'*, which was both a contract and handbook for all involved. This alone resulted in the twenty percent forecast savings. Coupled with a new method for risk assessment and inbuilt design flexibility (Gil, Tether 2010) better ways at incorporating flexibility in the design increased the adaptability of the project outcome.

This brought effectiveness to a project of this magnitude, while efficiency demanded managing the risks from design with a certain amount of fluidity, to deliver the project *'on time and to budget'*. This was due to the fact that planning and limiting all the commercial portfolios at the beginning of the project, while aiding the designers, would curtail and restrict the leases, especially in the duty free area, to an unmanageable degree. Shopping trends and marketing can change very quickly meaning it is difficult to tie down (commercial) anchors at an early point in the design. Rather they would like to express an early interest, but only commit later in the process, closer to completion when the market's buoyancy and expectations are better known.

The role of GIS has a significant influence here but it is addressed in another chapter. Likewise, the impact of augmented reality and the advances in smart technologies will be dealt with later. I will now look at the impact of the new opportunities on management and the process, followed by a look at the changing role and the depth and malaise that can be found towards adoption.

7.8.2 The Impact on Management

The opportunities for Information Technology (IT) and Information Management Technology (IMT) are immense and growing daily. As mentioned in my introduction both AIA and RIBA, to name the main protagonists, are seriously looking at the implications of IT on their work stages and the procedural recommendations for their members.

The definition of Integrated Practice (IP) (AIA California Council) is defined as:

'At its essence, it is a deeply collaborative process that uses best available technology, but goes beyond merely the application of digital tools, such as Building Information Modelling. Second, the Essential Principles are set forth as necessary assumptions in this collaborative process. Unless all parties are committed to these principles, integrated practice will not succeed. Finally, the Working Definition characterizes project workflow beginning with Building an Integrated Team and concluding with Integrated Closeout'.

They have invested time and money in looking at *'how, who and what…'* as well as the realisation. They define the essential principles required and compare them to business models. This work parallels what has gone on in the digitalisation of commercial markets and the dotcom era. James Carlopio (Carlopio) in his book *'Changing Gears: The Strategic Implementation of Technology'*, outlines the trials and tribulations faced in this segment of the market. Much of his insight applies equally well in this emerging segment.

Defining the current model will require some form of measurement, both for the Design Team and the Architectural Technologist. But interestingly, contractual documentation in the form of *'ConsensusDOCS'* is making progress with the mantra of avoiding litigation among parties, because it is seen as unproductive and very negative when viewed in the larger context of the good of the industry.

'ConsensusDOCS' is a series of standard contract documents written and endorsed by a coalition of 34 leading construction industry organizations in North America (Perlberg, Ciliberto et al. 2011). The *'DOCS'* part is an abbreviation for the Design, Owner, Contractor, (Subcontractor) and Surety organizations represented in the coalition. They offer over 90 different construction contract documents through many methods of project delivery. Their mission is to advance the design and construction industry, by identifying and utilising best practices, and fairly allocating risks to all parties.

One of the major drawbacks with them is that AIA has not been as active in the formulation as might be hoped, preferring their own AIA Contracts. This means that ConsensusDOCS do not provide a *significant* role for the architect during the construction phase of the project. Furthermore, the role of the architect during construction is principally limited to certification of payment applications and certification of substantial completion. This tends to marginalise the architect's role (Cobleigh 2008).

Secondly, the AIA mean that there was little or no input from the design industry in the process. Neither the AIA, nor the Engineers Joint Contract Documents Committee (EJCDC), including many other engineering associations have endorsed ConsensusDOCS. Finally, the AIA mean that they themselves have been publishing *standard form documents* for 120 years. That they are time tested and widely used. That a huge body of case law exists around their contract provisions, and that the ConsensusDOCS are largely either new documents or edited versions of former AGC documents.

Clearly there can be seen some heavy posturing here and a stern contest to front negotiations and contract administration. In looking at who endorses ConsensusDOCS, it is clear that it is the contractor organisations alone, where the professional organisations have stepped back. This situation harks back largely to whether architects win appointments and form procurement teams, or whether contractors and/or increasingly consultancy engineers take over this mantle. The latter scenario brings the architect in as a sub-contractor for the design alone while keeping the risk and establishing best practices in-house. This broadly is the crux to the problem to which I will return.

That said, ConsensusDOCS contract document series include:

- General Contracting (200 Series)

Including Standard Agreement and General Conditions Between Owner and Constructor, to Change Orders, Bonds and Certificates.

Collaborative/Integrated Project Delivery (300 Series)

Including; Standard Form of Tri-Party Agreement for Integrated Project Delivery, Building Information Modeling (BIM) Addendum and Green Building Addendum.

- Design-Build (400 Series)

Including; Standard Design-Build Agreement and General Conditions Between Owner and Design-Builder, various Standard Agreements and a Statement of Qualifications.

- Construction Management (500 Series)

Including (but again not exhaustively); various Agreements and General Conditions Between Owner and Construction Manager and Change Order/Construction Manager Fee Adjustment.

- Subcontracting (700 Series)

Including: Standard Purchase Agreement for a Contractor, Invitation to Bid/Sub-bid Proposal and various other agreements.

- Program Management (800 Series)

Including; Standard Program Management Agreement and General Conditions Between Owner and Program Manager among others.

Being contractors there is a serious attempt at getting the contract right. Jack Mumma, J.D., Past Vice-Chair of the ConsensusDOCS Drafting Council said:

> *'Today's biggest opportunities in design and construction are based on collaboration and information sharing... in the hope that this will improve the process for all.'*

In their literature, (Mumma, Beck et al. 2011) they stress that this puts the owner back in the driving seat, with regard to control and delegation;

- That transactional costs and time are saved by having a flexible structure in place;

- That it attracts the best contractors and pricing, with better and fairer results in plainer language;
- That it leads to better projects and brings success and progress while saving costs and time
- Contentiously, they claim that the architect's authority is now properly aligned with the owner's goals; with improved access to copyright.
- That it prevents, mitigates, resolves disputes and claims before they become intractable, meaning communication is better with incentives to settle arbitration claims.
- That it establishes positive working relationships with direct communication, acting ethically and being better focused with innovative mitigation procedures.
- Moreover, there are strident claims that it accommodates BIM satisfactorily, within the process, as well as electronic protocols (in a land where a wet signature is still obligatory).
- That it has a tri-party platform for collaborative agreement, with a core management team, that yields greater efficiency and reduces waste.
- Finally, they claim there is a better-balanced approach to liability exposure, adopting a mature approach to consequential and liquidated damages.

Leaving the last word with the architects (Allison 2010):

'The key to smoothing the downhill slope with the multi-party agreement is goal alignment. There are many measures of success on a project: satisfied clients, a stellar safety record, on-time delivery, reduced cost, no claims, and public recognition are just a few. However, almost all of the entities involved in the project will have some sort of monetary goal buried in their hopes for the project. The owner typically has a pro-forma budget for their project. Designers are typically compensated on an hourly basis. Builders are looking to beat their estimates'.

7.8.3 The Impact of the Process

Leaving the legal side of things aside and delving into process itself opens up a refreshingly new aspect. Authoring the model is one thing, how it is used and by whom is the next development. From the project's usual preamble and in connection to the architect's work stages it starts with commissioning and the conceptual phase of building. But there are arguments mainly from Facilities Management (FM) that their input should also be harnessed into model at inception, and that their outcomes should also be extracted from the model after handover and through operations and maintenance or that Life Cycle Assessment needs to be brought into the picture.

Beyond FM, all the differing stakeholders in the project team have an agenda and a goal to both enter data into the model, and interact with the other stakeholders to progress the project through all phases to practical completion. Issues arise in how that data has to be protected. Issues also arise in who controls the entry of data, who checks the fidelity of the entered data and who integrates and filters the entered data for the other stakeholders in the equation.

Generally the above calls for some form of management. For the model to be robust enough and to manage *itself* is a recipe for disaster. For each to be responsible for their own data has potential, but also challenges how well the data is entered. Finally who takes overall responsibility for the wealth and well being of the model and who owns the model all leave much unanswered and the water's muddied.

Traditionally these issues are met with each discipline building their own model (internally or in isolation) and then tabling their (many) models at meetings for discussion or more often than not sending copies to each other for verification. This process is nothing more than the normal method of correlating data and is both time consuming and error prone, which was the object of the exercise to minimise or eradicate.

If there are two or more models, then the likelihood of uncorrelated mistakes increase. If there is one model then practical considerations come into play. Prime here is ownership. Is it part owned by each stakeholder or is there mutual or communal ownership.

Next is size and manageability, several stakeholders will have a multitude of differing needs and requirements from the model. Some will be all consuming, others will be marginal. Methods are then necessary to marshal and protect each stakeholder's input, while making it available to the others for inspection and use. This system of bells and whistles is not thoroughly accepted and endorsed by all the disciplines and needs more work from vendors to make it transparent and robust.

Finally should all stakeholders have the same set of work tools or the same workbox of tools to author and analyse the project. The answer is no and this is the most interesting paradigm shift in building information modelling. Undoubtedly architects and engineers (both structural and services) will need compatible authoring software, and this is currently a leading debate with several vendors and several players all making largesse in the attempt to capture the market. But the reality is that there will never be a single source and so appropriate management considerations need to come into the equation. Some form of transparency can be attained with the use and enforcement of Open Standards such as Industry Foundation Classes (IFC's) being the lowest common denominator for all programmes (Pazlar, Turk 2008).

Beyond authoring there is a need for the analysis of the data provided, and this comes in two forms, one where the model is interrogated to establish that the proposals are up to grade. This can be seen in Code Checking and Life Cycle Assessment. Code Checking offers the ability to check the model against proscribed code that has been written from state legislature, local planning and building regulations (Conover 2008a). The other, life cycle costing and sustainability can be checked through simulation against acoustic data, energy frames, lighting data, heating and cooling patterns, daylighting factors and finite element analysis to name a few. Compliance can quickly be ascertained or reports can be generated showing the extent of conformity or where agreement needs to be entered into to complete the process.

At the other end of the equation, the data can be also extracted in the form of quantities, allowing resources and costs to be allocated for the procurement stage of the project. Here the model is transformed from graphic data to numeric data and a new set of programmes allow the fourth and fifth dimensions to be added to the model. The fourth dimension is time and the fifth resources (materials and manpower). This phase is being driven by contractors who were not initially identified as main drivers (Young, Jones et al. 2008).

It does not end there either, the next wave will see sub-contractors accessing the model to extract the material and quantities they need to complete their portion of the work and to also liaise with others as to when the work will commence and when it will be expected to be completed. But it is not expected that the white-van-man or the site-hut-container will have multi-licensing software or state-of-the-art hardware installed for their pleasure. No just as a document authored in Microsoft Word (DOC) can be printed as an Adobe Portable Document Format (PDF) file to make it available, without making it editable has transformed the way the written word has been digitalised, so will add-ons like Naviswork's Freedom perform a similar role on the building site (Hardin 2009).

Typically, these add-ons will allow scheduling and take-offs to be performed, as well as allowing clash detection or best fit operations to be carried out before committing resources. It is also well within the realms of possibility that Radio Frequency IDentification's (RFID's) will become more prevalent on-site, meaning that hand held devices will continue to proliferate the building site in a similar fashion as to when mobile phones first appeared a decade or more ago. Sub-contractors were welding these small additions long before the suits in the city, incidentally they even had pockets in their overall legs, long before one existed inside the jacket of business suits.

Where smart devices will come into their own, is in a capacity to provide just-in-time information in the right place at the right time. Take for example the delivery and installation of a pre-cast concrete staircase. On-going trials are placing RFID's, embedded into the concrete, that can be activated by mobile phones. Radio Frequency IDentification (RFID) is an automated identification process based on the storage and retrieval of data using transponders or tags.

An RFID is a *'tagging'* system, like *'bar codes'*, where each building element can have tags in-built that are then read by radio waves, not unlike metal detectors. The technology consists of a tag containing information, together with an antenna, or a radio-transponder, and a reader. Once it can receive the radio signals, it can return information. The RFIDs can be either passive or active.

In a passive tag, radio waves from the reader induce power in the tag, so radio-signals here can be transmitted and be readable by the reader. The distance between the tag and the receiver ranges from a couple of centimetres up to ten meters, depending on the frequency of the radio waves. The amount of data is small; often only an identification like an easy-to-read barcode. The information must be less than 8kb, typically a short sentence or a URL, which can link to more substantial data on a web site. The tags can be scattered widely in a building material like concrete due to low pricing.

So with regard to our staircase, information about on-site assembly, location data, metadata about grade of concrete, reinforcing and fire rating can be embedded and be recalled by waving a Smartphone over it or pointing at the fixture points. Where more information is required, the phone can be directed to an installation guide on the products home page, or to interactive videos describing the assembly or installation. The same could be relevant through the building's life cycle and especially at the decommissioning phase, there could be aid to demolition.

The active RFID tag has access to power, or a connection to the power supply, allowing the transmission of signals over longer distances. This would not have the same appeal merely embedded in a building material per se, but might have broader application as a sensory technology with access to a web monitor. The technology implies that data from a building part, for instance a roof, or a room, can be read and combined with other information on the net, can be transferred to a reader. This would make it possible to get information about the building, on health and safety, or information about the building in use (leaking roofs or snow loads), or about temperature and ventilation in rooms, for automatic regulation of the temperature and ventilation (Storgaard, Forman 2009).

This kind of management greatly improves the workload for a facilities manager and makes the building part more adaptive to its environment. But to be productive it needs a whole new structure to manage the operation, and it ties the two phases, procurement and operations and maintenance, neatly together. It too has the potential bring all stakeholders closer at handover so that there is less data lost and a better appreciation for each other's effort.

7.8.4 Depth of Problem in Adoption for all Stakeholders

The appreciation of all stakeholders' worth is a slow process. From a generational handover perspective it needs to be corrected with the new generation of personnel coming into the industry. The scope of the work therefore must also include the educational establishments. From my experience both from academia and the building trade there is a need for more leadership in this area, largely because it is an evolving phenomenon. SketchUp is a good example of this. There has been a noted uptake of SketchUp in many classes both where I teach and where I study, because it is easy to learn and the results look good. SketchUp was acquired by Google, so its future is assured.

But the problem with SketchUp is that while it is intuitive, it is a dead-end in itself. It cannot be brought into the next phase of the design without rework, or by beginning from scratch again. While many designers see this as a reiterate process, which allows the design to be scrutinised again and again, there is also the great danger of losing data. You cannot right click an element in SketchUp and add data. It is dumb geometry.

But such was its allure and popularity that Autodesk recently launched Vasari, *their own version of* SketchUp. It differs in that it uses the Revit file format (RVT), so that continuity is assured in the design process. There is now ensured a clear execution of design intent when moving from design to production. They claim that Vasari is an easy-to-use, expressive design tool for creating building concepts. Significantly, it has integrated analysis tools for energy and carbon testing, weaned from their sister product Ecotect. In having energy modeling and analysis features support, it makes wanting to use it an important facet in their end-user profiling.

This provides informed insight where the most important design decisions are being made, according to Patrick McLeamy and his BIM, BAM, BOOM principle. While it is focused on conceptual building design using geometric and parametric modeling, it is intended as tool for architects, especially technically challenged ones.

This is a very interesting development. Back in 2008, when making the switch from Autodesk Architectural Desktop/Architecture 2008 to Revit Architecture 2008 (ADT - Revit) there was a tremendous uptake at our school. It was intended that there would be introduction courses in the first three weeks for second semester (the trial project), but word of mouth saw 60% plus of the school wanting to adopt it within the agreed testing period of four months. Ultimately, the school saw a threefold productivity rate over earlier ADT classes. Essentially this happened in unquantifiable numbers, meaning the school hierarchy was not running the show.

As management we did not see this coming, indeed the other five technologist schools in Denmark, the technologist institute and the industry itself, looked on keenly to see how it developed, (they all have since adopted). There was indeed great interest, but there was much scepticism too. Within the school, too there was some resistance by the other disciplines, which is still ingrained in many parts of the school. Regularly there are tabled requests for a return to CAD and/or the pencil. That learning from first principles rather than learning another programme is the correct procedure.

At a recent planning meeting for the implementation of BIM next year, there was a serious call for parallel CAD courses, because some of the intern practices, where our students go for practical training, are complaining that our students cannot use CAD. It must be stated that the need for BIM skills is beginning to see our graduates employed, even during the prolonged recession. It has also recently been accepted that Navisworks or similar needs to be added to the tool set our students learn. But this too was not without a battle.

It has been said to me that it is not the students who do not want it, they do, and especially when they see the impact on their work, but the teachers who see themselves marginalised if they do not adopt the new process. My response to date has been to try and implement the programmes to their teaching methods in the hope that the student will bridge the gap. It is a sense of coaching that has evolved, supported by show case projects when the synthesis is achieved.

7.8.5 Management's Changing Role to Deal with Digitalisation

While on the one hand there has been an in-depth discussion of digitalisation and its impact on technology, there is an equally valid concern with regard to how management, and all it entails, embraces this virtual world. We have seen how the CAD era initially failed to bring management on board, and now how BIM is intrinsically not in the same process (to be renegotiated), but rather in a paradigm shift. So, how is the new message being brought across, applied and scaled?

In the mid-1990's, there was a marked period of innovation, in corporate IT, when enterprise software applications, typically enterprise resource management (ERP), customer relationship management (CRM), and enterprise content management (ECM), became indispensible practical tools for business. Corporate investments in IT surged during this time from about $3,500 spent per worker in 1994 to about $8,000 in 2005, (according the U.S Bureau of Economic Analysis) (McAfee, Brynjolfsson 2008).

But Chip Jarnagin tells us in 2008 that *'the failure rate for IT projects is reported to be around 70%, with the most cited reason for project failure being an unclear project vision/purpose as it relates to the business'* (Basu, Jarnagin 2008b). What is critical here is the how the message is interpreted in the business model. On the other hand, Jack Dorsey, the founder of *'Twitter'*, revealed recently that the mobile payments system, *'Square'*, of which he is CEO, is already processing an incredible $3 million in transactions per day. Just three months ago, it was seeing only $1 million in transactions per 24-hours (Essany 2011). Cleary there is volatility here, but we can also see that where there is clarity that the technology is winning out, especially if its potential is apparent and rewarding.

'In Praise of Dissimilarity', Gibbert introduces us to a completely different tack, also worth exploring. This involves the concept of *'similarities'* and the association businesses place on them when evaluating capital expenditure. Managers' traditional understanding of *'similarity'* has been taxonomic, whether explicitly or implicitly (Gibbert, Hoegl 2011). Taxonomy in general is the practice and science of classification.

So when Intel, a computer hardware chip manufacturer, bought McAfee, an antivirus software manufacturer, for a record $7.7 Billion, (their biggest in history), The Financial Times was very puzzled by the acquisition of these two most dissimilar entities. Apparently, in justification, experts envisage that the chips can and will be improved against viral attacks. Nevertheless, cognitive psychology goes further suggesting that there is something called a *'thematic similarity'*. Gibbert even supports this with a riddle; *'what has an athlete's footwear to do with a MP3 player, and the answer is in their association to working-out in a gym'*.

Figure 13 Joke in similar vein, courtesy of Facebook

So in essence, there are new territories to explore and new markets to exploit. What Gibbert is telling us, is that there are new breeds of manager open to this association of dissimilar entities that would otherwise be blinkered using traditional methods. Finding these types in the construction world might be an awesome task, but likewise preparing for their appearance would be an astute one too. Where the argument begins to bear relevance is in his next comment that:

'The first camera phone appeared in 2001, but it took smart phone manufacturers six years to integrate the GPS and camera function'.

With regard to BIM, there is a similar situation. This can be found in the association of BIM with GIS. Essentially they are two most dissimilar entities, with one based wholly in the 3D world and the other very much in data layers. Furthermore, there are not pan-uniform definitions of the term, and even more so, *'business model'* terms. Mark Bew takes us through some very interesting definitions of BIM, including how it is interpreted by the various stakeholders, drawing particular attention to:

'...keeping critical design information in digital form' (to make it) 'easier to update and share, and more valuable to the firms creating and using it'

As well as:

'...creating real-time consistent relationships between digital design data, with innovative parametric building information modeling technology' (to make it) 'possible to save significant amounts of time and money and increase project productivity and quality'

These two comments encapsulate very well much of what BIM is about to those who understand it, but as he rightly continues, they fall far short of what could or usually is presented to a CEO, or boardroom, in a language that made sense to them (Bew, Underwood 2010).

So considering when Citibank decided to tactically force information technology on to electronic banking, it dramatically changed the banking. When American Hospital Supply decided to reshape its customers' supply chain and procurement processes through order entry terminals in customer sites, it positioned the company to compete effectively in healthcare cost management. When American Airlines pushed its travel solutions systems to customers, it changed the travel industry forever (Basu, Jarnagin 2008a).

But despite these visionary examples there is clearly a lack of functioning communication and interaction between general management and IT, which Jarnagin describes as a glass wall, not unlike the glass ceiling often alluded to in gender promotions in business. He goes on to define the cause for this:

> *'There are five primary reasons for the development of the wall: mindset differences between the management staff and the IT staff, language differences, social influences, the immaturity of IT governance, and the difficulty of managing rapidly changing technology'.*

The mindset is akin to left side (brain) people, largely IT personnel, talking to right sided people, usually management. The person hired to bridge this gap is the ubiquitous Chief Information Officer (CIO), referred to here as the Chief *'Integration'* Officer. The next is language and this is easily alluded to in the jargon that surrounds both spheres in their encoded acronyms. The next could be described as a cheap shot, but the social standing of *'geeks and nerds'* within the IT community is easily recognised (rightly or wrongly), followed by the immaturity of this largely new discipline. Finally, there is reference towards the rapidly changing rate of the technology, and the resources needed to master it.

If the solution, as he says, is to *'detect, assess, and respond'* then *'flexibility'* is named as the key in healing this rift. This involves bringing in IT literacy into the boardroom, and coupling this with effective leadership. This can be implemented with the notional rotation of management roles within these positions. It can also be helped by creating new demand, to align strategies across the board. Finally, removing the jargon, rationalising the expenditure and creating an IT portfolio, aids the demystifying of the two polarities, while bringing transparency and analysis, which ultimately restores confidence.

This warped thinking has progressed to the point that if you search in New York for *'movie show times',* the results now are tailored to that vicinity only, which of course, opens up innovative and opportunistic potential, lateral fields rather than closeted vertical silos. This implicit progression from a simple association has led to new markets and applications. Just as app.'s can now find a vacant parking space with a street or two of where you are searching, it is very indicative of how intuitive and indispensible that these small aides can become, and how apt they are becoming (Jarnagin, Slocum 2007).

This brings us back to the mindset and a new layer of thematic similarities in BIM. Once elements or components are formed, then data and fields can be attached to them. With the bridging of BIM and GIS then a whole new plethora of associations, present themselves. The Real Estate Norms (REN) might link themselves to Appraisal and Brief work stages, giving a better-informed picture. Very soon, it will be a punitive exercise not to have these features included.

Isikdag draws attention to the single shared information backbone that BIM affords us. He also points out that some urban management tasks, and cityscape visualisations are managed using Geospatial Information Systems (GIS). These two unrelated fields are can be conjoined using a BIM web Service, which he calls *'RESTfull BIM'*. REST is an anagram for Representational State Transfer, and this is a method of allowing both entities to integrate (Isikdag 2010).

Dr. Dennis Shelden at a conference in 2006 spoke about sport stadia design and parametrics concerning the capacity and the breakdown, or the demographics, of the spectators. In real-time, on screen, he entered a capacity for the stadium, together with a percentage for corporate hospitality, all the way down to the proportion and percentage of the cheapest seats, which resulted in a bowl design, meeting the specified criteria. Changing any of the aforementioned fields met with an immediate response. Making changes to the form with sight lines or proximity to the playing area, reflected in the schedule reports generated from the model, informing the potential capacity and match-day revenue. He concluded that you would have to be suicidal not to implement this parametric before financing any sporting stadium (Shelden 2006).

What this reinforces is the notion that the model can be interrogated and analysed even at the formative stage of the design. The importance of this is slowly permeating through the decision making process that engages management.

With regard to expertise in BIM, Randy Deutsch maintains that opting for depth over breadth is a false choice. He means that it will lead individuals, organizations, professionals, and industry in the wrong direction. Expertise, he claims, is a much more social, fluid, and iterative process than it used to be.

> *'Being an expert is no longer about telling people what you know so much as understanding what questions to ask, who to ask, and applying knowledge flexibly and contextually to the specific situation at hand. Expertise has often been associated with teaching and mentoring. Today it's more concerned with learning than knowing: less to do with continuing education and more with practicing and engaging in continuous education.'*

Developing this idea he goes on to ask the critical question:

'The answer to should I be, a specialist or generalist, is yes (both). There must be people who can see the details as well as those who can see the big picture. One gift of the design professional is the rare (and underappreciated) ability to do both simultaneously. As with any hybrid-generalizing specialist or specializing generalist-one's strength provides the confidence to contribute openly from many vantage points and perspectives'.

He then draws on a metaphor in the shape of a capital 'T' to illustrate the two parts:

It is critical for "T-shaped" experts to reach out and make connections (the horizontal arm of the T) in all the areas they know little or nothing about from their base of technical competence (the vertical arm of the T). T-shaped experts have confidence because of their assurance that they know or do one thing well.' (Deutsch 2011)

This concludes with:

'Design professionals must be both BIM technologist and building technologist. Those who accept this model will lead, persevere, and flourish in our new economy.'

'It is not just that the integrated team is now multidisciplinary, but we each must become multidisciplinary. Doing so requires a multidisciplinary mindset. This entails empathy, a genuine appreciation for others' ideas, seeing from many perspectives, and anticipating possible consequences to any course of action'

Before BIM, leadership and management was by and large top-down with someone senior designing or detailing, having some underling drawing it up. BIM demands a different workflow; namely side by side. Increasingly the senior and junior professional will need to use and help each other through the design process. However, it does not end there either, this binary operation grows into a network of others working together, and this network needs management and understanding.

With *'whole building design'*, the project team needs a collective vision. This is being heralded by Bill Reed as the *'Composite Master Builder'*. The term harks back to the Master Builder of old. The intention is to bring all of the specialists together, allowing them to function as if they were one mind. The process avoids, as Mario Salvadori says, the *'reciprocal ignorance'* of the specialists in the design and building field (Gabrielli 2006).

The team can include:

- site professionals, such as planners, civil and environmental engineers, and landscape architects
- design team members such as programmers, architects, and interior designers
- building systems experts, such as structural, mechanical, fire protection, and building science and performance engineers

- construction professionals, including cost estimators, project managers, trades people, and crafts people
- owners, including financial managers, building users, and operations and maintenance staff
- local code and fire officials

An architect is ideally suited for the leadership of design teams, because of their legal obligations to the profession, comprehensive training in holistic problem solving, and an understanding of broad cultural concerns. This presumes that architects would maintain a clear overview of the project team's work, to oversee and coordinate the work of the project team.

7.9 The Manner in which Emerging Information Management Technologies (IMT) will Lead to an Evolution of the Manner in which the Construction Design Team is Structured

7.9.1 Introduction

The manner in which the design team is structured traditionally evolved around the architect as lead consultant. This role established the team, ran the job and administered the contract. The architect was the point of contact for the client and the architect often wined and dined clients, building up bonhomie and developing relationships. On large projects, those days are gone.

Design & Build, Partnering, PPP and PFI all indicate that the architect's role has diminished, with managers, controllers and contractors now manning the pole position. A poignant clause in an AIA contract (B141/CMa) states:

> *'The Architect shall not have control over or charge of and shall not be responsible for construction means, methods, techniques, sequences or procedures, or for safety precautions'.*

Compare this to the personal architectural services of the legendry architect Frank Lloyd Wright, who wrote:

> *'The Architect undertakes to itemise mill work and material for the building, lets contracts for piece work and eliminates the general contractor where possible by sending a qualified apprentice of the Taliesin Fellowship at the proper time to take charge, do the necessary shopping and hold the whole building operation together, checking cost layouts, etc... and endeavour to bring the work to successful conclusion.'*

Non-architectural professionals might roll their eyes up to the heavens and ask why is the architect there with regard to the former quote, while lamenting the iron fist that Wright wreaked havoc with regard to the latter. I am not unduly concerned with both comments, but when Rab Bennets describes the damaging schism between concept and detail work stages, with the following, then there is something to answer:

> *'...there is a rapidly increasing tendency to separate the concept from the detail, a divorce that leads in precisely the opposite direction to architectural integrity (Bennetts 2010'*

This chapter examines this development, looking at the procurement team, collaboration, trust and cost savings that can accrue from the emerging information technologies.

7.9.2 Evolution of the Manner in which the Design Team is Structured

In setting out his stall, Patrick MacLeamy, CEO of HoK, has made two major contributions to the debate about how and why changes must occur (MacLeamy 2010a,b).

The first is the now famous *'MacLeamy Curves'*. This is a bell chart showing the expected resources plotted against time for a traditional project procurement process. Naturally enough, the biggest portion is tied up in design development, technical design and production information stages, beginning with appraisal and brief formulation and tailing off with mobilisation and practical completion. Work stages C, D & E are the meatiest and most resourceful stages currently in most projects.

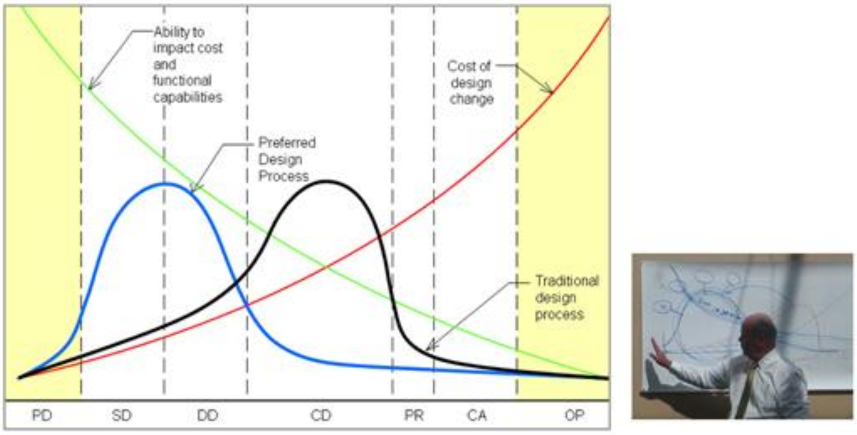


Figure 14 The MacLeamy Curves by Patrick MacLeamy CEO Hok. Courtesy of HoK

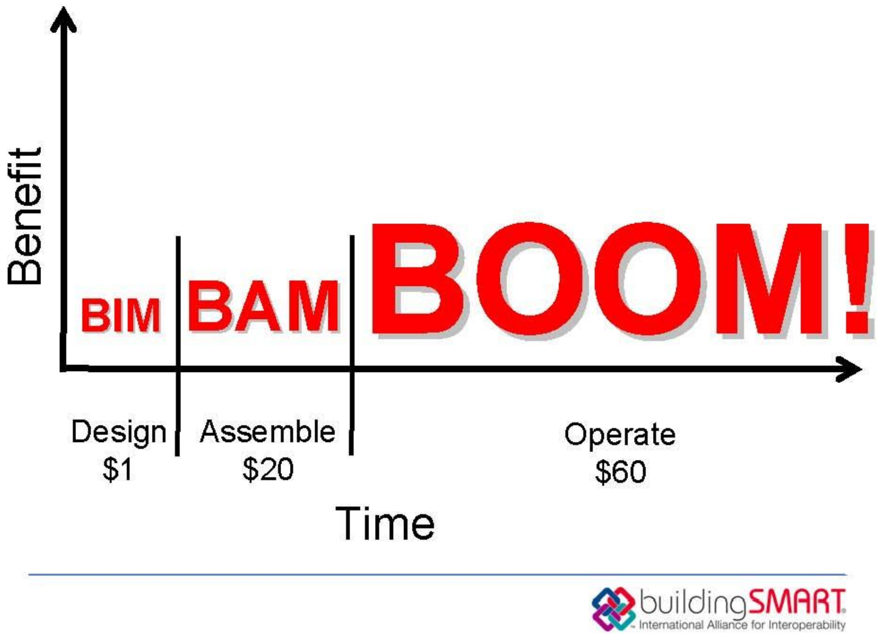


Figure 15 BIM; BAM BOOM by Patrick MacLeamy CEO HoK. Courtesy of HoK

With the adoption of BIM, more decisions and co-ordination mean that the bell chart moves more to the beginning of the time line. Mapping the two charts against each other shows a telling proportion outside the original line and this is where the risk lies. Risk in this instance is that work is being done but not remunerated according to the work stages, meaning should the work stop or falter the design team is out of pocket.

With the hopeful normal running of a job, payment catches up in production where this slack is recovered. Balancing the books would suggest a reforming of the work stages to spread the risk and charge a higher amount for the new work associated with BIM. Some do this, but many architectural firms, while acknowledging this also point out that charging more earlier is not an option for many architect/client relationships. They cite that the client cannot raise funds to offset this spike in the process, as the financial institutes have their own guidelines and clearly, they have not embraced BIM yet.

The other contribution is *'BIM, BAM, BOOM'*, where appropriately enough BIM means Building Information Model, BAM; Building Assembly Model and BOOM; Building Operation Optimisation Model. MacLeamy portrays the benefits over time, in the following fashion:

> *'For every dollar spent in design, twenty dollars are spent in construction and sixty dollars are spent in operating the building over its useful life of fifty years or more.'*

> *'... BIM supports development and testing of design ideas. BIM also supports budget and programme compliance, Finally, budget enables compliance with energy goals.'*

> *'... Contractors do not build these days, they assemble manufactured products brought to the site. Contractors now use BIM as a Building Assembly Model or BAM. BAM allows better scheduling, BAM facilitates sub-contractor co-ordination, BAM supports cost control and BAM manages construction value twenty times the cost of design.'*

> *'... During its lifetime, an owner can leverage BIM and BAM to optimise building operation. I call the use of the model in this manor Building Operation Optimisation Model or BOOM. BOOM helps the owner manage energy consumption. BOOM also helps the owner with scheduled maintenance. Since BOOM is managing a value of sixty times the value of design, the cost savings potential is enormous.'*

> *'... The real promise of BIM is better design, better construction and better operation. In short BIM, BAM, BOOM!'*

These two vignettes are very compelling, the first addresses the evolution within the design team and the office, the second the lifetime analysis of the building or project. Taking the first on board could ultimately herald a production programme of zero fees in the distant future, due to automation. The second changes the whole design philosophy, as facilities management leverages its way into the design office with demands both for the founding principles of the process right the way through to scheduled maintenance. Architects must find ways of facilitating these two evolutions or risk being marginalised out of the process. In their defence, they claim that they are a holistic profession, made for change management and new ways of working.

Examining the RIBA work stages and Plan of Work, reveals many options in how they can accommodate differing projects and contracts, and much time and effort has gone into making these differing scenarios. A parallel development is the plan of work for the Office of Government Commerce *'Gateways'* (OGC, UK), where the is focus to build up a programme of management, where *the best policy makers* have thought through the end-to-end process to translate policy into delivery plans and into desired outcomes (Crown 2009). It is underpinned as such:

Strategic Assessment: *'Is a programme (only) review that investigates the direction and planned outcomes..., together with the progress of its constituent projects. It is repeated over the life of the programme at key decision points'.* The assessment is then coupled up with several reviews during the project as follows:

0. Business Justification: *'The first project review comes after the Strategic Business Case has been prepared. It focuses on the project's business justification prior to the key decision on approval for development proposal'.*
1. Procurement Strategy: *'This review investigates the Outline Business Case and the delivery strategy before any formal approaches are made to prospective suppliers or delivery partners. It may be repeated in long or complex procurement situations'.*
2. Delivery Strategy: *'This review investigates the Outline Business Case and the delivery strategy before any formal approaches are made to prospective suppliers or delivery partners. It may be repeated in long or complex procurement situations'.*
3. (A) Design Brief and Concept Approval, (B) Detailed Design Approval followed by (C) an Investment Decision: *'This review investigates the Full Business Case and the governance arrangements for the investment decision. The Review takes place before a work order is place with a supplier and funding and resources committed. A project will normally go through on OGC Gateway Review 3. However, in some circumstances it may be necessary for a project to repeat the review'.*
4. Readiness for Service: *'This review focuses on the readiness of the organisation to go live with the necessary business changes, and the arrangements for management of the operational services'.*
5. Benefits Evaluation: *'This review confirms that the desired benefits of the project are being achieved, and the business changes are operating smoothly.*

The Review is repeated at regular intervals during the lifetime of the new service/facility'.

The philosophy of these reviews and checks is to ensure that government and estate spending is getting thorough inspection:

Delivering value for money from third party spending

Delivering projects to time, quality and cost, realising benefits

Getting the best from Government estate

Delivering sustainable procurement and sustainable operations on the Government estate

Support the delivery of Government policy goals

Improving central Government capability in procurement, project and programme management and estates

However, in true evolutionary terms the OCG will be part of the new Efficiency and Reform Group (ERG) within the Cabinet Office from the 15th June 2011, (closing its web site on the 1st October 2011). Paul Morrell, the (UK) Government's Chief Construction Advisor, essentially wearing the hat of the client or client advisor, in a *'BIM Roundtable Discussion'* (Waterhouse 2011) in the *'NBS BIM Research Report'* contributed the following:

'...let's work off the same data, that should not be controversial. With the power of virtual modelling, it has always struck me as insane, that we find it so difficult to construct a 3D computer model, but that we go out there and do it in the wind and the rain at one-to-one, as an experiment instead, which leads to a massive amount of waste. So, let's build the model.

It's almost literally true, that I retired from my day job (as a QS), because I did not want to sit through one more meeting, where we argued why a duct and a column wanted to be in the same place. We cannot begin to understand the cost of that, across the whole of construction...'

Table 2 BIM Roundtable Discussion, RIBA, 66 Portland Place 13th April 2011

Roundtable Delegates	Position
Richard Waterhouse	CEO RIBA Enterprises
Paul Morrell	(UK) Government's Chief Construction Advisor
Dr Stephen Hamil	Head of BIM, NBS
Sam Collard	Engineering Leader, Laing O'Rourke
Anne King	Membership & Marketing Director, BSRIA
Nigel Clark	Technical Director, Hilson Moran
Alistair Kell	Director of Information & Technology BDP
Richard Klaschka	Director, Studio Klaschka

The roundtable discussion brought many key figures in the UK construction industry to clarify what BIM is, going through collaboration, adoption and discussing the role of who manages BIM. Klaschka said BS 1192, (a standard for managing the production, distribution and quality of construction information, using a disciplined process for collaboration and a specified naming policy), manages the model quite adequately, meaning that you do not need a manager. He continues:

> *'...the architect is responsible for co-ordinating the zones in the building at design (stage). If the structural engineer's structure is in those zones, and if the service engineer's services are in those zones, then spaces that are left are big enough for the people to wander about in, and do the things that they want to, then the design of the front end of the building is there.*
>
> *What BS 1192 sets out, is the way for that to work. One of the debates that is going on in the industry at the moment is should you adopt a more risky approach than that, and I think that this is where the term BIM Manager and management of the model comes from. At the end of the day the architect is responsible for co-ordinating the stuff that is in the building... that is what is in our contract'.*

In reply to this statement, the chair asked the table *'... is it the architect, who manages...'* which was met with a resounding *'no'*. Morrell even interjected:

> *'...that the idea of the model being managed by BS 1192 is fascinating... (continuing, assertively that) There will be managers! There is no doubt about it... If you are looking for a career for your kids, a model manager would be a pretty sustainable profession!'*

Clearly, the difference between the architect and his colleagues was deafening. He bravely and courageously made the first gambit, but the other stakeholders were having none of it. Collard contributed that:

> *'...we (Laing O'Rourke) have got more traction in the areas of the business where we have employed BIM managers who invest in the training and take people along the journey. That is not just our own internal company, that is allowing designers to engage in the technology, to hold their hand, (and) to talk about how you co-ordinate a model. These people are doing it day-in, day-out. They are problems that they are now able to fix, (typically) how we integrate models...'*
>
> *Instead of integrating models by pressing buttons and drawing them in, we are now doing it automatically. That is saving hundreds of hours. I think a BIM manager is essential. I think that documents such as BS 1192 are fantastic, but what we need to realise is that it is all about behaviour, re-enforcement, and that writing a protocol, putting a document in place, is not going to guarantee that you are going to get the output (required).'*

Klaschka attempted to reiterate his position, only for Morrell to interrupt:

> *'...you describe the BIM manager, you said that the architect takes all responsibility to co-ordinate the work of all the others. That would be a terrific world, I would love to live in it, and if it happened consistently, then the architect would be a BIM manager.'*

The chair then alluded to this being an opportunity, and that where opportunities like this happened in the past, new professions appeared. For the chair, being an RIBA delegate, this was significant and I will return to this statement. The debate then shifted to a new area, where Kell commented that in his experience it was generally the lowest tender that got the job. Morrell again, took up the cudgel:

'...because the industry has no better proposition!'

He would prefer to move away from the *'lowest competitive tender'* to *'show me your best school'* (for example). He elaborated that there was a contractor in the States that was offering *'zero-change-order'* contracts to clients, meaning that if you do not change your mind about the brief that the tendered price is your contract sum. He added that, as a client, this is a very potent/desirable offer.

7.9.3 Team Collaborations in Relational Contracts

If we accept that value is added through people (Smyth, Pryke 2008) then human resources is arguably the most prized asset to a project. Management has a huge role to play here, and managing collaborative scenarios requires developing front-end strategies and tactics. The contract drawn up between the parties and stakeholders now assumes greater significance than previously thought. The first wave of collaboration sought open dialogue and unlimited access to documentation and hard earned experience. This has now been tempered with collaborative relationships, which are trumped by initiating and nurturing trust (Smyth, Pryke 2006).

They outline four types of paradigmatic approaches to managing projects; *traditional* project management approaches; information *processing* approaches; *functional* management approaches and *relationship* approaches. The first three are well documented and covered, ranging from the execution types found in *lean construction* and *supply chain management*, to a cause-effect models reducing uncertainty and lessening risk, to task driven agendas pursuing functional outcomes. The fourth type, relationship approaches, is seen as a method of improving project performances while giving clients satisfaction. This is achieved through developing relationships between people, people and firms, and firms and even their social interactions. This in turn reduces adversarial behaviours but typically, it is non-linear, seeking both general and particular outcomes, relevant to the prevailing context and conditions.

Implicit in this is *relational contracting* as can be seen in partnering and supply chain management. Relationships occur in networks and these can be further structured into frameworks. Frameworks fall into two categories, the first the more traditional providing a basis for organising actions on the ground. The later and more importantly is the sense of a framework agreement, which provide a continuum beyond a project's contract period.

Smyth and Pryke go on to say:

> *'Client organisations rarely feel confident to predict and effectively guarantee future workload, preferring a 'statement of intent' type of approach, thus avoiding the litigation that would follow from the inevitable failure to accurately predict workload some years in advance'.*

7.9.4 Strategic Alignments through Cultural Change

If strategic alignments need levels of trust, what is trust? John Egan (Egan 1998) failed to define or formalise what is meant by trust or how it is recognised. Initially in open collaboration, there was a call for open communication. But Hedley Smyth reiterates that trust is not about open communication, saying that if there was complete transparency of communication that there would be no need for increased levels of trust (Smyth, Pryke 2008).

Rather he defines trust as being a dynamic set of concepts that are present in its formation and development, with a philosophy underpinning this set relating to both the moral and economic issues, together with a methodology showing how trust is formed including its dependency and its management. This is then broadened into the characteristics of trust, the components of trust, the conditions of trust and the all-important levels of trust.

Strategic alignments objectively look at the revolution from draughting to modelling, together with the collateral that is necessary to implement such a shift. Draughting has always been a formalised procedure allowing a creative person a method to capture thoughts and to convey them to another for implementation. It blossomed in the Renaissance bringing abstraction in the form of proportion into buildings. In modernism of the last century it brought a new life to form in its absolute meaning. It is constantly balancing these two concepts of form and formality.

With the complexity of modern life, this process has evolved into a collective operation. The size of buildings invariably means that it is a team that prepares the documentation for the building and another that executes these instructions on site. It is this process that attracts my attention here, it has nurtured a whole industry that acts as a barometer to the national economy.

Where this is changing is the teams that are forming and growing to blur the polarities into a continuum. By pooling resources into a single model or a federation of models, IMT's allow management of these enterprises, administer risk and eliminate double work while diminishing human error. IMT's have changed the focus away from the technologies and directed attention towards the process, which is admirable.

A lack of designers and constructors working together is changing. Clark of Hilson Moran, a leading multi-disciplinary engineering consultancy, are doing a lot more work with contractors, where they are on-board early, and this is very much a two way street (Waterhouse 2011).

> *'We are designers, we like to think we know about buildability and construction, but the input we can get from contractors is invaluable, and that is improving our design work'.*

There is a cultural change:

> *'It is a different way of working. Gone are the days of where you have an engineer doing (only) engineering, where he does a mark-up and it goes to a CAD operator to draught it with a certain amount of engineering intellect... that's now different. Even*

in our office, you walk into an area that used to be the CAD department, now you have got an engineer and a CAD operator sitting next to each other, almost all of the time'.

7.9.5 Cost Savings through Project Certainty

As mentioned earlier, on a project in Hong Kong, the developer saw things differently.

'The design and procurement methods being used on the job represent a full integration of information into a single 3D Building Information Model. This 3D database is being used simultaneously to coordinate architectural, structural and mechanical design information. As well as producing detailed project specifications for cost estimation and construction scheduling...'

(It discovered)

'…close to 2000 clashes leading to a cost saving of close to $13 million. The contractor is updating the virtual model as the building is being constructed, so that the model can be used for operations and maintenance once the construction is completed'.

For the developers this was about project *'certainty'*, knowing what was going to be built and at what cost. While this certainty gave control back to the architect, it was the client who was instrumental in the procurement method (Fong 2007). Tse noted many trends against BIM adoption in Hong Kong and they are worth naming as they surmise the general thinking at the time (Tse 2005). They included that there was no perceived need to produce BIM, existing CAD systems were adequate, BIM would not reduce draughting time as it was not flexible enough, it was not required by clients, and finally it was not required by other team members.

Comparing this to the McGraw-Hill Smart Market Report on Interoperability (Young, Jones et al. 2007) a mere three years later there are stark differences. Under factors influencing BIM, 68% believe that there is less draughting, 49% cite client demand, 47% improved communication and out of nowhere comes Code Checking at 25%. There are many causes for this and prime among them was the American Institutes of Architects (AIA) national convention in Las Vegas in September 2005 where Thom Mayne (Strong 2005) said the immortal words: *'If you want to survive, you're going to change; if you don't, you're going to perish. It's as simple as that'*. The AIA championed Integrated Practice, Interoperability and Integrated Project Delivery, which are all variants of the same thing; collaboration. The other significant fact was that when Autodesk acquired Revit which Chuck Eastman claims had the effect of legitimising BIM.

7.10 A Deep Analysis of the Changing Role of the Architectural Technologist

7.10.1 Introduction

A constructing architect graduates with a Bachelor of Architectural Technology and Construction Management after three and a half years, amassing 210 ECTS points which is the minimum equivalent of a BSc (Hons) 2.2. The education is accredited by the Royal Institute of Chartered Surveyors (RICS) and there is a Memorandum of Agreement between the Chartered Institute of Architectural Technologists (CIAT) and the Danish Institute, Konstruktørforeningen (KF) to mutually recognise the members of each organisation and their respective qualifications and experience through joint development, commitment and action.

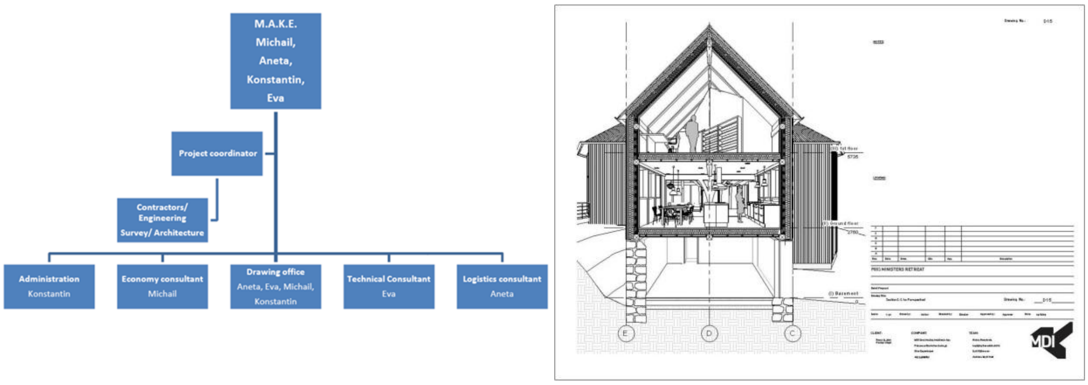


Figure 16 Groups form a matrix and deliver a project over the semester

It is worth repeating, that pedagogically the course is structured through group work in a matrix diagram on project driven semesters. It is practice orientated and uses problem-solving methods. This is a huge benefit where collaborative work is involved and this is the case with BIM. The work can be divided into two parts, one where authorship is to the fore and the other where analysis is primo. Authoring involves building the model and developing it through the various work stages of the project. Analysis allows the model to be checked and controlled so that certainty is achieved, bringing projects on time and to budget. Allowing the data generated to be mined and tested is not new, it is in fact an integral part of the planning process and of great concern to the client.

The school's new course syllabus is making inroads in this direction, looking to introduce an appreciation of these mechanisms in the first semester to full management of them in the fourth semester. Having a matrix organisation within the classroom allows this to happen, so that the differing roles can be played out and their integration fully experienced.

Two things have emerged from this arrangement, first (and the one that was not anticipated) is the reduction of stress levels coming up to evaluations and exams. Each group can see the model, address its problems and contribute to the group work in a meaningful manner. Second communication is incredibly better, both internally and externally. The model is usually in place much sooner in the semester than previously and this allows the more difficult operations more time to be completed.

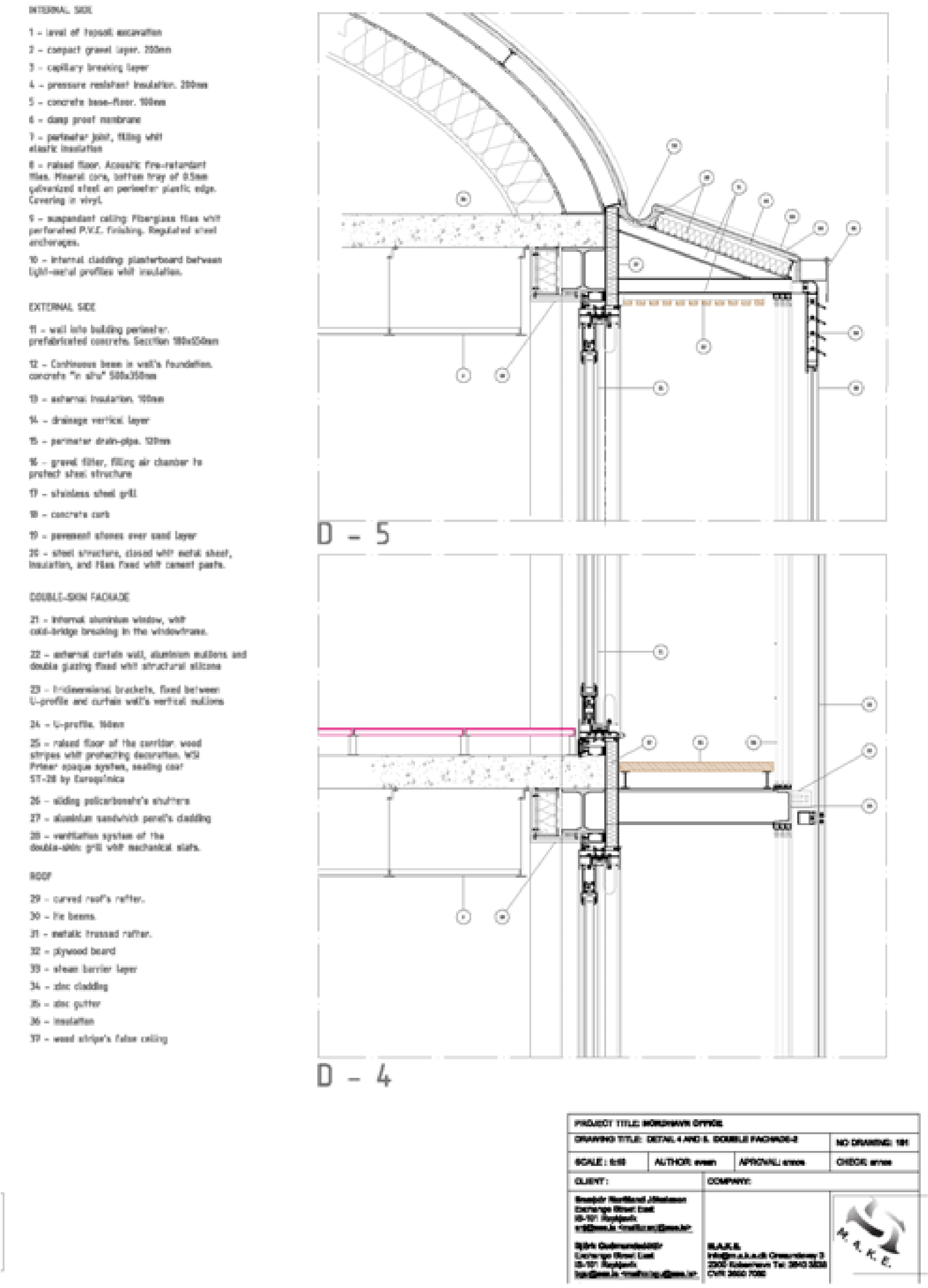


Figure 17 Student project, section of double facade office building

7.10.2 The Need of Developing a Curriculum

Developments are underfoot to establish the technologist as a professional body with the ability to sign-off work in Ireland. What is interesting and relevant in examining this, is that the registration body, for architects and technologists in Ireland, is one and the same, namely The Royal Institute of Architects of Ireland (RIAI). With the free movement of architects throughout the European Union (Directive 2005/36/EC on the recognition of professional qualifications, which came into force in 2007), the door will be opened for technologists to qualify in Ireland and then move freely through the EU.

This has the potential to have a two-way effect, raising the professional ethos of all technologists because it creates a window of opportunity for all, forcing other bodies to adopt the same principles, or see trafficking of technologists through the RIAI's portals to gain accreditation. The following is generally a synopsis and distillation of the relevant points in the new syllabi and proposals for content for a new course being tabled by the Dublin Institute of Technology (DIT).

To address the educational needs of the professional architectural technologist, DIT has now replaced its three-year Ordinary Bachelor's Degree with a Bachelor of Science (Hons.) in Architectural Technology together with a Postgraduate Certificate in Applied Architectural Technology. The Postgraduate Certificate is intended to lead to the award of a Master's Degree.

> *'New methods of design and procurement have led to changing roles within the design and construction teams, with Architectural Technologists frequently playing a key role as technical designers, and in doing so emerging as professional partners to architects, engineers and surveyors in the building design process.*
>
> *...The RIAI welcomes the emergence of honours degrees in architectural technology ... and seeks to work with the educational institutions in developing a context for professional accreditation of the new degree programmes.*
>
> *...Whether or not Registration is introduced, professional membership and accreditation systems will have to make provision for these developments one way or another'*
>
> President James Pike, (RIAI), November 2006

The vast majority of Irish Architectural Technology Graduate Network (IATGN) members have lobbied strongly and have expressed a strong interest in obtaining further qualifications at undergraduate and postgraduate levels, where among other things the technologist should maintain proficiency in emerging computer application software in information technology in general and building information modelling in particular. The technologist should play a leading role in information management and quality assurance processes (Allen 2009a).

The issues raised are many and varied. They include title, competences (limits and overlaps relative to the competences of an architect), function (responsibilities arising from competences as employee and in self employment), recognition of experience in place of formal qualification, authority to sign documentation, variable education standards, professional support for self employed technicians, and the implications of Building Control Act, especially the technical assessment process.

The impact of European Union policies and regulations on the building industry over the last decade has been considerable. Legislation in the areas of Building Control, Planning and Health & Safety, alongside the ongoing development of EU standards and other codes of practice, continue to inform and control an ever more complex legislative environment.

The EU Energy Performance of Buildings Directive (EPBD) requires the development of energy calculation methodologies and EPBD certificates of energy performance. Building Energy Rating (BER) and Dwelling Energy Assessment Procedure (DEAP) energy performance assessment have been developed in response to this, while Building Regulations have been revised to include for higher energy performance of buildings and renovations. All these developments require additional technical training.

The Bologna Declaration (1999) recognises that European higher education systems face common internal and external challenges related to growth and diversification. Its goal is to create, by 2015, a European space to enhance the employability and mobility of citizens, and to increase the international competitiveness of European higher education. Its objectives are the adoption of a common framework of readable and comparable degrees and the introduction of undergraduate and postgraduate levels in all countries, with first degrees no shorter than 3 years with ECTS-compatible credit systems

With the changing nature of building procurement and construction systems in recent years, some graduates have established architectural technology consultancy practices, which offer technical consultancy services to architects in areas ranging from fire engineering and energy design to technical design and information packages. Opportunities exist for the development of technical design consultancies with the proposed new academic programmes aiming to address this need.

As a result of this, the intended outcomes are:

'To engage critically and collaboratively with the architect in the building design process, using knowledge and understanding of historical and contemporary developments in architecture and architectural technology, with an understanding of the architectural design process.'

'To engage critically with structural, mechanical, electrical, fire, acoustic and other engineering disciplines, applying knowledge and understanding of engineering

design in the management and coordination of consultant design input in the building design process.'

'To engage critically with cost control consultants, applying knowledge and understanding of cost measurement, quantification and control, and the role of the QS in monitoring the cost impact of technical design decisions in the building design process.'

'To engage critically with domestic and nominated specialist design Sub-contractors, using an understanding of design and construction procurement processes and contracts in the management and coordination of contractor design input at post tender and construction stages of the building design process.'

'To engage critically with the building contractor in the building design and construction process, using understanding of site practice and procedures and of building contracts.'

No other institution is offering this degree of critical engagement at the moment in an official capacity, while many are seeking to address this new development soon. Also, it should be noted that only within the technologist field is there the wherewithal or the ability to dovetail all the above mentioned collaborations in a meaningful way. Sure enough, a hierarchical management structure can supervise the process but having this intricate interaction with the other disciplines is the technologist’s domain.

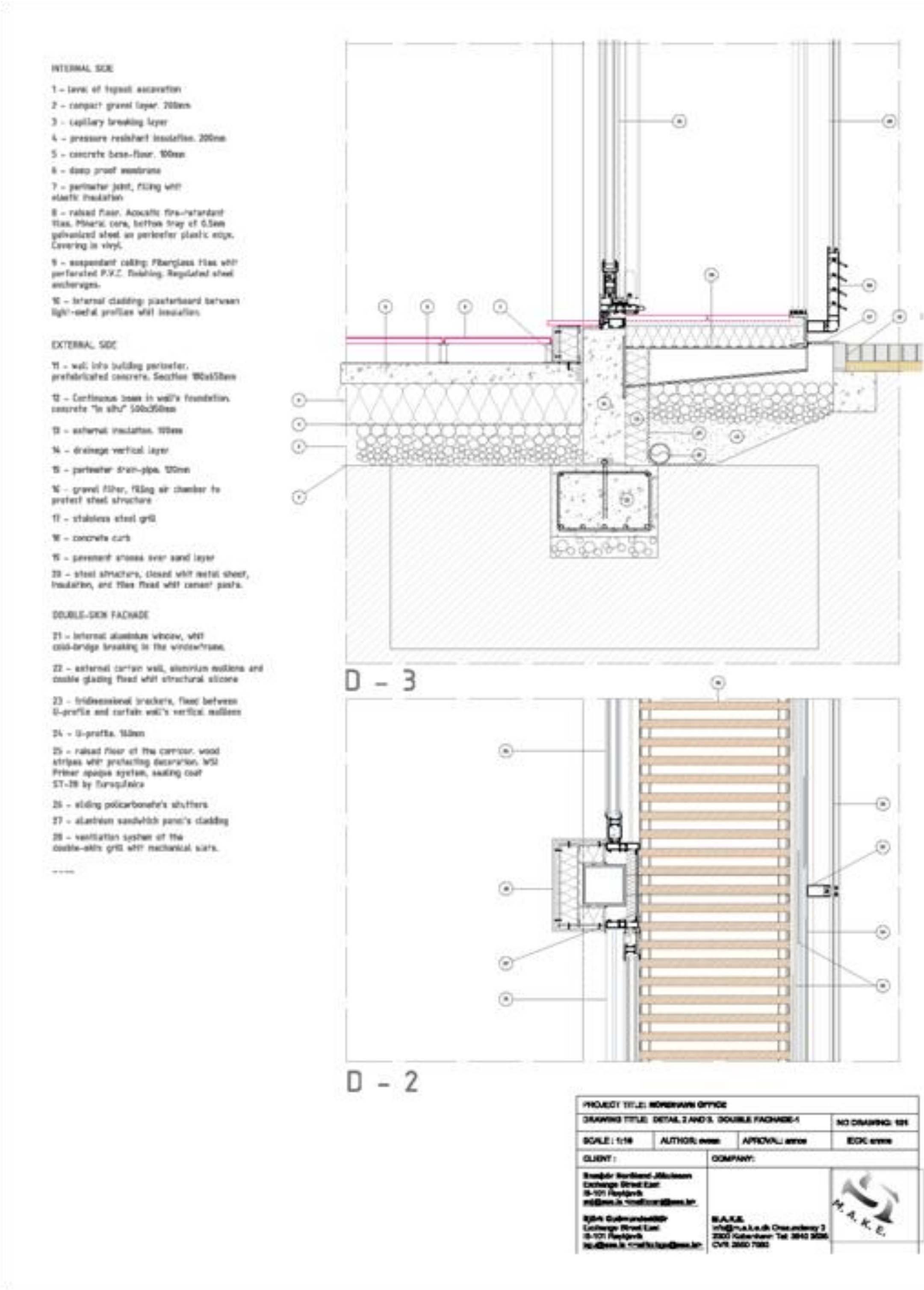


Figure 18 Student project, details of double facade office building

7.11 The Role Envisaged for BIM at DIT

The application of these aims is then further developed into modules for the delivery of the course content. The course modules are intended to run over the latter three years of the four-year undergraduate programme. There is a progressive and comprehensive build-up to the graduate’s education, which structures the exposure and presupposes achievable outcomes so that the levels are realised in tandem with the student’s studio work.

The first module aims to develop the learners' understanding of the role of the architectural technologist on the design team, using the building model to explore the collaborative roles of the architect, technologist, structural engineer, mechanical & electrical engineer and Quantity Surveyors (QS) in the building design process.

The learning outcomes are that:

- the digital model is used to develop the architectural design in collaboration with the architect/architectural student,
- that it is used to coordinate engineering design input in collaboration with the structural and mechanical & electrical engineer/engineering student,
- and that it is used to coordinate cost control input in collaboration with the QS/QS student

The design process is to:

- compare and contrast the roles of the architectural technologist, architect, engineer, quantity surveyor on the design team,
- and to participate in design team meetings playing a technical design development and coordination role

The second module aims to develop the learners' understanding of the role of the architectural technologist in the construction process, using the building model to explore the input of the specialist design Sub-contractor/fabricator and construction manager in the building design and construction process.

The learning outcomes are:

- to demonstrate an understanding of interoperability,
- to use the digital model to coordinate Sub-contractor design input
- and to use the digital model to extract and elaborate construction detail in collaboration with the construction manager/construction management student

The construction process is:

- to compare and contrast the design roles of the design team and the roles of the domestic, nominated, specialist and design sub-contractor and building contractor,
- to describe the sequence of principal events in the design and construction of a building,
- to compare and contrast traditional sub-contractor drawing development coordination systems with BIM, and
- to participate in construction team meetings playing a technical design coordination role

The third module aims to develop the learners' understanding of the use of BIM on facilities management, post-construction measurement and geometric data integration using a variety of related software applications.

The learning outcomes are that on completion of this module, the learner will be able:

- to use BIM for building energy performance analysis,
- to compare and contrast the roles of the architectural technologist and the geometrical surveyor,
- and to participate in construction team meetings playing a technical design coordination role (Allen 2009a)

7.11.1 PG Cert Applied Architectural Technology

The Post Graduate Certificate (PGCert) aims to develop and deepen the learner’s sense of professionalism, building on their undergraduate learning and their experience in practice, and provide the opportunity to plan career development and prepare for further study in areas of architectural technology specialism.

The aim of the *'Construction Legislation'* module is to:

- develop and deepen the learner’s understanding of construction legislation, regulations, codes and standards, building on their undergraduate learning and their experience of construction legislation in practice

The aim of the *'Regulations in Practice'* module is to:

- develop and deepen the learner’s understanding of the building regulations in general, and the areas of fire safety, universal design, and sustainable design in particular, building on their undergraduate learning and their experience of building legislation in practice

The aim of the *'Procurement and Contracts'* module is to:

- develop and deepen the learner’s understanding of the building procurement process and the use and application of building contracts, building on their undergraduate learning and their experience of construction legislation in practice

Finally, the aim of the *'Management & Quality'* module is to:

- develop and deepen the learner’s understanding of the various management processes involved in the practice of architectural technology, building on their undergraduate learning and their experience of construction legislation in practice (Postgraduate Certificate in Applied Architectural Technology, Part B - Dublin School of Architecture January 2009)

Generally, it can be seen that the modules mimic and duplicate the Professional Practical (Part III) exam for architects. A new post has been advertised, and filled, for a senior lecturer to run both courses, with what seems to be identical content. The only difference is that the architect will complete this after a minimum of three (bachelor) plus two (currently a diploma) with one year practical training and two years professional practice (i.e. 8 years), whereas the technologist will require an extra year in total (9).

These are significant changes and developments in the course structure. Likewise, it also shows a definite tendency to position the technologist in a more professional light. In Spain, the *architecto* and the *tecnico* sign construction contracts jointly. In The Netherlands certain master’s courses allow technologists to become registered architects. Many countries have technologists that go on to complete an architectural qualification but many IATGN members see this as a damning compromise and a general disservice to technologists.

The course content also reflects on the growing importance of BIM as a procurement tool. Many graduates would relish the chance to top up their education with these new skills, but there is no means in place. The same can be said for fire precaution, health and safety, contract law and a host of other niches or specialisations not covered in the general education of the technologist. Ironically, these areas are now beginning to be offered by the academic institutions. In Denmark Aalborg University and Denmark’s Technical University are the universities that are looking at courses in these areas. The Royal Academy of Fine Arts (School of Architecture) is even considering offering a BIM Management course.

7.11.2 How these findings can be Integrated into an Educational Syllabus

'...educational success is no longer about reproducing content knowledge, but about extrapolating from what we know and applying that knowledge to novel situations.' Andreas Schleicher (Schleicher 2010).

According to Aristotle there are three activities in which we, as humans, engage; *theoria*, *poiesis* and *praxis*. Theoria is the theoretical, where truth is the goal, poiesis is the poietical, where production is the goal, and lastly praxis is practical, where action is the goal. Where there is project work and group work as at the Copenhagen School of Design and Technology, praxis is a pedagogy that drives the basic principles including project organisation, interdisciplinarity, problem solving, participant management and exemplary learning through *'learning by doing'* (Olesen, Jensen 1999).

Two types of experiential learning can be identified in *'learning by doing'*, the first is *'direct encounter with the phenomena being studied rather than merely thinking about the encounter, or only considering the possibility of doing something about it.*' (Brookfield 1983). This occurs mainly in professional courses. The other *'occurs as a direct participation in the events of life'*. This is achieved by reflecting on our experiences and is typical of learning in general.

Praxis is also used by educators to describe a recurring passage through a cyclical process of experiential learning, such as the cycle described and popularised by David A. Kolb (Smith 2001). At the school, each semester is characterised by having a complete themed semester-long project. Typically, this means a single-family house in first, where basic design and construction skills are groomed. Second semester expands into a cluster of houses so that interdependence is explored and examined. Third, reverts to a single house, which is pre-fabricated, so that the building is thoroughly componentised and elementised. Fourth, sees a large building with all its incumbent issues, while fifth looks at refurbishment. Sixth semester is now practical training (internship) and seventh is an individual graduation project and dissertation.

Each semester's goal is building procurement of differing degrees, meaning that there is a cyclical process where levels of difficulty and complexity are continually added, to what is essentially a repeating scenario. In the first semester, basic and typical constructions are encountered. Second semester expands into looking at the practicalities of common building elements with regard to fire safety, acoustics, building regulations and codes. Third is all about the process and its management, while fourth offers the good opportunity to test the accumulated knowledge on a larger project (a multi storey office or similar). Fifth deals with an urban context and sixth is practical training. Seventh semester is where the student works alone and shows his or her command of the whole procurement process.

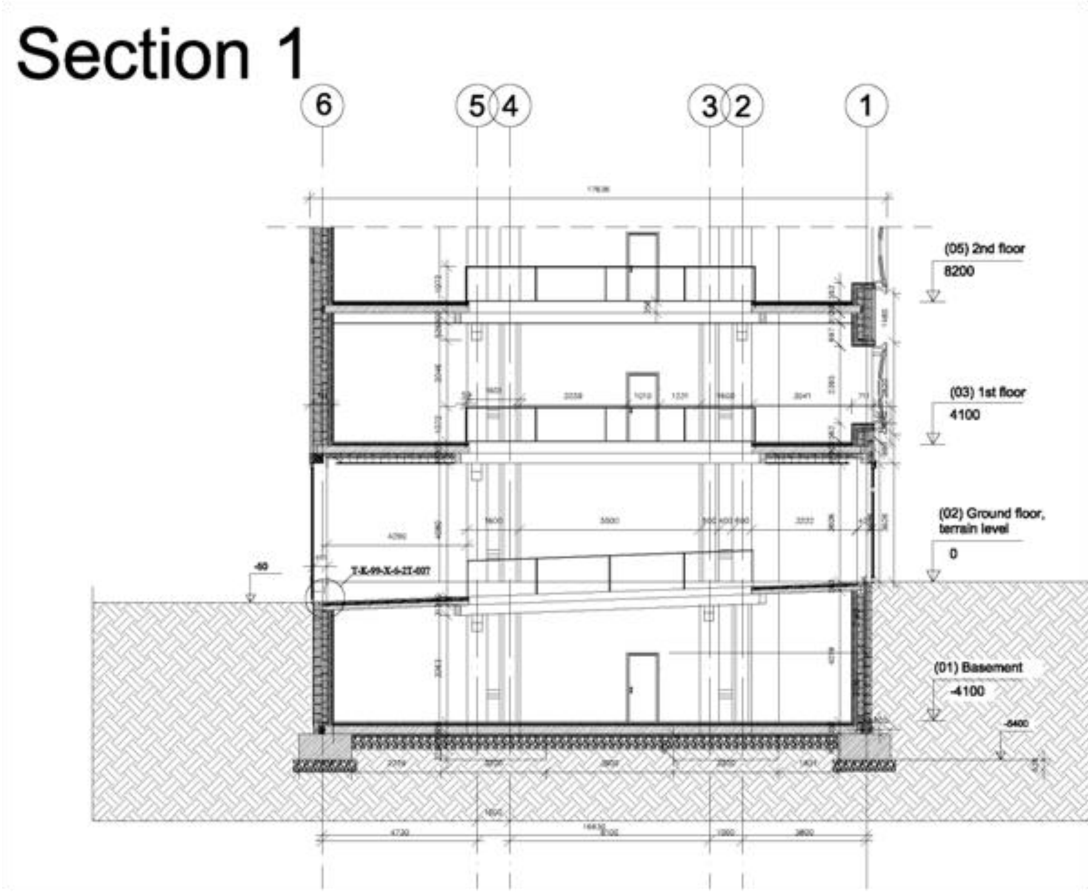


Figure 19 Student project, cross section of art gallery

In all the earlier semesters (1-5), the students work in groups, typically of four. This involves a matrix diagram where defining roles are played out, and each student gets a chance to adopt these roles through the course. Typically but not exclusively these roles include; CEO, architect, structural engineer, service engineer, company secretary, legal adviser and estimator (quantity surveyor). Tasks include all drawings and documentation to complete the procurement of a building as if the group functioned as an architect's office (with input from engineers and other related disciplines).

With regard to the RIBA's Plan of Work each semester is given the brief or concept phase (C) and progress the project to Design Development (D) and Technical Design (E). The latter semesters delve even further into Production Information (F), Tender Documentation (G) and Tender Action (H). Mobilisation (J), Construction to Practical Completion (K) and Post Practical Completion (L) are covered in as much as can be in a studio environment (RIBA 2007). It goes without saying that the most of the work is to be found in the work stages C to F, which reflects the percentage of fees usually paid out for such work.

The school and the staff provide an overarching framework that sets the agenda to align resources, activities and hence outputs in terms of infrastructure and skills for the student to complete the task. We are there to inspire a sense of wonder, to transmit learning, creating new knowledge and developing the necessary skills that both link and provide a context to educate the students to reason for themselves (Conduit 2009).

The relevance and interest of all the above to this work is that Building Information Modelling (BIM) is transforming the whole approach. While the input and output are essentially the same, everything in between is in a state of flux. But to its credit the framework is still holding and the experiential learning pedagogy is well placed to adopt this new era. The new buzzwords in connection to education are collaboration and (modular) outcomes, which are cornerstones to the teaching methods here.

What is missing is up-skilling and lifelong learning that are fast becoming the new goals of the 21st century. Teaching by rote does not equip the student of today for the changing world of tomorrow (Schleicher 2010). The models being developed worldwide for higher education all have an important element, which includes a section on lifelong learning and career change studies. If we do not follow suit the workforce will not be as adaptable to technological and social change (Kelleher 2009).

This is very relevant for the construction industry and the constructing architect (or technologist to give it a more generic term). While Industry and its clients share a range of strategic interests with higher education, which include a stream of suitably trained graduates, currently there is very little Continuing Professional Development (CPD) for existing personnel, research with international market potential and access to beneficial collaborative partnerships. New mechanisms such as postgraduate programmes might allow learners to develop a portfolio of modules, which lead to a particular or specialist qualification, but do not necessarily come from the same institution, discipline or mode of delivery. There is also a chance to exploit the unique benefits of IT to increase access and participation.

The introduction of a policy and funding framework based on transferable credit-based learning that came with the Bologna directive in 1999 (EHEA 2011) would help tailor new modes of delivery and a provision to enable greater access opportunities. Increasingly, flexibility of provision will be a key indicator of the responsiveness to society. The Bologna process can also facilitate a substantial reorientation in programme delivery towards part-time and flexible courses.

There is also a general consensus that a strong relationship between business and higher education is critical to economic competitiveness. Business even favours the concept of becoming a real partner and voice within higher education. Stronger partnerships with the business community including Small to Medium Enterprises (SME's) bring opportunities for educational institutions to enhance the prospects for graduates. Therefore, higher education institutions need to respond better and faster to the demands of the market and to develop partnerships with businesses and others, which harness scientific and technological knowledge. The potential of higher education institutions to contribute to the economic, social and cultural development of their regions is far from being fully realised and cannot be underestimated. Higher education institutions must become more entrepreneurial, widen their service portfolio and address the needs of wider range of organisations and employers. They should be more dynamic in their approach to collaboration.

If industry can be brought in as a key stakeholder as it must beyond the impact that it has today, then new avenues need to be opened up in the curriculum and new courses offered to meet the demand. As it stands the constructing architect's course in Denmark is a generalist's course specialising expressly in its flat pan basic education. It is a kind of Jack-Of-All-Trades, master of none without being too dismissive of it, but clearly, it forms the basis for someone to operate across the disciplines and understand what the differing silos of professionals require. This is its genius.

But just like the technologist graduates in Dublin Institute of Technology (DIT), their graduate network clearly identify that there is no next step for them to take should they wish to study further at a later time or specialise. Their only course of action is to continue their education and become architects. While there is a certain logic in this, the graduate network clearly identified the shortcomings in this and stated that it demeaned them and their education and that they wanted to be technologists and not necessarily architects (Allen 2009a, Allen 2009b).

So what are the options? Prime is to formulate a postgraduate course or courses, either as a Post Graduate Certificate (PGCert), a Professional Practice Certificate (PPCert) or a Masters course. This last option is in fulfilment of the Bologna directive to offer anyone who takes a bachelor degree (level one) a route to a master's degree (level two) and ultimately a Doctorate of Philosophy (PhD). This states that a system must exist so that if a student completes a first cycle degree, that there must be a second cycle degree. This is just the first part that ultimately would lead to the PhD mentioned above, known as the three-cycle system. This must be in place across the EU by 2015.

The stocktaking report of 2009 sees this as merely being a matter of time. But many countries have differing systems and the streamlining of the process is taking longer than hoped. The report states *'low'* adoption rates (Rauhvargers 2009). Under Denmark, it reports a green light in this regard meaning that implementation is complete. But clearly in reality *'Kandidat'* degrees are still being handed out (equivalent to Masters) and that Academic Bachelor degrees are rare, while Professional Bachelor degrees are gaining in currency as practical degrees. The Bachelor in Architectural Technology and Construction Management is one such professional degree. But having attained it there is no direct second cycle.

Regrettably, the Copenhagen School of Design and Technology (CSDT) does not currently have any plans to implement one. At Aalborg University (Denmark) there is a course, which our graduates can attend entitled *'Architectural Design'*, an MSc in Engineering with specialisation in Architecture (AAU 2011). In Copenhagen at the Technical University of Denmark (DTU), there is a master course in *'Management of Construction'* (BYG DTU 2011). There is also the *'Master in European Construction Engineering'* in Cantabria (Spain) (UNICAN 2011). There are countless more but none are individually tailored to the needs and demands that constructing architects (/technologists) might aspire to or seek.

However, there is a degree in the US that a few universities pioneered in the 1990, which combined science and mathematics with business management. By 2008, 58 universities in the States were offering this Professional (Science) Master’s Degree (PSM) as well as with the Open University in Milton Keynes (in the UK). David King *'thinks of it as the 21st Century degree'. 'It's interdisciplinary. It's a hybrid, which (he) thinks is more agile. It's responsive to rapidly changing needs in terms of the job market'.* King likens the growth of the PSM with the ubiquitous MBA (Master of Business Administration). The degree typically involves two years study focusing in two directions (theoretical and practical). For schools it offers *'a potential source of revenue, deepening the school's partnerships with business'*. For businesses *'it enables you to put people in business roles who really understand science'* (Rosenbloom 2010).

Such a development would allow the school to respond better and faster to the demands of the market harnessing the latest technologies. It could be a vehicle to remain innovative, relevant and responsive to the building industry, which they value. It would also continue to raise awareness within the business community of the expertise that exists within higher education and to provide pathways to make valuable connections. It opens avenues to develop an awareness of options for collaborative, contractual and consultancy type services. Finally, it also provides an opportunity to bring in new blood and find replacements for retiring teachers. CSDT is well placed to achieve this.

There are professional parallels with dentistry and surgery. Both can be claimed, from an academic point of view, to be technically based, and their origins support this. Surgeons, as a profession, arose from the barbers, as someone good with a blade, dentists pulled aching teeth. Other professions, such as nursing are also examining ways of developing and expanding. These vocational occupations are addressing methods of supporting and directing their graduates into better qualifications and new roles that are tailored to them.

One of the stumbling blocks in these situations can be the profile of the teaching staff. Often the very nature of the practice-orientated institutions is their resources. Their members are the product of the generations before and to burst through this non-academic ceiling requires an academic slant, not present in plentiful amounts.

Addressing this imbalance can be approached in two manners, the first is to better the rank and file of the teachers, by sending them on courses and improving their qualifications, the other is to essentially buy it in, by offering posts to higher qualified personnel. The practice is usually somewhere in between. One of the requirements for lecturer positions is a research qualification, and at The Copenhagen School of Design & Technology, it was intended that those teachers doing PhD's (six at the outset), would use the other teachers (c.100) in focus groups to satisfy the need. This small steps approach had great momentum at the beginning, but changes in management saw it diminish through time.

The creation of an Innovative Taskforce could build and improve the teaching and learning environment characterised by reflection, evaluation and modernisation. It could demonstrate best practices in methodologies, technologies and resources. The availability of accredited, postgraduate level, professional programmes giving pedagogically focused workshops, training events, conferences and informal seminars, with national and international speakers and facilitators would be of great advantage to a segment of the market that is lacking.

A vocabulary is gaining currency where the student is referred to as a consumer. In this scenario, teachers are seen as passive facilitators of learning or mere service providers, responsible for delivering a range of learning outcomes and subjects to some quality assessment of their delivery. Parity of esteem between the teaching and the research mission should be reflected in resource allocations, promotion criteria and in the full range of metrics that are adopted to assess performance at individual level, institution level and system level.

Kolb identifies four learning styles; the *'Converger'*, the *'Diverger'*, the *'Assimilator'* and the *'Accommodator'*. The Converger is strong in the practical application of ideas, can focus on hypo-deductive reasoning on specific problems, and is usually unemotional, having narrow interests. The Diverger is strong in imaginative ability, is good at generating ideas and seeing things from different perspectives, is interested in people and has broad cultural interests. The Assimilator has a strong ability to create theoretical models, excels in inductive reasoning, and is concerned with abstract concepts rather than people. The Accumulator's greatest strength is in doing things, he or she is more of a risk taker, performs well when required to react to immediate circumstances and solves problems intuitively (Smith 2001). While no one should be exclusively one of the four, style's tendencies exist with which we can all identify. All-in-all, there should be a *true parity of esteem* between research and teaching.

Where this impinges BIM, is that the construction industry in general has been shown to be slow in adopting and implementing the great panacea. In reality, when visiting students on their internships (practical training), the feedback we get cites lack of training, exposure and opportunity as the big factors preventing adoption where they are working. There is wholesale knowledge of what BIM can do and would do but the *where-with-all* to implement is missing.

Many would like to come back and get specialist training both in the hands-on phase, to the management, to the consultancy levels mentioned elsewhere. However, there is no easy prospect to do so. Education has not prepared those that qualified earlier to adapt easily to new demands and developments. In the draft *'Hunt Report, A National Strategy for Higher Education of the Strategy Group'* commissioned in Ireland some of their notable findings are:

'To address the societal needs over the coming years, increased attention must be paid to core skills such as quantitative reasoning, critical thinking, communication skills, team-working skills and the effective use of information technology.

There is an increasing need for the provision of educational opportunities that differ significantly from the traditional model...

Some of the jobs that people will do in 2015 and 2030 do not exist now, and some cannot even be foreseen. For that reason, we now need to take a broader approach to knowledge and to foster the core enabling competencies that will empower future workers *in whatever environment they find themselves...graduates need to be job shapers and not just job seekers.*

Research has strong potential to create the new knowledge that can be used to create new enterprise opportunities' (Hunt 2010).

This has equal relevance here and many of its finding while still in draft format are highly likely to be adopted when it is finally published. We are at a very exciting moment where the industry is facing a whole new method of procurement together with a higher education course that is showing the way forward and could serve the industry in a very complementary way, building on the good vibes and egger reception that patently is out there.

7.11.3 The Changing Roles of an Integrated Team

Information Management Technologies (IMT's) are establishing a carcass or structure onto which differing roles can align themselves. They are developing the playing fields but it remains to be seen how effectively and quickly they are adopted. Norman Strong, FAIA says (Strong 2005):

> *'This revolution is already changing my firm, and it will change yours… Our profession will be utterly different, transformed, within the next 5-10 years.'*

In building an integrated team, it is critical to assemble people committed to the collaborative process, and who are capable of working together. This means identifying participants across the whole project; from owners and operators, to designers and contractors, to suppliers and manufacturers to finally integrators and even lending institutions. They must be pre-qualified in technical competences, in their commitment, experience, integrity and collaboration qualities.

Third parties should also be introduced and briefed from an early stage and organisations and businesses best suited to Integrated Project Delivery should be ear marked and targeted from the outset. This has overtones of priming or even over-priming but until some best examples are available for the industry to see, there is residual resistance and reluctance to be early adopters.

Educational Institutions have a duty to mirror and reflect the paradigm of changing roles and to comment and debate its course. Uniquely, my work has been spread over five years, and in that time I have seen BIM adopted in the school and have seen its impact, which is to be applauded.

Figure 20 Typical make up of a class where students form groups of four or five, acting as quasi firms collaborating together for the whole semester

7.11.4 Local Authorities' Role, especially with regard to BIM & GIS

Øivind Rooth, Deputy Director General of National Office of Building Technology and Administration (http://www.be.no) from Norway, gave a keynote address about how they are dealing with the matter at the BuildingSmart Conference in Copenhagen 2010. Norway is a country of 4.7m people with a Gross Domestic Product (GPD) of €60,792 per capita, meaning they are relatively rich (Rooth 2010). This means that they are good at investing in infrastructure and one such project is dealing with energy and the amount of energy buildings consume.

The parliament has recently had a white paper on building policy and has gone on the offensive. It has looked at their building stock and found out what are the desired qualities for their lifestyle in a cold climate. This has led to the introduction of legislation and now they are identifying qualified practices and practitioners to deliver their goal. This leads to better products and most importantly better processes as Rooth says himself.

He then outlined what his government can contribute:

- Predictable framework conditions for the players
- Development of good, coordinated instruments

- Deliberate use of model projects
- Requirements beyond the minimum for all state-building and all tenancies
- New certification schemes
- New contract forms

His agency, BE, (www.BE.no) has then acted as an instrument providing a knowledge database, regulatory incentives, tools and methods and appropriate information. This is culminating with *'Byggsok'*, which is a public system for electronic services in zoning, building and construction matters. Its vision is to improve productivity and efficiency in the planning and legal process. Its objective is to facilitate this process through the internet.

The next phase is to go directly from design to permit, using code checking, (an automated process on an open source BIM platform). This is achieved by using and reusing data in the planning and building process. First, there is the data exchange with the project and the central server. Data is then added from the national registries and this is sent to the municipality where the approval is processed. It then updates the national registries again. General, site specific (or local plans) and building regulations are all checked.

The checking relies on two, up until now, disparate technologies. One is BIM and the other is GIS. Construction information is extracted from BIM, while geographical information comes from GIS, together with zoning and property information. Both are based on open source platforms with BIM relying on IFC, and GIS relying on Geography Markup Language (GML), an ISO standard developed by Open Geospatial Consortium (OGC). It has not been rolled out yet, but in tests, there is a twenty-minute turnaround, (instead of the three-month building permit normally experienced.

Open standards have been insisted upon so as not to be dependent on or tied to proprietary systems. In addition, the major issue in amalgamating the two systems is that one is largely vector based while the other is raster based. The various layers have grown out of two totally different systems that were never intended to meet.

7.12 How IMT's will Drive Changes within the Discipline of Architectural Technology

7.12.1 Introduction

There is no doubt that Information Management Technologies (IMT) are persuasive throughout the building industry today, from inception and procurement, to operations and maintenance, all the way to decommissioning and demolition. At one level, it could be fair to say that their implementation could be a straight swop over of each manual process to the digital process without further impact, but this would be wrong. Digitalisation is having a really huge effect on the industry and will continue to change the way we work and perform. Fundamental to this is that BIM is in fact data based. By this, I mean that when databases become the bedrock for any process, the potential and possibilities multiply. Implicit in this is that methods and procedures change too.

Look at the impact of barcodes on the haulage industry. Suddenly the supply chain knew how many items were needed (and where), as it kept track of inventories across the globe. Furthermore, it was a dumb trucker that returned home from any delivery without another for the return journey. Logistics made this possible making the industry twice as profitable in one simple procedure (Wikipedia contributors 2010d).

Likewise, the mobile telephone industry adopted texting with the Short Message Service (SMS) being a simple throwaway inclusion with the phones initially, only to sire a whole generation of texters with twitchy thumbs. SMS text messaging is the most widely used data application in the world, with 2.4 billion active users (Wikipedia contributors 2010e). Even so, due to another feature; telephone number memory, how many even know their own telephone numbers. When I log my new students at the start of a semester very few can recite their number by heart, but all can send me a calling card, meaning they know where the number is and how to disseminate it.

On a slightly different tack, banking has also changed irrevocably due to the internet. In its simplest form, it again merely digitalises the paper process but in a broader context, it has seen the demise of the local corner branch. It has said farewell to the chequebook and more importantly it allows customers to engage in *'what if's'*, regarding loans at differing interests and payback periods. This means people not only manage their money better but also are better informed about how their money can work for them. This metaphor has a relevance to building modelling. Both are using essentially models; one mathematical (or numerical) the other geometrical (or physical) with appended data. But their mere existence opens up new avenues of knowledge and understanding, to better serve their masters. It is these latent possibilities that will drive the changes within the discipline of architectural technology.

Previous chapters examined the practicalities of integration and procedure, here how the changes will be driven is examined. Within this theme, there are also two streams, the first how the discipline will develop within itself and the second how it will grow beyond its current limits.

7.12.2 Project Information Management

The changes that have and will come about in the construction industry are not purely technical, but must be accompanied by changes to the management process (Froese 2009). Project Information Management (PIM) is now making more demands on integration within construction. Froese identifies three eras, which map the progression; the first being stand-alone tools which covered draughting, structural analysis and estimating; the second being the computer-supported communication such as e-mail, the web and document management systems, and the last being integration and building information modelling.

Each of these eras has heralded new milestones in the digitalisation process, but none more so than BIM. From a management point of view the three eras are remarkable in that they mark a schism or a fission between management and operators, for want of a better word. Most books on management, advising the implementation of digitalisation, stress from the very outset that in all procedures:

- *'to ensure senior managers are committed'* (Elvin 2007), *'that they review the implementation and give feedback'* (Hardin 2008),
- *'that the full understanding and support of the leaders of their company is first obtained'* (Smith, Tardif 2009), and finally to
- *'get senior design team leaders to adopt the new practices'* (Eastman, Teicholz et al. 2008)

Generally, this alludes to a traditional regime where they were masters of the traditional process, and had severed an apprenticeship of sorts to reach their current position. Under the new system, they became unstuck from the process that they themselves had come through, meaning they can be disjointed or distracted from operations.

Moreover, understanding why information is important, rather than technology, is an asset. This helps the new regime and sooths the changeover. Information benefits from the using and re-using of data held within organisations. This asset-centric perspective is a proactive approach. It is successful because it focuses on the exploitation of information assets and, because we normally take more care of what we value, it leads to better protection of it. When information becomes widely recognised as part of the lifeblood of the organisation, the culture embraces both the need to democratise access to it and the importance of its quality and security.

Ultimately, modelling encourages this transparency. Communication improves because issues can be readily seen and solutions usually suggest themselves. Whether it is clash control or design development the magnitude and scale of the problems are visible and a perspective can be maintained.

7.12.3 Sustainability as a Driver

Recent publications from the EU (and in most of the developed world) have made it clear that concerted efforts to cut carbon emissions are crucial to the future of economic and social sustainability of the region. While there is broad agreement in principle, practice is entirely another matter. The shear amount of data and the shear spread of influence is enough to scare even the sincerest practitioner. Thankfully, a rack of solutions is making this task a little easier.

In initiatives like 2030 Challenge and 2010 Imperative (Desmarais 2010), the scientists have set goals and the politicians deadlines which make the problem more manageable. Categories and weightings have been established (including energy, water, surface water, materials, waste, pollution, well-being, management and site ecology) in which ratings can be drawn. These then give an indication of how successful the exercise has been, carbon-neutral being the highest of six results.

These nine categories are broken down to credits (energy is 36.4%), and 90 out of the 100 achieves the highest score. So far so good, except that researchers are falling over themselves to provide toolkits to calculate these categories and the waters are becoming muddied again. However, of the list two, the *'British Research Establishment Environmental Assessment Method'* (BREEAM) in the UK and *'Leadership in Energy and Environmental Design'* (LEED) in the USA stand out. The German Sustainable Building Council (DGNB for 'Deutsche Gesellschaft für Nachhaltiges Bauen') is gaining momentum as a second wind system building on the learning curves of the pioneerinfg bodies.

Analysis software that produces BREEAM reports can use the building information model to give quantifiable results. This has significant appeal. The Netherlands are now considering adopting BREEAM (Kennett 2010) and Denmark is also seriously looking at the situation, but will probably choose DGNB. This means that the model can provide information about compliance, while also providing a place where experimentation with values (insulation for example) can quickly render results. Changes to the model are reflected in the reports and there is a seamless interface were the toolkits plug directly into the modelling programme.

This is Code Checking in practice. The University of Applied Science in Berlin is using modelling and analysis software in the studio to inform the process of the design in an ongoing way, while interrogating the model with *'what-if'* scenarios and achieving sustainable solutions with scientific results.

7.13 Agent Augmented Ontologies as Catalysts

Augmented realities are virtual worlds that echo reality, agents are catalysts that help the operation. Ontologies are the classifications that result from the whole operation. Basically, what Agent Augmented Ontologies do is number crunching, to find acceptable solutions for the various voids in the design. These results put names and products against the performances set out or demanded from the specification. There is a rapid growth in applications to analyse functionality in the early stages of design. As generic forms are tested for their constructability, methods are required to swap-in the components as they are prepared without jeopardising or compromising the remainder of the model until completely transformed.

Typically, this might mean that a generic window is placed in the model initially. During the design phases, this window will undergo many operations to get the design right, including tests for daylighting, ventilation, energy frame and even fire escape, all before the process begins of finding a manufacturer. At this point, each manufacturer's window must be popped into the model for testing, until either a winner is declared or an acceptable range of products is found to comply.

This same method can be applied to all elements and components of a building in a new and very exciting manner. Previously several somewhat subjective procedures had to be executed, totally divorced from geometric model or drawings. These involved listing all requirements in a tabular form with remedies and compliance notes or sources to the demands. What followed next required sorting them under importance and finally ranking them with weightings to particular instances. The best performer then got picked.

This is a technologist's job, finding appropriate solutions for the job in hand, backed up by a pseudo scientific models to demonstrate documentable procedures which allowed closure at each work stage, thus removing the possibility of renegotiation at a later stage.

This is not said negatively, but rather as an acceptable method to make logically sound decisions. The problem with the system is that it is removed from the model and as a such relies on the technologists experience and know-how, again it must be stressed this is not a bad position. In fact, many of my colleagues would hold that this is a core competence for a technologist.

But imagine a scenario, where Obonyo describes a buyer's agent who needs to match a designer's requirements together with the manufactured products found in brochures (Obonyo 2010). Built into the search process there are building regulations to adhere to, as well as cost, materials and any other peripheral criteria that might go toward making the optimal decision. The agent assembles the products that meet the conditions set out. The designer makes a choice and the subsequent documentation is then drawn up.

Various cycles are performed to achieve this outcome. The various products are identified and compared. The relevant data is extracted and compiled into legible form. A secondary round might now take place refining the first set of results with more detailed data. The distillate surfaces again. The actions that have been performed include widespread communication to identify products that meet the desired standard, this is gathered from manufacturers. Next, an internal process takes place, to weight the selection set and rank them in order. The final communication phase suggests the preferred options, which are presented for nomination. Once the choice is made, a secondary process compiles the specification documentation in a useable form for the project.

The object of the exercise is to extract the performance requirements from the designer and turn this into a detail product specification. The method has been to interpret the designer's requirements and to make the result useable. Imagine no human involvement except at the user interface. These are called *'Bots'*, as in robots, and they simply software applications that run automated tasks that are relatively simple and structurally repetitive.

In a sense, this is what Google search engines are getting better at doing, and it happens instantly or in the background. This automates the demand process and soon it will be linked or embedded in the model. Already type codes or instance codes can be attached to the building elements or components. By this, it could for example be a brick or the whole wall composition. A code can be as simple and as passive a blank field into which a piece of text can be placed either as a marker or as the link, that ties the process together.

Soon it can also be an active *'bot'* that once released can go about its business assembling data for better selection. Its scope can be curtailed to generic choices before tender or in other forms of procurement, it can go direct to the manufacturers. Once the decisions are taken analysis cycles can test the candidates for best fit, allowing the designer to select the best suited.

7.13.1 A New Focus and a Widening of the Scope

In their Autodesk University Keynote address in 2010 Jeff Kowalski, (Autodesk vice president and CTO), Liam Quinn, (Dell business client CTO), Will Allen, (HP IPG graphics solutions business group chief technologist) and Balint Fleischer, (Intel workstation and server group CTO) were panellists in ' *What's New, and What's Going to be Cool'* (Kowalski 2010).

The discussion at one point entered into how cloud technology is evolving and how it will affect customers. Fleischer explained that there are really two major models of what the cloud is:

- Infrastructure as a Service (IaaS), which enables organisations to outsource computing infrastructure, including all the servers, storage, and networking. The organisation rents capacity and performance as needed rather than having to build a data centre or other infrastructure.
- Software as a Service (SaaS), which involves providing actual functions, so users rent the ability to perform the function rather than the capacity. Good examples of SaaS include customer relations management (CRM) systems and Google Earth.

Quinn mentioned that the cloud is possible because of the evolution of other parts of the technological ecosystem, including virtualisation and the increases in raw processing power, network bandwidth, and other technologies. He said that its real value is collaboration, because both businesses and customers are increasingly global and distributed.

Kowalski alluded to the matter of distributing and provisioning data to mobile devices. While previously they were completely under the control of the distributor, now through the Apple App Store and the Android Market, control is given back to the user.

'People need to be able to take their data with them and be able to collaborate in the field.'

He also said:

'The computer can monitor the world and keep the design alive. As an example, he imagined a system that can monitor progress on a job site without manual intervention and feed all the information back to the model.

He also talked about smart spaces. I want data to follow me, I want context to follow me, and I want to collaborate with others who have data with them.'

His meeting room of the future would automatically sense who is there, put the right people on the conference phone, and bring up the correct data on the projector.

7.13.2 Future Trends in Real & Virtual Worlds

So if the pressure is not coming from within then what will drive the changes? Clients were instrumental in the DWG format being adopted as deliverables more than twenty years ago, and they appear in the factors influencing BIM as having 49% influence. Code Checking's appearance at 25% in the McGraw-Hill Report on Interoperability is significant in that there was not widespread checking then, so it must be determined as a *'wish-list'* item (Young, Jones et al. 2007)

Tomas Pazlar (Pazlar, Turk 2008) found that moving a simple wall in and out several programmes led to data being dropped. Typically, a field would have no corresponding field in the new format and if not critical would be dropped. On passing back that field would be voided. Even using IFCs, evidence was shown that all export functions were not supported. It could be as innocent as the wall hatch or pattern being lost in a vertical section, but even so it meant that the operator had to be vigilant *'not blindly trusting the mapping process'*.

Alan Baikie of Graphisoft argues in Building Design's 2008 World Architecture 100, an annual survey of the top architectural firms in the world, that larger firms are slower to invest heavily in newer technologies in terms of money, time and effort in their migration into the 3D realm, leaving the door open for nimbler firms (Littlefield 2008).

This is what can be done now, augmented reality is beginning to emerge in the construction industry. Augmented reality superimposes virtual data about your surroundings via a mobile phone. This layering can be filtered to your requirements. Suppose you point your mobile phone at a historic building, the in-built GIS knows where you are and which direction you are facing, and so can recognise the building in question. Historical facts can pop up, details can be displayed, information about the architect, style or previous residents can be solicited. This happens now in museums where information can be given for each exhibit, in your preferred language. Point your phone at the Abbey Road pedestrian crossing and see John, Paul, George and Ringo superimposed on the street.

Taking this further, point your phone at a building site and see what the building will look like when finished. Give it to a sub-contractor and he can see the installation he is required to do. Give it to a construction manager and he can see if the progress of the building is up to schedule and if the reality matches the model. Give it to a surveyor and he can see the position of all utilities in the ground, no more hitting water mains when excavating.

Replace the phone with spectacles and a raft of information is available on the inner surface of your lenses. This is happening with the visors of fighter pilots and the dashboard of some concept cars where the focal point is set to infinity. This mapping of the reality with the virtual world completes the call for adopting the model. The closest you can get to a real building, that is not a real building, is a virtual one, and BIM is that situation. Before a real building exists, it has to be modelled in some matter or form (Pazlar, Turk 2008). It is worth repeating: BIM is here to stay, as claimed in the introduction.

7.13.3 Project Certainty Improves Communication

In fact, anything that makes the project more certain spells success to any client or developer (Fong 2007). Just as clients were crucial to the implementation of the Autocad file type format (DWG) for all deliverables back in the early days of CAD, increasingly they will be the driver for BIM adoption for all projects in which they are involved. Back then a common file format was required if a client wished to prevent a designer ring fencing a project by adopting a lesser-known file format at the inception of a project. Once a project was defined, the odds of it being translated to another propriety software lessened, meaning the chances of keeping a project in house improved. Also at handover, a generic format was required so that it could be utilised later for maintenance or future work. Autocad as the biggest player adopted that mantle and all other software houses had to write DWG exporters to remain in the loop.

Project certainty offers more than a mere standard, as it tells the client that the project is on time and to budget. Clients have been crying out for this and have been refocusing on professionals who can offer this service. Frank Gehry relates the unease of approaching a client to inform him of budget overspends and the changing role facing architects where traditionally they held the parental role of the design/procurement team to the infantile role where the contractor once onboard offers concrete savings from practical considerations and becomes the leading role in the eyes of the client.

In a recent promotional video clip Laing O'Rourke, an engineering enterprise in the UK, presented a new project, The Leadenhall Building in the City of London by architects Rogers, Stirk, Harbour + Partners. The 47 storey, 224m, tower is set to become one of the tallest buildings in London. It will combine a landscaped open space with modern, flexible offices including retail and dining facilities.

The video not only demonstrated the building site set-up, but could also established the site and documented the temporary structures and plant needed to build such a building in a cramped site with neighbouring buildings and the bustling day to day life that needs to continue despite the construction programme. Moreover, the erection could be shown and assemblies visualised both to demonstrate best practices but also confirm health and safety adherence. This cannot be overestimated.

8. Case Studies

8.1 Introduction

The case studies presented here cover a wide range of projects in a variety of scales. Their scope and level of detail differ markedly for good reason, demonstrating how BIM has been adopted and to what degree. Whether it is a simple first foray into the new way of working, or whether it is a most comprehensive implementation documented to date is of concern but no more than that. They have been chosen from what was readily available but also with a view toward drawing vignettes of what is happening now. There is a range and scale moving from simple 3D authoring, all the way up to fully integrated project delivery.

It has been the intention to present them in a structured manner to allow cross-referencing and comparisons but owing to their subjective nature, this has not always been possible. Your tolerance is appreciated. Overwhelmingly the feedback has been positive and engaging. There has been a keenness to hear about the others in an attempt to position oneself in relation to the others. The topics raised have been both interesting and revealing.

Generally, all feel that it is the future and that the correct decision was to commence down this path. No one is going back but that said there are several major issues to be resolved. The driving forces too have been many and varied, from client demands to a better way of working, from in house expertise to conditions of engagement, and finally from a sustainable standpoint to a position of project certainty.

It has also been an enjoyable part of the exercise, in both testing the theory being expounded and underlining the practices being adopted out there in the field. Each demonstrates a diverse set of benefits and alludes to special interests. The format adopted will name and locate all case studies. Next the project work phase will be listed at the time of interview (or at time of writing if significantly different), followed by the participants, either by role or role and name (depending on disclosure), the benefits experienced and the methods deployed. These results will be tabulated for easy reference.

Each will then be presented individually, introducing the case itself, the project, the team, the design process followed by conclusions and comments. Some have diversionary stories and asides, which embellish the account and these, are included for your delectation.

8.2 Case Study 1: Brian Sheldon, Site Architects, Copenhagen

Name:

Kregme Kindergarten

Location:

Ølsted, Halsnæs

Project work phase:

Completed 23rd June 2010

Participants:

SITE a/s (Architects)

Brian Sheldon

Tuborg Havnevej 18, 2900 Hellerup, Denmark

Tel.: (45) 3031 0012

Figure 21 Figure Kregme Kindergarten Concept, courtesy of SITE A/S

SITE A/S was established in March 2006 by five architects having a total of 100 years professional experience and a thorough knowledge of construction and design. They represent a new generation of architects that work strategically and use 3D computer programmes to explore and communicate the many aspects of architecture. As facilitators in the different project phases, they work with the notion of creative partnering as a tool to collect and develop knowledge from clients and collaborators. One of their goals is not to surrender the architect's artistic superiority, but rather involve it in a practice that ensures quality architecture in a democratic decision making process.

They have an international profile with three nationalities represented in the partner group and a large network abroad. In this, they reflect society's diversity and this is borne out both in their design solutions and employees, having eight full time employees. Their approach has always strove to create optimal architectural solutions from a clear concept, a thorough analysis of the client's needs and an open dialogue. They claim in this that they are the preferred professional choice for translating client visions into innovative architecture through an analysis of organisational needs, function, culture and an open design process.

Being relatively young, this puts them at the leading edge of the creative design process precisely using new technologies and the possibilities they offer. SITE produces all projects in 3D CAD (dgn & dwg) and BIM (Building Information Modelling). This meets all the requirements outlined in BIPS 2006/7 (the new DK national drawing and documentation standards) for 3D work processes. They use Bentley Architecture/Microstation V8i Select Edition and Sheldon holds the chair position of Danish Bentley User Group in 3D-visualization. DANSKE ARK's quality control system and BIPS specification tools are used to regulate their work.

Their design approach makes them unique, they claim, through creative partnering and an analytical approach to the project's conditions. The concept is first developed, then tested and fine-tuned through the design work phases. Regardless of the project type, the creative process is made factual and the communication of ideas and results are weighted highly.

SITE's special fields of competence are in architecture; from the initial ideas to 3D design and documentation to supervision, and in consultation and research; from analysis of functions, economy and building regulations. As said they are a network-based organisation that puts project teams together to best meet the demands of a project. They draw upon their network partner's expert knowledge as well as their internal skills. Project responsibility is allocated to the partners according to their qualifications and the project's specific requirements.

They are a limited company owned and operated by its five partners. Directors Marc Wilson and Jette Lind Johansen are responsible for daily management of the practice. SITE is a member of the Danish Association of Architectural Practices (DANSKE ARK).

NIRAS (Engineers)

Peter Noyé

NIRAS Allerød (Head office), Sortemosevej 2, 3450 Allerød, Denmark

Tel.: +45 4810 4200

By contrast, NIRAS is a large international consultant engineering firm of over a thousand employees, founded in 1956 by civil engineers Jorgen Kristian Nielsen and Konrad Rauschenberg. Their growth along with mergers has enriched NIRAS with a number of core activities, both in the traditional and the specialised engineering disciplines, including project management and the development of human resources. They are members of the Danish Association of Consulting Engineers (FRI) and the International Federation of Consulting Engineers (FIDIC). Their main business areas are agriculture, construction, climate control, energy, environment, management services, social sciences and transport logistics, and have completed projects in more than 180 countries.

Figure 22 Figure Kregma Kindergarten, Interior view courtesy of SITE A/S

HHM (Contractors)

Svend Pedersen

HHM A/S Bragesvej 4, 3400 Hillerød

Tel.: +45 4825 3300

HHM vision is to be Nordsjælland's leading construction company, within their three core competencies. The work is primarily performed by their own engineers, technicians and craftsmen. In 2006, HHM was named Contractor of the Year, and in 2007, 2008 and 2009 was appointed a Gazelle (elite) Company of Børsen, a national newspaper. To achieve the honour, the company showed an attractive financial progression and development over a long period. This and other criteria was achieved with a healthy relationship between growth and earnings. The knock on effect to customers is increased reliability and stability.

In 2008, HHM was the only construction company building family houses, whose working had been fully certified. For both customers and employees the certification meant, sites with better control, fewer accidents and houses built under excellent working conditions.

The Project

This is their first project where BIM plays a small but significant role. Essentially the process outlines a methodology where BIM is fully implemented in-house, but that it is currently what can be called a one way street where collaboration is concerned. This means that the consulting engineer received the model in IFC format and analysed it, (using SOLIBRI). Reports were then generated, which were then returned to the architects where the content of the reports was actioned and this process continued until compliance was achieved.

In 2015, the Danish government will impose new energy requirements for buildings. This project meets those requirements meaning the building had to comply with the strictest demands on energy and heating consumption. SITE together with HHM won the first prize in a competition for this class 1 low-energy integrated kindergarten in Kregme. It was inaugurated by the Mayor of the Municipality of Halsnæs on 23rd June 2010. While the work was still ongoing, the Danish Prime Minister Lars Løkke Rasmussen also visited the site to see and hear about the centre.

Class 1 meant the focus was on energy, but surprisingly it became more about light calculations rather than heat loss. The architecture and spaces were designed to emphasize and enhance the identity of the institution. The conceptual layout was inspired by a *'Hedebyhus'*, (a dwelling from the Viking ages), which was found in an archaeological dig close to the Church in Kregme. The collection of rooms was arranged around a central common area encouraging interactions between the individuals, as well as between groups, under a double-height ceiling perforated by skylights. The new section was designed to be a flexible unit, connected to the existing building by a sheltered roof, which could be incorporated into future extensions of the kindergarten. The kinked form optimised the playground areas outside while at the same time providing spatial diversity and variation to the common areas inside.

The compact form was chosen also to optimise the interior and reduce unnecessary corridors, which minimises energy consumption. Daylight performance was essential, due to the shape of the building. Daylight was provided by large windows and skylights. The design thus created variations in light quality as one moved through the building due to the diverse orientations of the different rooms. The spaces were designed to emphasise and enhance the identity of the institution, while hopefully challenging the children's senses.

Kregme kindergarten is the first institution in Denmark that is listed in the low energy class 1. The building is highly insulated, the heating is re-cycled from the expelled air, the structure is optimised and the savings are reinvested in solar cells. The building's total energy does not exceed 50.9 kWh/m^2. Energy savings of these proportions require well-researched solutions from for all building parts. It has a climate envelope that is airtight and well insulated with a minimum of thermal bridges. Special, energy-efficient windows have been used and good daylighting conditions established. Together with daylight control systems and energy-efficient ventilation, low consumption of energy for lighting and climate control is ensured.

The centre's heat consumption is comparable to that of the newest energy-efficient and climate-friendly buildings that were erected as landmark buildings when Denmark has hosted the climate conference in 2009. The majority of the energy comes from geothermal and a solar heating systems. There are 30 square metres of solar cells which will supply supplementary electricity. The building is placed on the site to optimise a new central entrance with the existing building and the playground layout. The interior has been laid out to achieve a spatial experience for the children compromising energy usage. The building's heated areas are minimised through the compact form and the roof is angled to take maximum advantage of optimal solar panel placement.

The kindergarten is home to four child groups and four crèche groups. In all, there is room for 120 children from nought to six. The building also houses a playroom for Kregme's after school system. In the centre of the building, there is a large, high-ceilinged common room with direct access to all of the groups' rooms. In addition to the fact that energy-efficient solutions have been integrated everywhere, it is an architecturally aesthetic and exciting setting for both the children and the educational activities.

'Many local authorities are interested in building low-energy housing but find the task insurmountable because there are so many different parameters in play. This is a shame because it is easily do-able if it is approached in the right way from the start',

... says Jette Lind Johansen, architect with SITE A/S Architects, who follows it up saying:

'If low-energy buildings are to gain ground in municipal construction, projects must also be subjected to a thorough evaluation during the assessment process. Only if professionals with the necessary technical expertise are members of the panel of judges, can local authorities ensure that the project that best meets low-energy class requirements is the one that wins. Unfortunately, the reality in local authorities is often quite different.'

NIRAS noted that local authorities are very interested in building low-energy houses but a lack of technical expertise can curb development. It is important for them to minimise the consumption of electricity and heat in our buildings if we are to meet the UN's climate targets to reduce CO_2 emissions to a level of 3 tons/year per inhabitant by 2050. Because of the climate summit, many good low-energy initiatives have been launched in Denmark.

Peter Noyé, engineer and energy and indoor climate consultant at NIRAS says:

'It is a well-researched project and we succeeded in achieving extensive energy savings due to the fact that design and concept are closely coupled with carefully planned structures and energy-efficient installations. This, in itself, results in considerable energy savings.

It is a saving which, combined with individual renewable energy initiatives, creates a house with extraordinarily low energy consumption - at a fair price', he adds and continues:

'The... summit in Copenhagen is all about solutions at a general global level and this is difficult for the individual to relate to. The kindergarten day care centre in Kregme is an example of a solution that we – and not least the children – cannot fail to notice in our daily lives.'

Table 3 Energy Requirements Kregme Kindergarten

Energy requirements	Gross energy factor	kWh/m2
Room heating		25.4
Domestic hot water		5.7
Ventilators, electricity	2.5	10.3
Pumps, electricity	2.5	0.3
Lighting, electricity	2.5	25.5
Heat pump,	2.5	17.0

electricity		
Excess temperature		0.0
Solar heat		-2.8
Thermal pump		-28.3
Solar cells	2.5	-5.8
Total		47.3

From this, it can be seen that a high performance, award-winning building was achieved at little or no extra cost, due to good early assessment and proper initial analysis. This was possible because SITE used a 3D model, built in Microstation, which could be exported to NIRAS in IFC format. The engineers analysed the model in SOLIBRI and reported back that the biggest issues were the skylights and southern facing fenestration rather than the insulation thicknesses which was quite adequate. The form was slightly modified to achieve compliance.

Interestingly there was no offer or request by members of the design team to return the IFC model, modified or redlined. All correspondence was conducted through reports with verbal clarifications where necessary. This demonstrated two things, the first that SITE were using NIRAS purely as a consultant and that NIRAS were performing as such, saying little of what or how they were producing or quantifying the data. This is not a criticism, merely an observation, because it clearly shows that the roles performed well and the product pleased all concerned. An improvement would have been a bidirectional link.

Figure 23 Figure Kregme Kindergarten, Halsnæs, courtesy of SITE A/S

8.3 Case Study 2: Christina Tolstrup, Gottlieb Paludan, Copenhagen

Name:

Extension to Per Aarsleff A/S, HQ in Hvidovre (Copenhagen Office)

Location:

Industriholmen 2, Hvidovre, 2650 Copenhagen

Project work phase:

Completed 2010

Participants:

Gottlieb Paludan A/S, Finsensvej 6E, 2000 Frederiksberg (Architects)

Christina Tolstrup

Gottlieb Paludan (GP) chose to run the erection of an extension to Aarsleff's head office in Hvidovre, with Niras as a pilot programme. Both GP and Niras wanted to do this project using BIM, and after winning the competition GP offered the client this option, which they claimed could be used later for their operations and maintenance, but the offer was politely declined. Per Aarsleff A/S, it should be pointed out, is a major general infrastructure contractor. They specialise in foundation engineering and pipe renewal. Their annual revenue is DKK 4.3 billion, with 35% coming from work abroad. The Aarsleff Group has 3,200 employees in total. Despite this, GP and Niras choose to continue with it, as they envisaged many co-ordination advantages internally coming from such a set-up.

But that said, they entered into a comprehensive traditional contract with the client, and this meant that they would use more time and resources on the project during the early design than normal, meaning they were exposed to a degree of risk. Underlying this strategy, there was a perceived expectancy that ultimately they should recoup this outlay, further down the line. This meant that there was no extras paid for building the model, and all deliverables were digital 2D drawings (dwg or pdf) as per contract. They even implemented collision testing in 2D, despite both parties having a 3D option.

Their initial cost overruns however did pay dividends during the development and production phases. Ironically too, when the main contractor, Pihl and Son, came on board, they made their own model, and even though they was great interest in GP's, which could extract quantities, under the terms of the contract GP had to refuse to share this information. This impasse resulted in large discrepancies in the project with much checking and rechecking of all stakeholders' work. Moreover, this was further compounded when the design team could not give the contractor their work without consideration under the terms of the contract, without some form of compensation for same. This was to become a large handicap.

When the changes and revisions that accrue from this type of work started, all parties were bound to log, revise and invoice their work as per contract. Very quickly, the client knew that all stakeholders had their models, and that all changes were relatively easily made, albeit in parallel worlds. By this, I mean that each stakeholder had a model of their own domain that was co-ordinated with relation to traditional methods, meaning corrections were easily effected. It is worth mentioning here too, that all resources (human) were largely recruited from the traditional method of working, meaning they all understood and normally worked in this situation.

It transpired therefore, that the many revisions to the project, could actually be made through the models, by the differing parties. This was not missed by the client, and the twist was that the client, while aware of these simple alterations, had no option but to pay top dollar under the terms of the contract. The client knew the changes agreed at project meetings could effectively be made with little or no effort. Following the contract, this was hefty remuneration for simple changes, and this in turn meant a big payday for their earlier investment.

Figure 24 Industriholmen 2, Hvidovre, Denmark

8.4 Case Study 3: Miles Walker, HoK Architects, London

Name:

Autodesk's Gallery and Offices (3,900m² refurbishment)

Location:

One Market Plaza, One Market Street, San Francisco, USA

Project work phase:

Completed August 2008

Participants:

HoK, Qube, 90 Whitfield Street, London, W1T 4EZ, UK &

HoK, One Bush Street, Suite 200, San Francisco, CA, 94104, USA

Miles Walker (UK) & Bruce Madsen (USA)

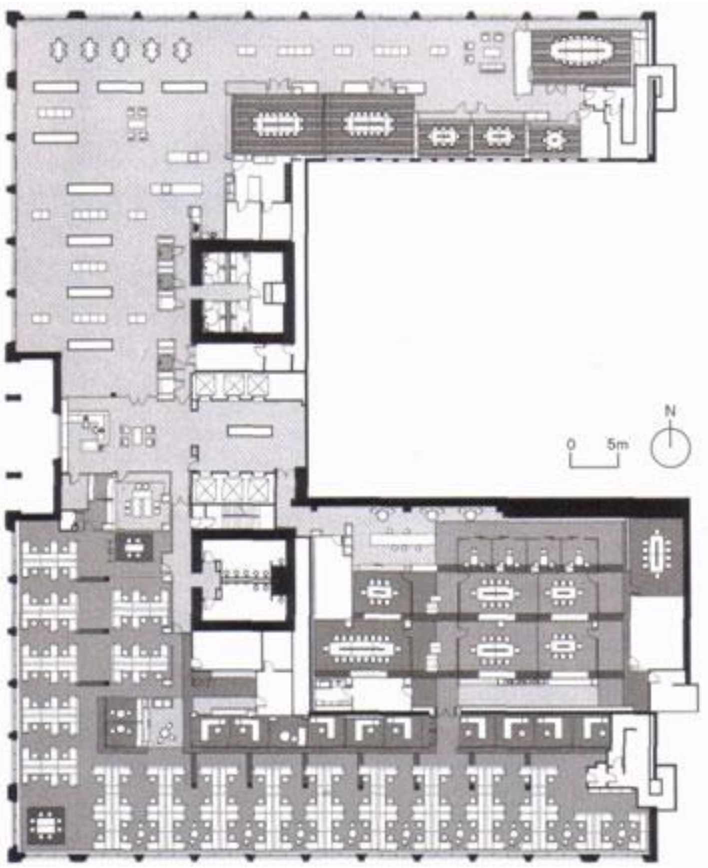


Figure 25 The £6 million remodelling of Autodesk's gallery and offices at, One Market Street in San Francisco is HOK's first completed project using its new Integrated Project Design (IPD) contract, courtesy of Architects Journal 23/07/09.

When the client is Autodesk, then the rest can nearly be guessed. Autodesk wanted a showcase building, in a showcase manner, using top of the range procurement. This was achieved by involving one of the biggest architectural practices globally, HoK, who had moved up to second place on Building Design's 2008 World Architecture 100 listing. They had moved up from third the year before with an increase of architects from 884 to 1205 with a fee income of over $250M (Littlefield 2008). In fact, they were only nine architects short of being the world's largest practice over Gensler.

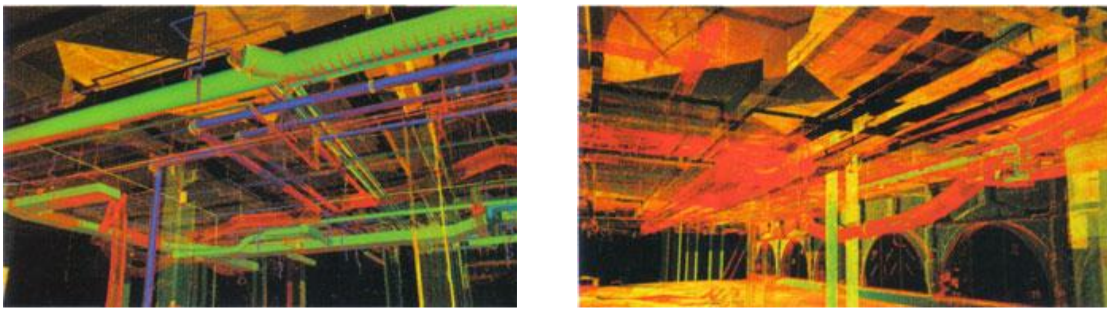


Figure 26 One Market Street Laser Scanning, courtesy of Architects Journal 23/07/09

The team was impressive too. DPR Construction, have carved a niche market as being one of the most technically advanced contractors in the business. They had equal ownership and management responsibility for the BIM model alongside HoK and Anderson Anderson Architecture, who were the local firm. Alongside this, there was structural engineering from Tipping Mar and mechanical engineering from ACCO Engineering Systems.

The brief was succinct and to the point, meaning that there were clear and unequivocal demands. Sam Sparta, director of HoK buildingSMART (Alexander 2009) had this to say:

'A typical construction contract for a project like this would be at least two-and-a-half inches (60mm thick; ours was only half an inch thick (12mm), with single-sided printing,'

Expected standards were high, with the brief stating that the building should achieve a LEED Platinum rating. Remuneration was high too, but with provisions. One Market Street was HoK's first completed project using an IPD contract. It was underpinning and rewarded with the incentive of shared profit. IPD aimed to achieve what the contract termed *'mutual success'*:

'The parties will within the limits of their professional expertise and abilities, worked together in a spirit of cooperation, collaboration and mutual respect.'

The budget for the project was structured in three layers:

a pre-agreed direct expense element for project costs (design, construction and legal);

a contingency layer for unforeseeable events; and an Incentive Compensation Layer (ICL)

This ICL translated into four riders:

If the project costs come in under-budget, 50% of the saving is added to the ICL

If the project is over-budget, the excess comes out of the ICL until it is exhausted

If the project is within schedule, £4,500 for each day won is added to the ICL

If the project runs over schedule, £1,500 a day is deducted from the ICL.

The project was a success and all targets were met, releasing an ICL pool of £467,000. This was split between the parties as follows:

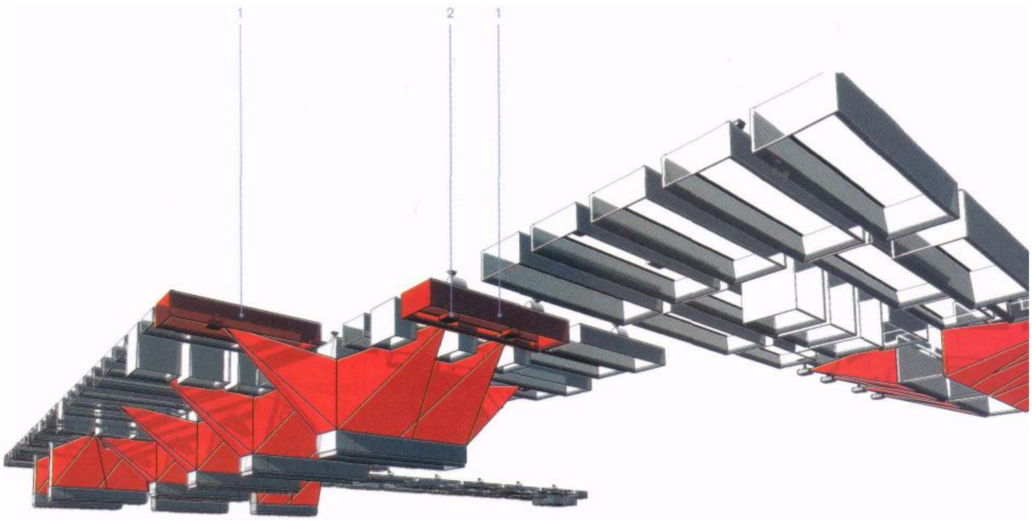


Figure 27 The BIM model was used to position the ceiling-mounted projectors accurately, courtesy of Architects Journal 23/07/09

HOK (11%; £51,370)

Anderson Anderson (23%; £107,410)

DPR (66%; £308,220)

Table 4 One Market Plaza, Autodesk/HoK

Client	Autodesk
Tender date	November 2007
Start on site	February 2008
Completion date	August 2008
Form of contract	IPD
Total cost	£6 million
Cost per m2	£1,560
Office architect	HOK
Gallery architect	Anderson Anderson Architecture

Main contractor	DPR Construction
Structural engineer	Tipping Mar
Mechanical engineer	ACCO Engineering Systems

The delivery combined BIM, an IPD collaborative team relationship and a fast-track design-build schedule, with very ambitious sustainability goals, gaining a LEED Platinum award. Autodesk's Briefing Centre Senior Manager, Jason Medal-Katz said:

'The space is highly coveted by our employees and has set the standard for delivering office space and client-facing environments'.

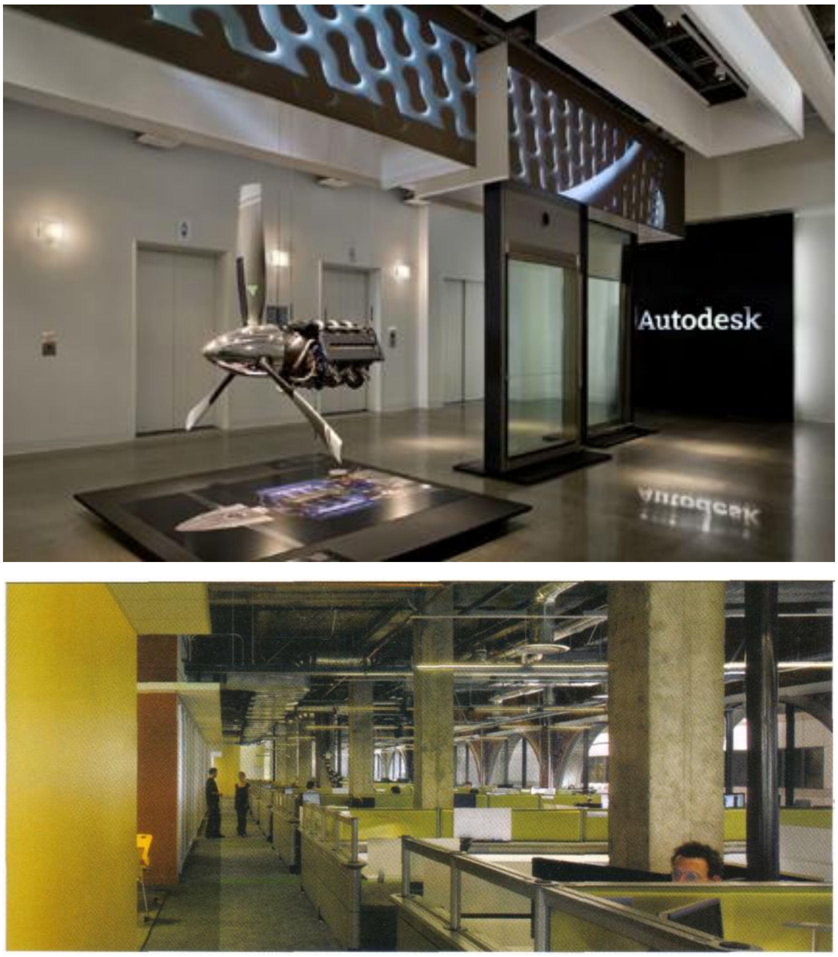


Figure 28 One Market Street interiors, courtesy of Architects Journal 23/07/09

8.5 Case Study 4: David Throssell, Skanska, London

Name:

Barts Hospital and The Royal London Hospital

Location:

St Bartholomew's Hospital (Barts), West Smithfield, London EC1A 7BE, UK &

The Royal London Hospital, Whitechapel Road, Whitechapel, London E1 1BB UK

Project work phase:

Ongoing until 2016 (started in 2006)

Participants:

Skanska UK, Linslade, Bedfordshire, UK

David Throssell (3D CAD & Data Management Leader, Skanska Technology Ltd)

Figure 29 Barts & The London Hospitals, courtesy of Skanska ©2010

The Barts Hospital and The Royal London New Hospitals Programme is worth over one billion pounds in construction costs alone, making it one of the largest PPP’s in Europe. On top of that, it has an operation’s contract for 42 years. Barts will be the

'Cancer and Cardiac Centre of Excellence', with 1,248 more patient beds, and 8 operating theatres.

The Royal London Hospital, is being almost completely rebuilt. It will include London's leading trauma and emergency care centre, and incorporate 22 theatres, to become the capital's second largest children's hospital, and one of Europe's largest renal units. Additionally, London's Air Ambulance will operate from the rooftop.

While there have been plans to redevelop Barts and The Royal London since 1998, it was only in 2003 that Skanska Innisfree, a private consortium, was appointed as the *'Preferred Bidder'*. Planning permission was only granted for Barts in 2004 and for The Royal London in 2005, with the financial closure following in April 2006. Skanska's equity investment was £48m and Skanska ID's stake is 38% of the development.

With regard to procurement, Skanska have said:

'The first phase of the programme involved the demolition of a number of vacant buildings at both hospitals. This work is now largely complete at The Royal London, and work is advancing on laying the foundations for the new hospital buildings. At Barts, demolition of Queen Mary Wing is now underway to create space for the new cancer facility at the hospital.

The entire redevelopment of both hospitals is expected to be completed in 2015. The new Cancer Centre at Barts is due to be ready in 2010 and most new facilities at The Royal London should be operational early in 2012. The existing hospitals will be fully operational during construction. Protective screens have been erected around construction areas to reduce the impact of building work on patients.'

Table 5 Barts and the Royal London Hospital

Construction period	2006-2016
Concession period	2006-2048
Operation and maintenance	Carillion, Synergy and Siemens
Skanska ID's share of ownership	38%
Skanska ID's investment	SEK 540m
Total construction value	£1 billion
Construction	Skanska UK (100%)
Construction workforce	180
Partners in construction	Skanska ID Innisfree
Partners in development	John Laing Infrastructure

To complete the picture, Paul White, Chief Executive of Barts and The London NHS Trust, said the following:

'This is the biggest hospital redevelopment programme in Britain. It will transform Barts and The Royal London. Our hospitals have a long and proud tradition of providing first class care to patients not only from London but from across Britain. We have some of the best clinical results in the country. This redevelopment scheme not only guarantees the future of these historic hospitals but also ensures that our excellent clinical results will soon be matched by facilities to rival the very best in Europe.'

In this context, David Throssell at a conference, by the Chartered Institute of Builders (CIOB) at their HQ in Ascot, outside London, candidly recounted the problems and magnitude of running a job the size of Barts and The Royal London. The presentation was entitled *'Getting your ducks in a line: a case study of the Bart's and London Hospital'*, and outlined the procedures they have enacted to manage the job (Throssell 2009). Because of this wonderful presentation, I followed it up with an interview at the RIBA in Portland Place the following year, both to discuss the earlier work and track new developments (Throssell 2010).

His first comment claims that hardware and software are not the issue anymore, but rather that it is *'the paper medium'* itself that engenders the overall liability, because it is no longer reliable or controllable. This, he went to elaborate, was due to change being constant, in the building process, and that versions and revisions only make the problem endemic in printed format. This is of immense interest.

Two points are worth mentioning here, first is the churning out of the data, in paper formats, creates potential problems about ensuring that the most up-to-date versions are properly distributed, and similarly, that the lacking of control over superseded versions and their successful removal from active service creates doubts about veracity. Secondly, and significantly, there is tremendous physical effort in maintaining these up-to-date sets, and that there is incredible drudgery in tracking back and forth to the site hut every time there is a query.

While in other circumstances this might seem trivial, here it was claimed that savings of up to one hour per day could be made. Coupled with better control, the traditionally overspend went from 10% over budget to 0.08% under. On another totally different tack, it resulted in better (informed) decisions due to better instant responses and better linking of data. Moreover, there was better filtration of data, meaning it could be tailored and targeted to the intended person.

To understand these savings better, it must be understood that the project was handing over 50 rooms a week (out of 5000 overall). Logistical this was a nightmare, involving the handover and closure of more than 80 activities per room. Initially, the designers thought this could be achieved through a simple spreadsheet exercise, using a database (ArtrA) and their own SKANDOCS system. But due to Barts size and complexity, together with London's size and scale, the immensity of the problem proved daunting. Incidentally, another hospital of the same scale and size is Karolinska Solna in Stockholm, Sweden (also by Skanska), where many of the lessons that were learned here are being implemented or further reviewed there.

However, with the intervention of tablet PC's, their purpose was to support and assist the paper trail. When the tablets were first approved, it was on the grounds that it would improve communication speeds and allow the CM better response times when dealing with traditional problems. It was envisaged that the CM could get to where the issue was and be fully aware and prepared to deal with it, without having to return to the site hut to collect all drawings and documents related to the problem.

Previously, the CM would be called up to the problem, be told what the problem was and then, before deliberating on it, return to the site hut to confirm the circumstances, by referring to drawings and documentation. This travel part of the process incurred the extra hour each day. With the introduction of tablet PC's, the intention was to short circuit this, by providing up-to-date information at your finger tips, where and when needed. This involved the approval of 4 tablet PC’s initially, which grew to 40 Motion LE 1780 x 30 and Motion J 3400 x 10, (robust and rugged PC's made for use in the field).

One observation from their site office was that it was not now unusual to see three sub-contractors standing beside a construction manager above on the scaffolding, looking at a 3D model on a tablet PC. Rather than trawling through the approved or released data (drawings, specification and schedules), they were in fact interrogating the model. The CM would often show the subbies the model and by traversing and delving deeper into it, could show and explain complex details or assembly procedures in a manner more meaningful to the workers. This observation, about the abstracted material (2D drawings, specification and schedules) being harder to read than the 3D (virtual) situation is worth noting.

Away from the site and back in the drawing office, modelling was seen as a means to clash prevention rather than detection. Data could also be embedded on spread-sheets rather than in the model, while they were in transition. The model was seen as critical in the health and safety aspects of managing the site and the building programme. They also had a plug-in for Navis Architectonic Surveyor to help with their surveying, both pre- and post-stages of work.

There was a major role for FM and subsequent maintenance issues, because they would be involved with the hospitals for the next 42 years at least. Not alone was it a great help towards costs and benefits, but they also had begun adopting 4D aspects for small components packages while they felt their way forward, but not comprehensively throughout the model.

One area that needs more attention is bringing the (project) planners on board earlier so that they were more involved in the initial stages. As mentioned, the tablets started with 4 people, who were identified as young champions, but this (at the time of the interview) had risen to 40. Because of the novelty of this new departure, there was still a great need for monitoring the actual drawing requirements, independently from this project. This would help Skanska evaluate the success of their implementation.

With the handover of fifty rooms a week, generating reports to facilitate this process became more streamlined. Instead of colouring plans as progress was made, applications were provided to automate the process as they were completed. In all, 250,000 items to be checked off as a control status. Afterwards this was followed by snagging provided by a toolbox, which developed continuously through the job. David saw it as a journey.

Most notably, he saw ownership of model as a non-issue. Being further down in the supply chain, he saw the model as only a catalyst to procuring the job. From this vantage point, he also believed that providing a model was part and parcel of the design/procurement package and questioned why ownership was even up for discussion, meaning that it was implicit in the job description. He claimed too that it would diminish as collaboration grows.

Figure 30 Barts and the Royal London Hospitals, courtesy of Skanska ©2010

8.6 Case Study 5: Morten Alsdorf & Niels Treldal, Rambøll, Copenhagen

Name:

Rambøll's new HQ, Copenhagen

Location:

Hannemanns Allé 53, 2300 Copenhagen, Denmark

Project work phase:

Completed 1st August 2010

Participants:

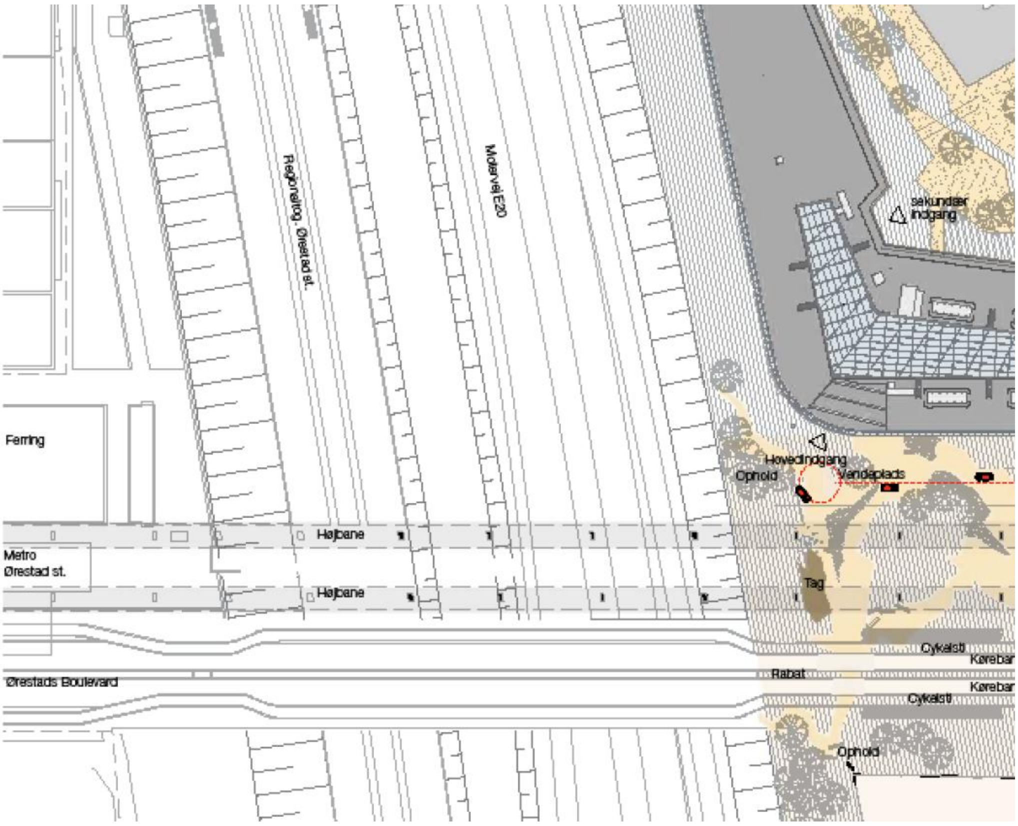
Rambøll, Hannemanns Allé 53, 2300, Copenhagen, Denmark

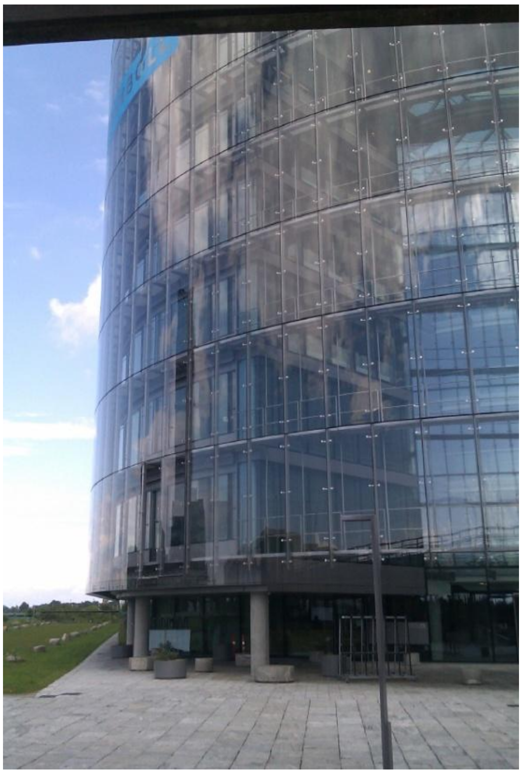
Dissing+Weitling Architecture, Dronningensgade 68, 1420 Copenhagen K, Denmark

Morten Alsdorf & Niels Treldal, Rambøll

Figure 31 Rambøll's New Head Quarters, Ørestad, Denmark, courtesy of Rambøll ©2011

In August 2010, Rambøll moved into their new headquarters in Ørestad in Copenhagen. With its 40,000m² office space, the new building is one of the largest office buildings recently completed in Denmark, and provides a work place for 1,800 employees. It was the product of four years of work, resulting in a coveted corporate headquarters. Internally, it is loosely based on Barcelona's famous Rambla. The central atrium ties the entire building, together, both horizontally and vertically, by focusing on a series of mezzanine floors and balconies, which traverse the space, making it very readable and easy to navigate. Through a combination of walkways and curved balconies, the interior challenges the rigour of the seamless 5,000m² double skin façade.





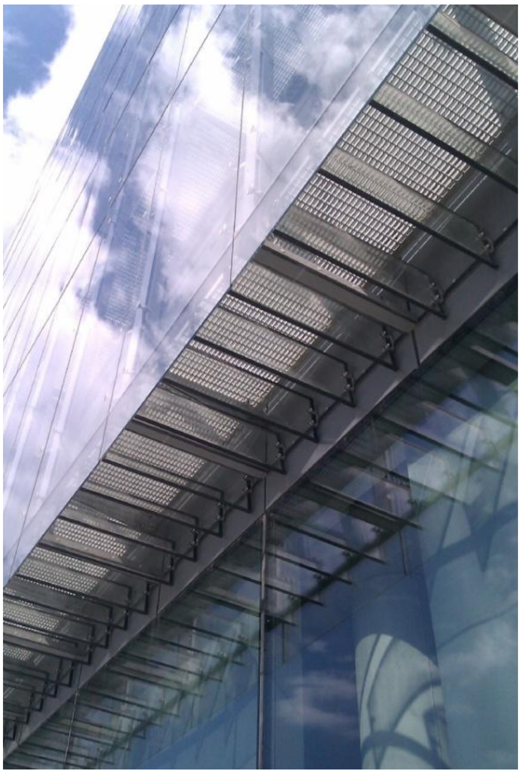


Figure 32 Rambøll's site location, courtesy of Rambøll ©2011

Figure 33 Rambøll's Double Skin Façade. James Harty ©2011

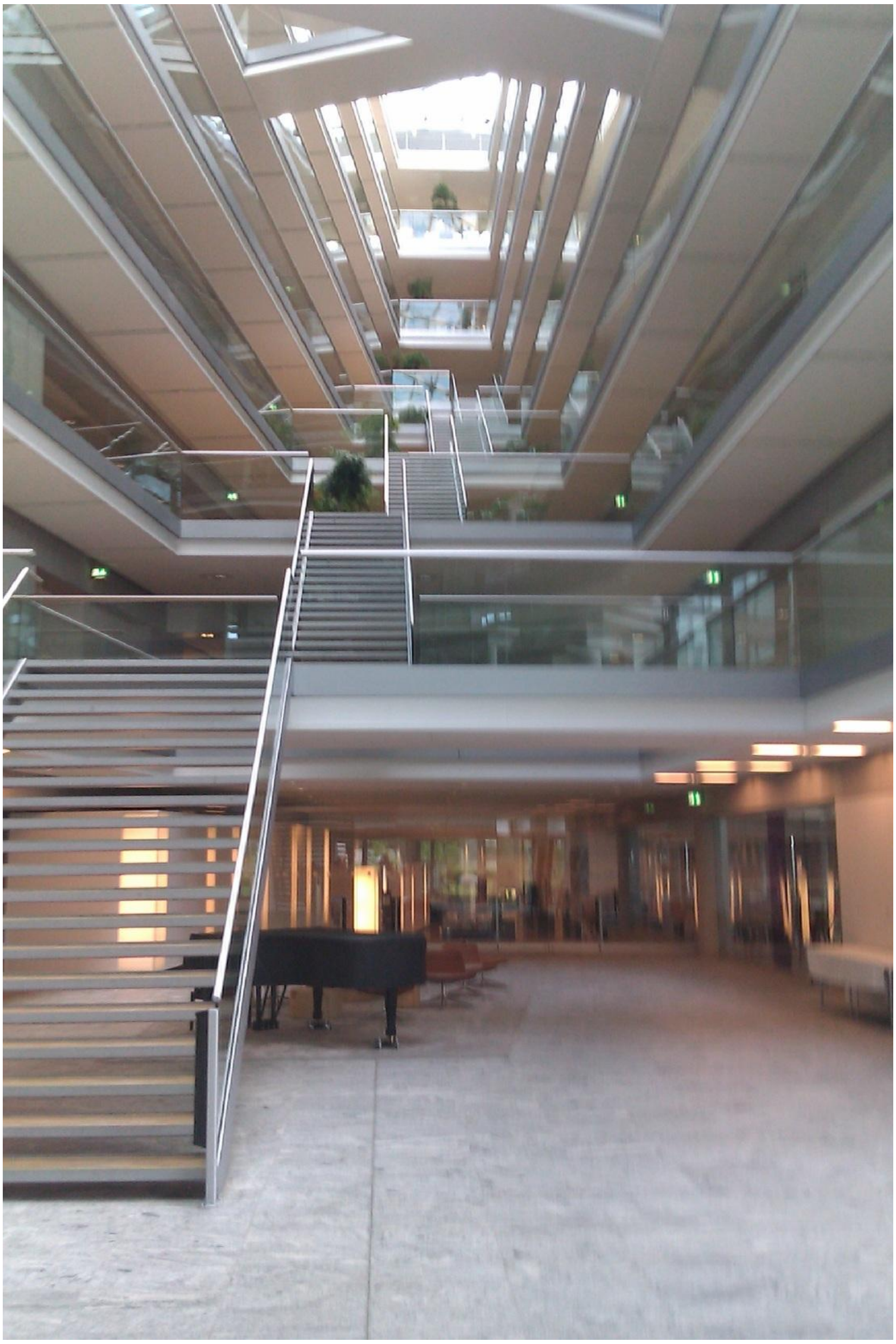


Figure 34 Rambøll's internal Rambla, James Harty ©2011

The project was driven by five demands:

Implementation of the Danish Building Classification system (DBK)

A Project Web

Digital project

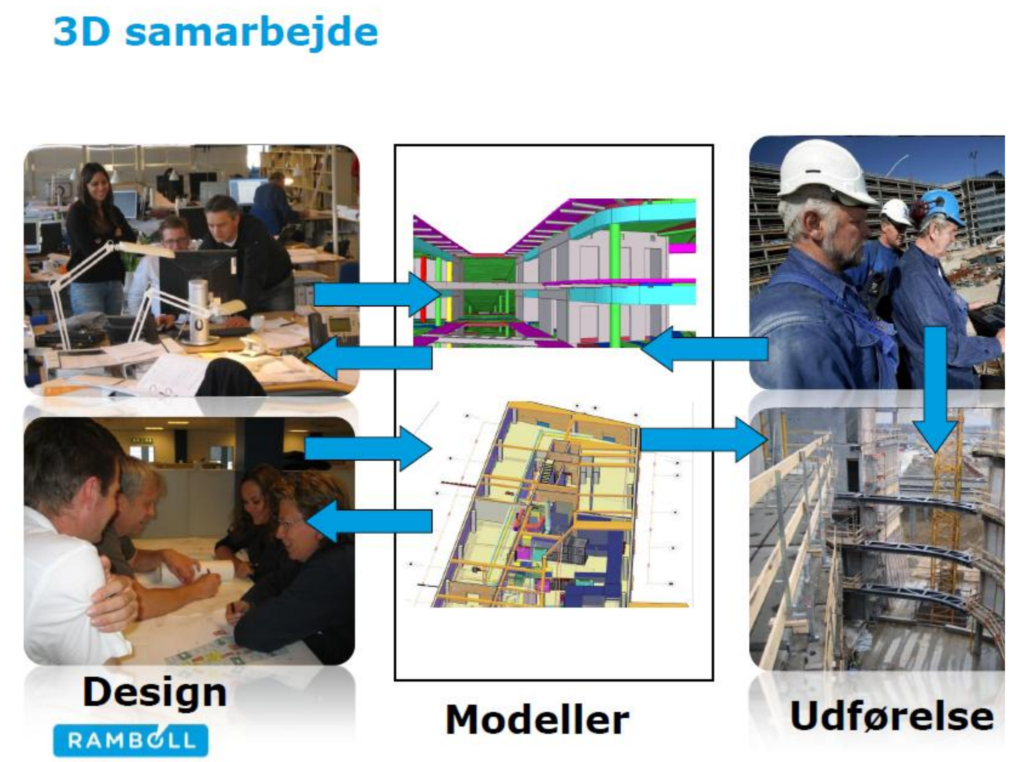
Digital tender

Digital delivery

It meant using *'Det Digitale Byggeri, 3D arbejdsmetode'* (Danish Digital Construction, 3D Execution Plan). This method represents a modelling concept that primarily revolves around 3D object-based CAD, but can also be used with geometry only models, and whose structure offers development possibilities towards an integrated BIM concept. This was important since the architects used AutoCAD Desktop, the structural engineers Tekla and the service engineers MagiCAD. IFC became the unifying glue to these differences. Solibri was used for all clash detection and Navisworks for rendering.

Due to Rambøll's close involvement, it gave them a great impetus to get it both right and to demonstrate their core business *par excellence*. This culminated in them being able to decant the model over to the *'Nintendo Wii'* games console, which meant that users and interested parties could traverse the model using the handset, with both material densities turned on (in collision mode) or off (in free penetration mode). This proved to be a huge hit with employees wishing to see their new work places and also with service level agreements (cleaning contracts), where no stone was left unturned (see below).

Figure 35 Model image and interior image, courtesy Rambøll & James Harty ©2011


3D samarbejde
Design
RAMBØLL
Modeller
Udførelse

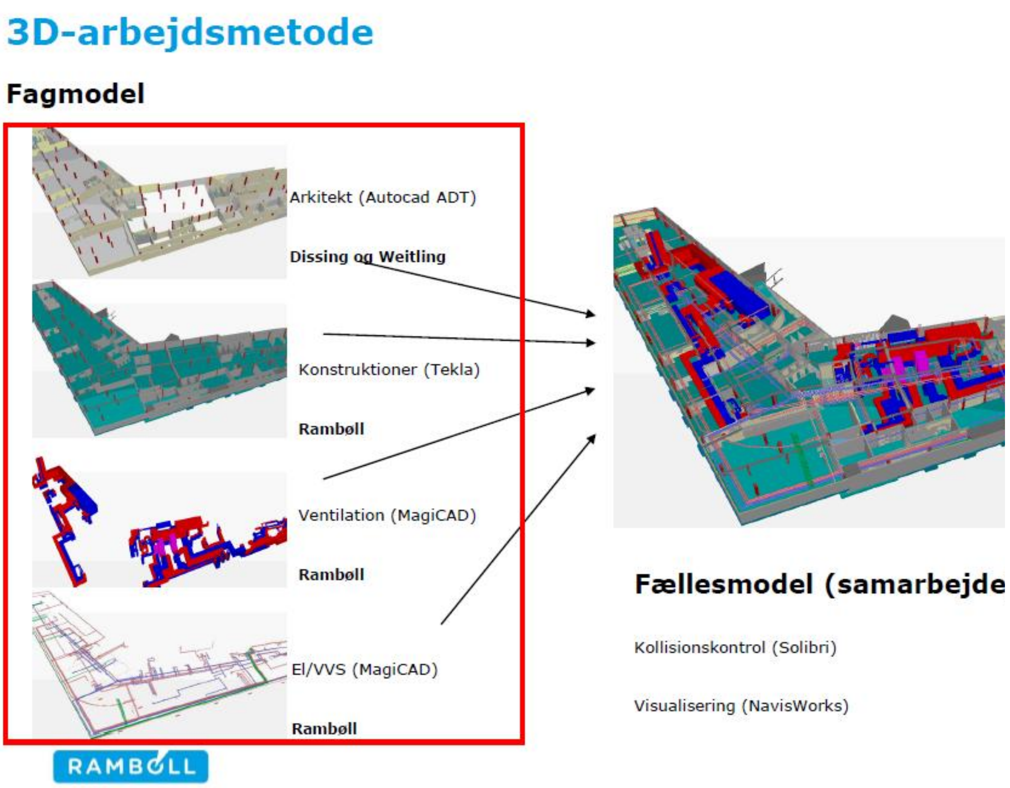

3D-arbejdsmetode
Fagmodel
Arkitekt (Autocad ADT)
Dissing og Weitling
Konstruktioner (Tekla)
Rambøll
Ventilation (MagiCAD)
Rambøll
El/VVS (MagiCAD)
Rambøll
RAMBØLL
Fællesmodel (samarbejde
Kollisionskontrol (Solibri)
Visualisering (NavisWorks)

Figure 36 Rambøll's Collaboration and Working Model, courtesy of Rambøll ©2011

Because of this close level of participation, the model ended up being a very good *'as-built'* representation of the building. This has had the knock-on effect that when the first alteration to the building took place, the development of an area of the basement, it could be reused and reused effectively. As they say themselves, it was an excellent example of FM in action together with continuity of the building information from procurement to operations.

Figure 37 Design Team collaborating in the one studio, courtesy of Rambøll ©2011

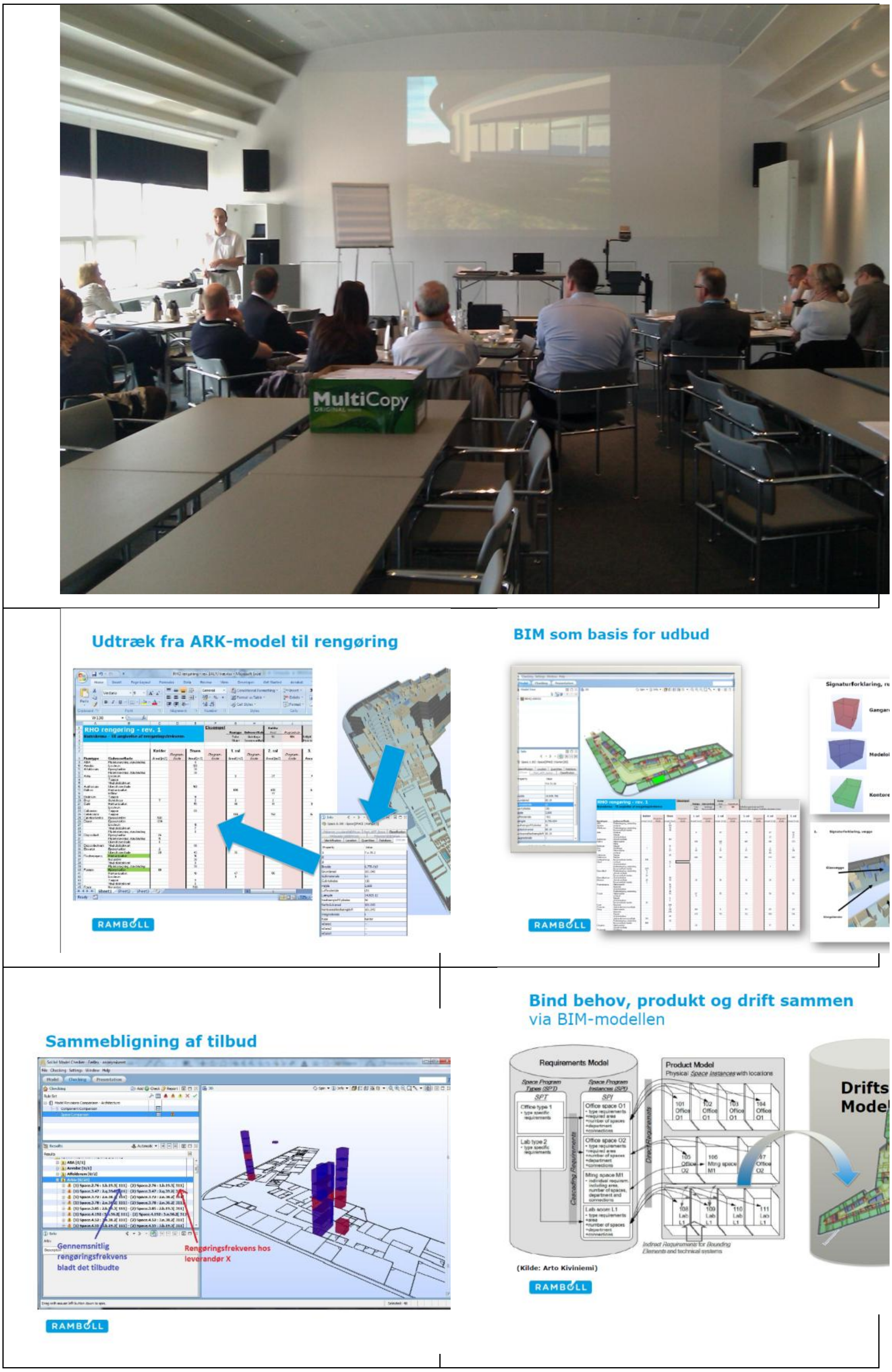


Figure 38 Rambøll's HQ Question & Answer session prior to bidding for Cleaning Contract. Courtesy of Rambøll ©2011

But returning to the cleaning contracts, when they were let it was done through a tender process where all relevant parties, bid through the model with accompanying room schedules. Each room or space had a rating and inventory of surfaces, and levels of cleanliness that Rambøll wanted. This meant that the bidders could limit their risk to over or under valuing the rooms. When spikes appeared in the process, where large discrepancies occurred between bidders, Rambøll could earmark the instances and make closer investigations to establish human errors or genuine cost savings.

Remarkably, when the bidders showed up to question and answer sessions and when taking the bidding material, more attention was paid to the digital material than the paper material on offer. What this suggests is that when properly presented the digital version is clearly better. Had they opted for the traditional fare, the process would be more dependent on previous practices, which was not an option for this new building with new ways of working.

The digital version gave expected occupancies, highlighted special circumstances, more easily, and allowed for better cross referencing and co-ordination of the practicalities of who, how and when cleaning would take place. The winning contractor who adopted this approach wholeheartedly believes that they can better do the job with the given resources. There is better understanding and little or no confusion in the tasks outlined, all the way down to the minimum waged night shift cleaner. When a particular surface needs a particular treatment, this is highlighted and the correct procedure is at their fingertips.

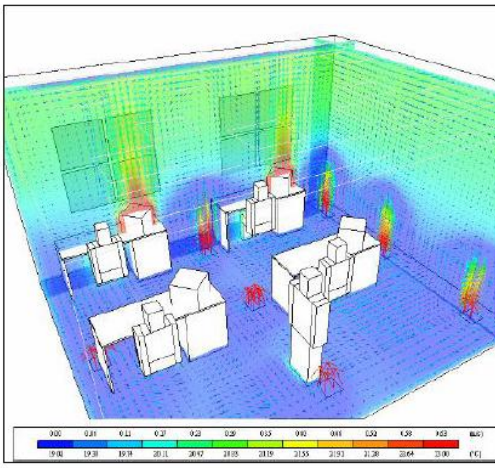
Another aspect worth mentioning is that the model allowed for full spatial thermal design. All pipes, ducts and equipment were designed and sized using MagiCAD, which could be overlaid on the ADT (architects) model through Solibri. Analysis allowed for tracking heating and cooling loads, hot water and heat recovery as well as having sensors to monitor the building's use.

The building is therefore engineered with a balanced approach, which will lead to longer term results, in reducing CO_2 emissions, while *'integrating responsible climate friendly solutions'*. Coupled with the reduction of energy through optimal daylight solutions, district heating and ground water cooling, cooling needs were reduced by up to 85%. The building will hopefully demonstrate a low consumption of energy, after three years, and in evaluating energy, transport, water, health and wellbeing, the building has achieved a rating similar to BREEAM *'Good'*. Finally, the building is a result of an open-minded process between users, engineers, architects, the investor (SEB) and the contractor.

Vi har brug for arkitektens model!
BIM og simuleringer

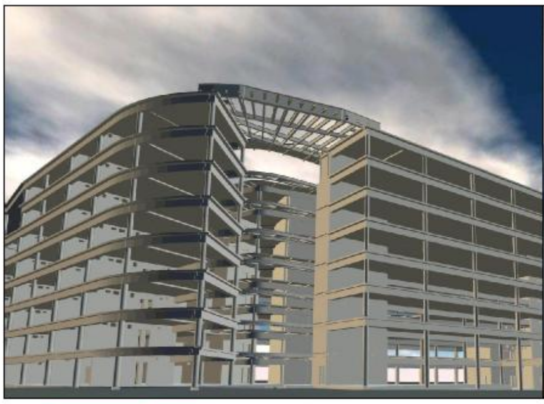
Nuværende brug af simuleringssoftware:

- 70% - 90% modellering
- 10% - 30% simulering



RAMBØLL

3D Brugerinvolvering



RAMBØLL

Figure 39 Rambøll's Sensor Networks & Semantic Webs, courtesy of Rambøll ©2011

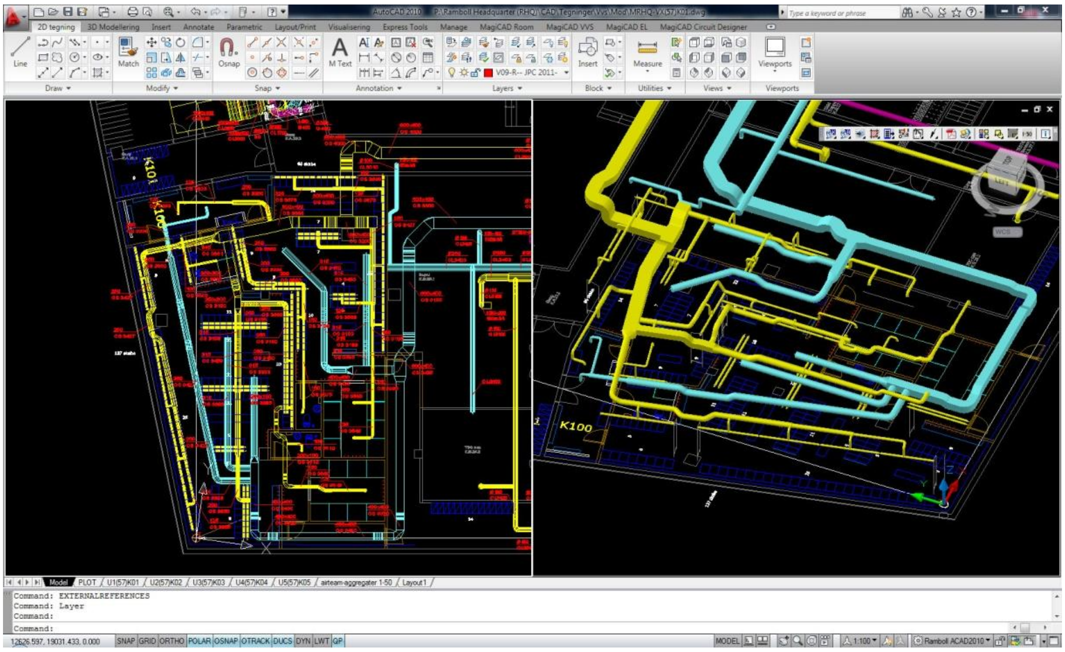


Figure 40 Rambøll are doing maintenance work on their new head quarters and the 'as-built' model is being used to co-ordinate the work and update the modell. Image courtesy of Rambøll.

8.7 Case Study 6: Jaap Bosscha, Triglyph, Rotterdam

Name:

Rotterdam Centraal (Grand Central Station), the refurbishment of the Public transport terminal including; integral station roof (30,000m²), concourse and travellers' tunnel, platform fit-out, commercial spaces offices, restaurants and cafés and facilities for travellers (67,000 m²).

Location:

Rotterdam Centraal, 3013 Rotterdam, The Netherlands

Project work phase:

Commenced in 1993; Practical Completion 2013.

Participants:

Designed by Team CS (a collaboration between Benthem Crouwel Architects, MVSA and West 8 Urban Design & Landscape Architecture)

Clients; Prorail, Rotterdam Public Works department

Co-ordinator; Jaap Bosscha, Triglyph, Rotterdam

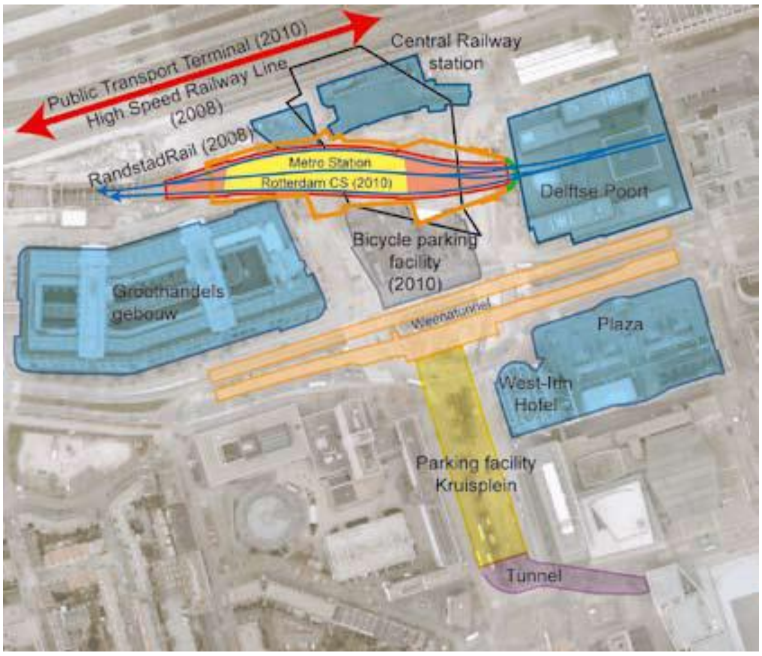


Figure 41 Rotterdam Centraal, Projects & Existing Buildings courtesy G. Hannink, V.M. Thumann Rotterdam Public Works

The compelling nature of this project is the sheer length of time involved, in all twenty years including acquisitions and demolition work, with six, in total, differing contracts being executed on or around the site at the same time. Breathtaking, when seen in context that when begun in 1993, 3D geometry, only, was their highest expectation. The contracts include:

a new overhaul of the main station platforms to meet international high-speed standards with new enclosing structure,

a new enlarged entrance and ticket hall,

a six storey underground car park with street level access,

a new underground metro with two tunnels, a station and interconnecting vertical circulation,

a new below grade regional rail link (RandstadRail) to the Hague and Delft with connecting facilities and finally

commercial/retail projects around the station concourse and entrance for the new urban district

The original station by Sybold van Ravesteyn was closed on 2nd September 2007, to be replaced by a temporary structure for the duration of the work. In all, there are thirteen platforms and a new terminus for metro lines D and E. There is also a connection between these two separate sections and the RandstadRail project.

Figure 42 Work in progress. Left: the building pit for the new Weenatunnel. Right in front: the building pit for the underground

Figure 43 Rotterdam Centraal, courtesy of Benthem Crouwel Architects ©2003

Not only are there many contracts, The Rotterdam Centraal Station project was funded by:

Rotterdam Municipal Authority,

the Ministry of Transport, Public Works and Water Management,

the Ministry of Housing, Spatial Planning and the Environment,

NS Dutch Railways,

ProRail &

Stadsregio Rotterdam

So, Rotterdam has rolled out the red carpet and is getting a new central station. It will secure the city centre and the new transport hub, created by the arrival of the high-speed rail system (HSL). This requires a Grand Station of international standing, says Benthem Crouwel, one of the design team. The city is tied into the new complex by making the small-scale urban fabric around the station into a single entity.

On entering the large concourse, travellers will have an uninterrupted view of the trains. The sunken and widened passage beneath the tracks will become an extension of this space. The platforms meanwhile, will have a largely transparent roof some 250 metres long spanning the entire track zone. Otherwise, the entrance from Spoorsingel (on the other side) is relatively modest, in keeping with the low-key residential area where there are fewer passengers.

While each of these projects is a worthwhile exercise in itself, on site, in the site hut, there is only one man who has an overview of what is going on, whether the projects are up-to-date, and where the bottlenecks might occur. That man is Jaap Bosscha, and he has a single Naviswork's license. Thankfully, all geometries were 3D and while being *dumb*, at least, collision control and sequencing could be mapped and managed. But even when *'requests for information'* were made, approved and written up, there was no correlation between Jaap and his fellow workers, who sit in the same office incidentally, to collaborate or share information.

Figure 44 Rotterdam Centraal Station Super Structure, courtesy Team CS ©2011

8.8 Case Study 7: Anders Lendager, MAPT, Oslo

Name:

Bølgen (The Wave), a waterfront restaurant pavilion

Location:

Aker Brygge, Oslo Harbour Front, Norway

Project work phase:

Winning competition entry in 2009 for restaurant and leisure facilities (2,000 m²), Bølgen is set to open in September 2011.

Participants:

MAPT (Mediating Architecture Process & Technology)

Ander Lendager, Ryesgade 19 C 1.Sal, 2200 Copenhagen N, Denmark

MAPT was founded in 2005 by two partners, Ander Lendager and Mads Møller, who both received the *'Vola'* award from the school of architecture in Århus. They have also received scholarships to SCI ARC, Southern Institute of Architecture, which has greatly influenced the way they work today. They claim that their combination of Danish dedication to details, European understanding of programme and function, and the American love for technology and design, creates a unique architecture. In 2007, MAPT was awarded *'Årets Arne'*, the young architecture office of the year.

Believing that architecture should reflect its environment, it is not sufficient to consider the site in isolation. Each project has its own history and identity, meaning they are influenced by signs of changes in society, and more importantly in technological development. Technology must be adjusted in order to achieve humane values, to create a sustainable, intelligent and interesting architecture. Technology is seen as a poetic, living organism, and it is their ambition to create architecture, which embraces the new digital world.

They have been involved in several workshops investigating new technologies in developable surfaces, including being able to allow complex forms to be unfolded, then laser cut and assembled into objects, to Computerised Numerical Control (CNC) cut moulds that evolved from using single curvature surfaces, fitted together, creating monolithic structures, and Voronoi objects. This is done using simple scripts for Rhino, where complex forms were generated and afterwards made ready for physical assembly in Pepakura. They also use Rhino and Grasshopper in the studio.

They see the situation as requiring the understanding of a new context with a new set of tools. That digital architecture is an embraced development in the educational system. They continue, that considering the fact that digital architecture is relatively-speaking new in Denmark, it is related mostly to technical constructional issues and digital standards, however, they feel that the potential is much higher.

Their digital architecture can be separated into three different categories:

A new digital world

New digital designer tools

New digital production tools

Text Box 5 Digital Architecture

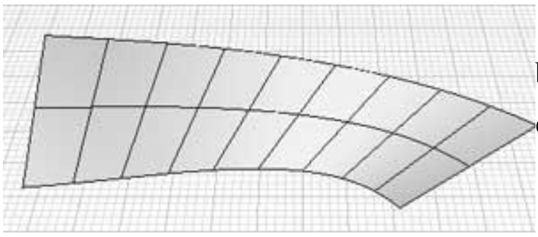
New up and coming practices like Bjarne Ingels Group (BIG) are also using quadratic equations to generate forms, and as each piece of programme alters the design, the equation is run again and again to keep the purity of the form.

This can be seen in their Danish Pavilion at the Shanghai Expo recently, which involved two interlocking curved forms providing a continuous ramp, taking the visitor on a journey around the temporarily-displaced Mermaid from Copenhagen. To be allowed to remove such a landmark, just shows that the whole ensemble must have been spectacular, and it was judging by the record number of visitors to the pavilion.

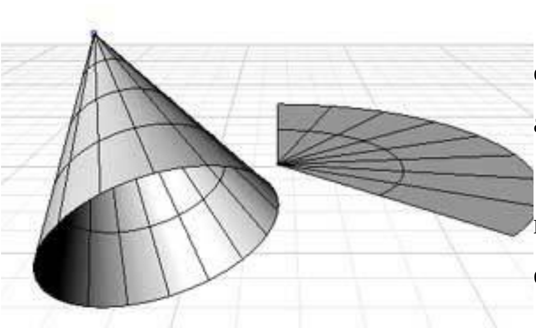
Rhinoceros (Rhino) is a stand-alone, commercial NURBS-based 3D modelling tool, developed by Robert McNeel & Associates. *'Non-uniform rational basis spline'* (NURBS) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces, which offers great flexibility and precision for handling both analytic and freeform shapes. The software is commonly used for industrial design, architecture, marine design, jewellery design, automotive design, CAD/CAM, rapid prototyping, reverse engineering as well as the multimedia and graphic design industries. Rhino gained its popularity in architectural design in part because of the Grasshopper plug-in for computational design (Wikipedia contributors 2011f).

Grasshopper is a visual programming language, developed by David Rutten at Robert McNeel & Associates, which runs with-in the Rhinoceros 3D application. Grasshopper is used mainly to building generative algorithms (McNeel 2011).

Table 6 NURBS

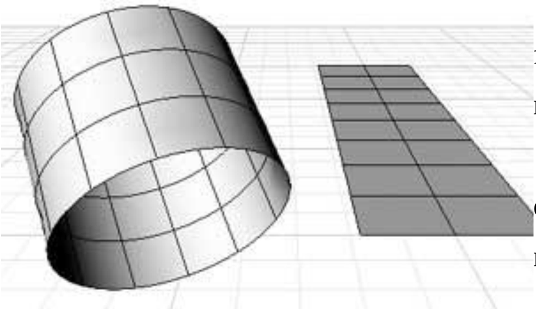


A ruled surface is a plane that can be contoured, meaning that it has common points.



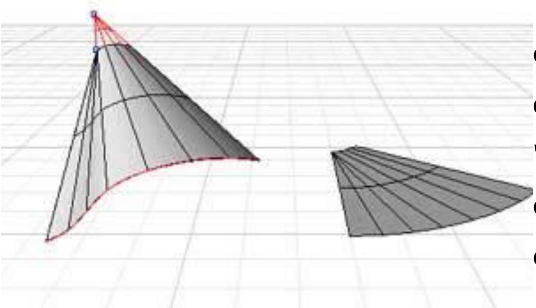
A developed surface is the consequence of unrolling a form where a modifier has been applied.

In both cases, there is a mathematical basis for them, and by extension rules governing them.

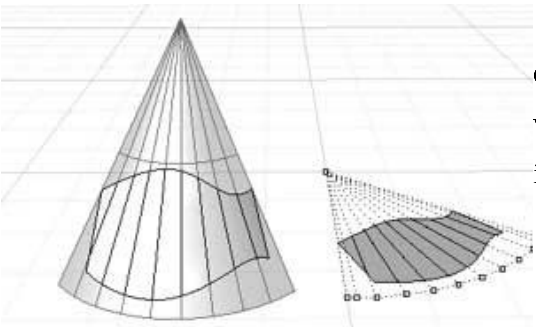


Developable surfaces can be formed by rolling a flat sheet of material without stretching it.

But if a surface is linear in one direction (u/v) then it does not necessarily mean that it is developable.

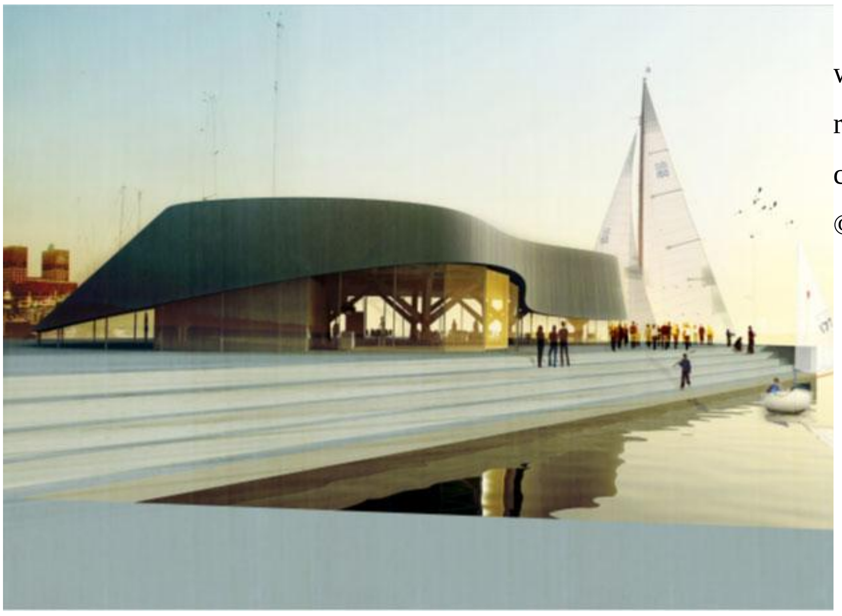


Developable surfaces can be created with parallel ruling lines by extruding any curve. Developable "cone-like" surfaces can follow any curve and can be created by lofting the curve to a point.



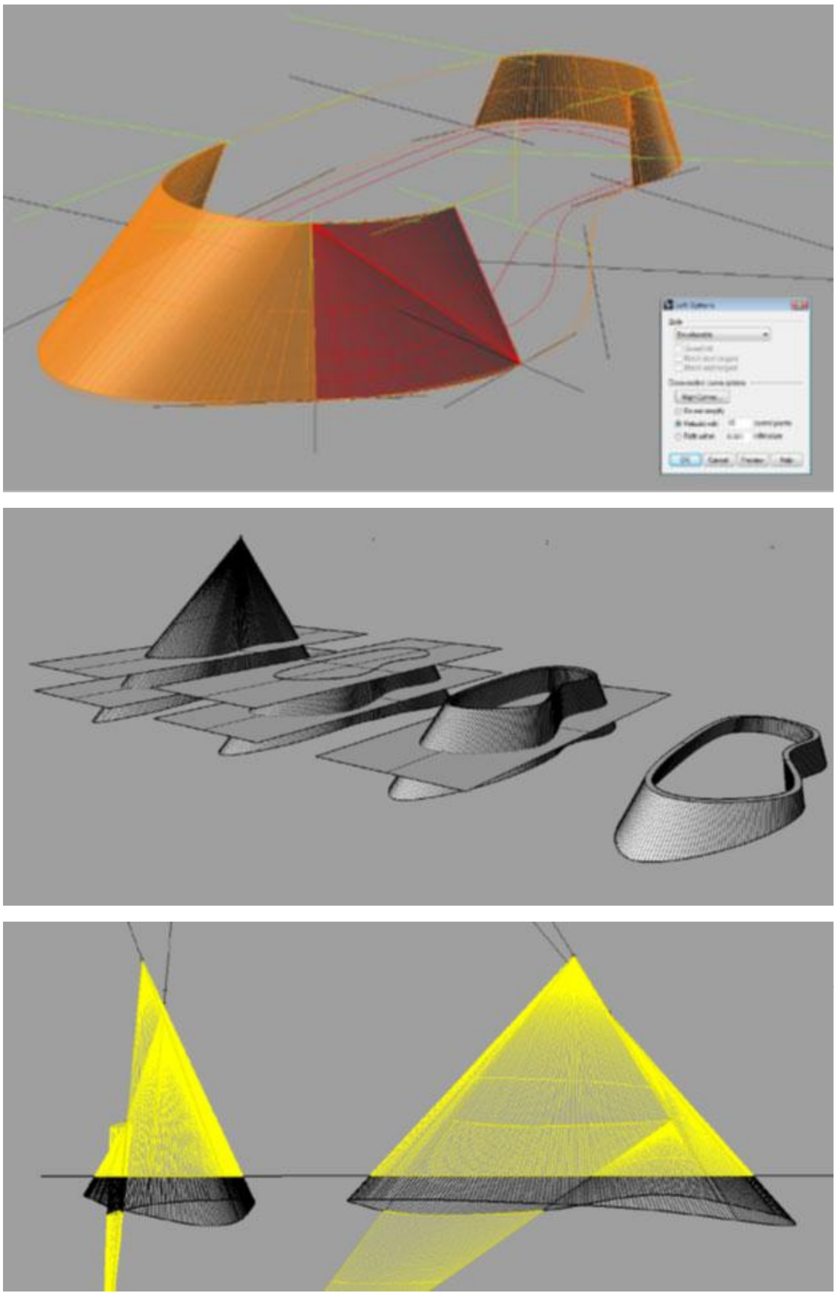
Once the underlying surface is developable, it can be trimmed in many ways using other geometries or intersecting planes.

Programmes such as Rhino and Grasshopper aid these generative forms and in the case of Bølgen once the competition was awarded, the next step was how to build it. This is where the option to transfer the model to Revit drove the operation. Going from Concept to Production was always going to be a huge task but it proved a daunting undertaking in persuading the client to embrace it and follow the consequences of the form.



Design winning rendering, courtesy of ©MAPT

View showing the roof terrace and perimeter sky light, later removed, courtesy of ©MAPT



DDe

Geometry Studies showing surface developments, and trimming planes, courtesy of ©MAPT

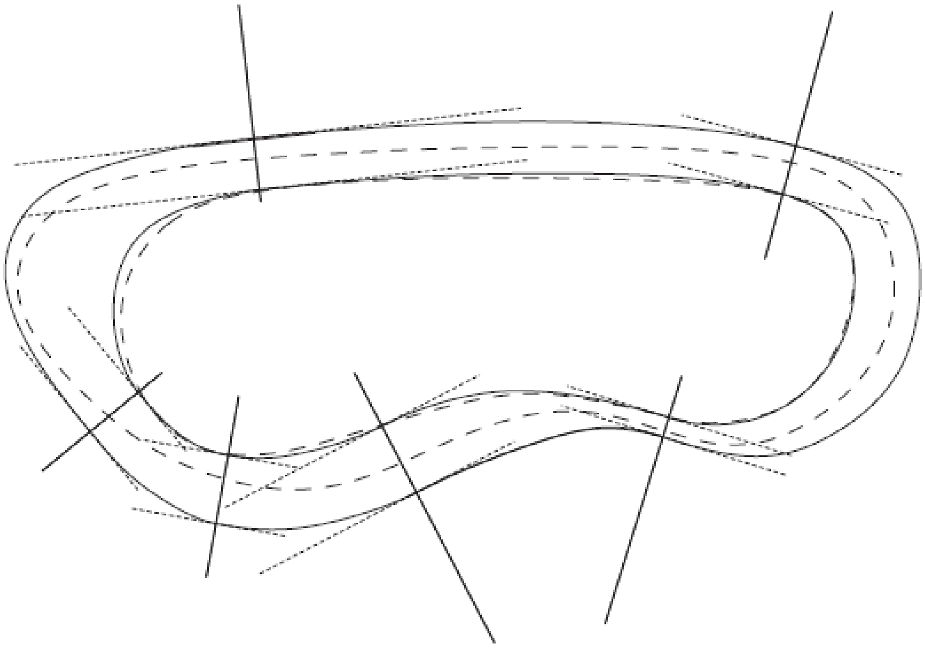


Figure 45 Bølgen Design Renderings and Form Studies, courtesy of MAPT ©2011

However, being bound by the judges' decision to grant first prize to this exciting design, the client none-the-less embarked on a damage limitation exercise cutting many of the design features out of the project. Most contentious was the removal of the tree-like structures holding up the form. These were replaced with simpler post and beam frames at regular centres across the building, which later caused more problems than it solved. The roof terrace disappeared too, and many other things like the internal heat-sink, changed as the design progressed.

The tree-like structure, giving the impression of an upturned boat hanging out to dry

The structural solution providing post and beam construction. The problem that developed from this solution was that a torque had to be applied to make them flush to the skin.

Figure 46 Bølgen structural solutions, proposed and executed, courtesy of MAPT ©2011

At this point, the client was listening more and more to his local (Norwegian) architects and engineers rather than the young architectural practice from Copenhagen. Whether this is cultural or traditional, it also impinged the form of contract drawn up to procure the building. Despite MAPT campaigning for the model to be used, tradition methods were seen as safer and less expensive. This did not prove correct.

A working model, showing that the developed shapes assemble into the correct form

A working model, showing the structural system and curved skin assembled

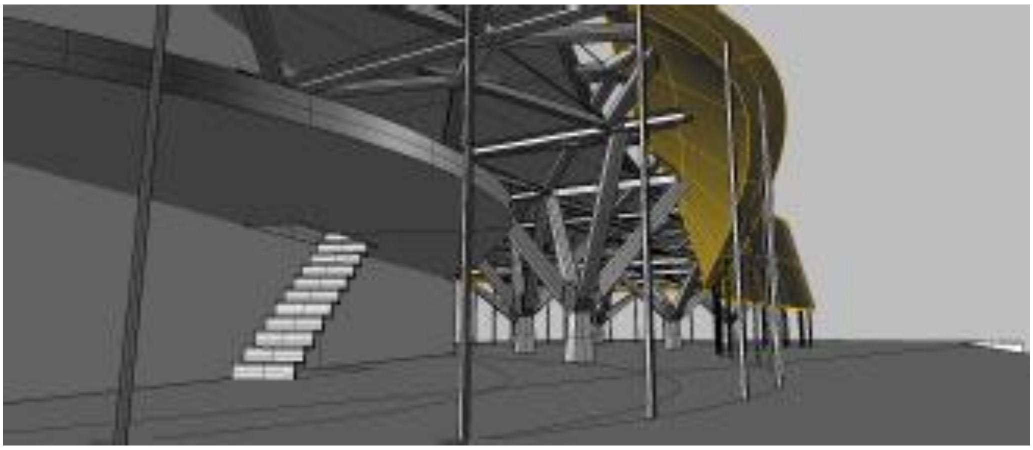
Figure 47 Bølgen Working model showing the developed shapes assemble into the correct form courtesy of MAPT ©2011

MAPT however, chose to develop the model at their own risk and expense, and during Design Development as the project became impossible to progress without a modelled form, MAPT regained the controlling position within the team. Being a traditional contract, they also ended up getting their initial expenses reimbursed, as suddenly they had all the solutions and the local team none.

Furthermore, when the project actually went on site, the main contractor, Skanska, expected much impromptu extra work, given the complexity of the shape. This did not materialise, as MAPT were able to provide working drawings of each element that were accurate and co-ordinated. The contractors, not having the means to receive digital content relied on liaison with the Danish office and one quote when the work was completed summed the situation up succinctly was:

'... thanks for all the screen dumps'

This was in reference to the many 3D shots that were printed and sent to the site hut.



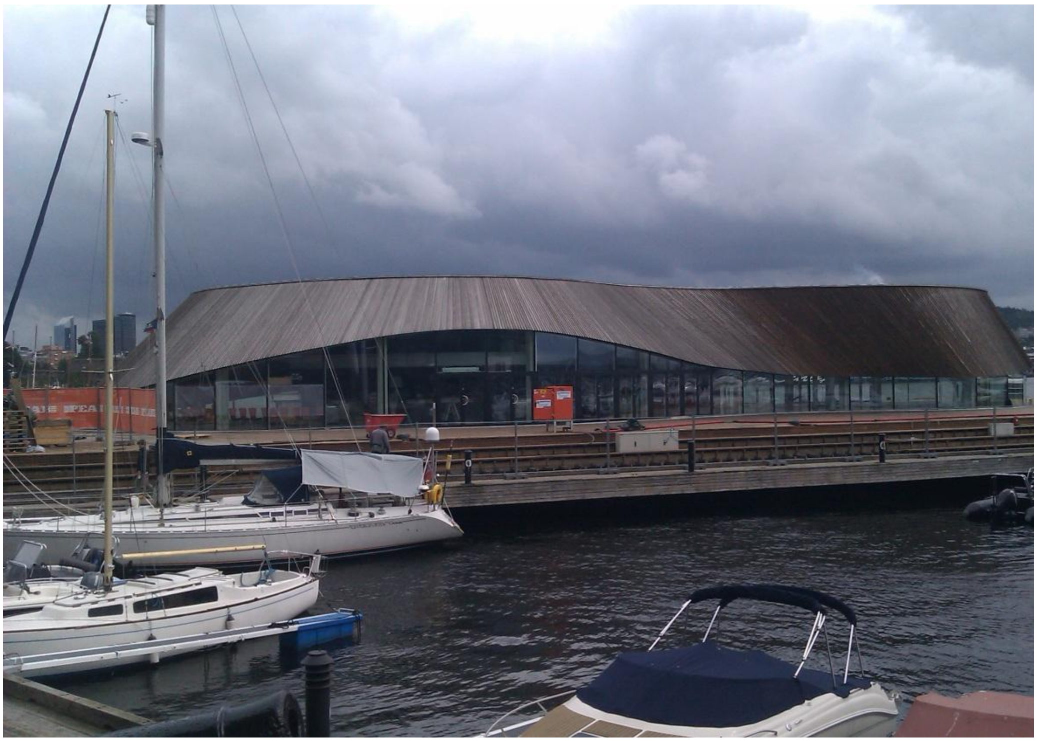


Figure 48 Working models and modelled image & site photos, courtesy of MAPT ©2011

8.9 Case Study 8: Knut Ramstad, TeleNor Expo, Oslo

Name:

TeleNor

Location:

Fornebu Oslo, Norway

Project work phase:

Completed in 1998

Participants:

Knut Ramstad, TeleNor Expo

TeleNor is a seminal example, which deserves to be documented here. It is one of the first examples of an attempt to use a virtual model. It had been courted by the industry for a long time but had to wait until 1998 to come to fruition, in Norway. It was a £400M Headquarters for a telecommunication company in Fornebu, Oslo. Fornebu is the former Oslo airport just east of the city, making it ideal for this development.

It was heralded as a major project, which was to be driven by an intellectual all-inclusive 3D model, through which everything was to be channelled. The design team involved firms from several countries, multi-disciplines and various programmes. An immersive 3D cinema was erected for the project, called a reality centre.

The intention was that a single complete model would minimise errors, make 2D drawing take-offs easier and eliminate repetitive tasks. Except that in some ways, it failed. The translators and input material from the various project teams never reached a common niveau, resulting in the physical manhandling of data into the model. It worked brilliantly for presentation purposes but never became the working model for which it was intended.

Special mention should be made about Knut Ramstad who was critical in modelling the whole project. When TeleNor embarked on the *'Fornebu'* project, because of the significance and massive scale, complexity and ground-breaking nature of the project, the decision was made to pre-visualise the entire project in 3D. This enabled the architects, decision makers, user representatives, government bodies, local community and entrepreneurs to see in advance exactly how the final project would look like and what impact it would make to the landscape. This worked incredibly well.

Figure 49 Reality Centre (DR Byen, left), a 3D immersive experience (both real-time and/or 3D glasses), where the model that can be travelled from outside right into the office interiors

Virtual mock-ups were used extensively to test design alternatives and make necessary adjustments. To meet the high demands on quality to make the planned virtual reality experience as real as possible, Ramstad and his team from TeleNor Expo used 3D Studio Max. More than 20,000 visitors have experienced in the reality centre how the project will look like, not only when finished but also in twenty years.

Figure 50 TeleNor, Fornebu, Oslo

But still it has to go down as one of the first. The reality centre, complete with 3D spectacles, and a joystick console allowed the viewers a roller coaster ride through the complex long before it existed. It could even advance the vegetation over time, showing the landscape now, in five years and in twenty, say.

It nestles on the quiet banks of a Norwegian fjord. The location is apt, because the complex allegedly upstages British Airway's HQ at Waterside, built next to Heathrow Airport in 1998 and hailed at the time as the most advanced office in Europe. The man who designed that building, the Norwegian architect Niels Torp, was understandably chagrined not to win the commission to do a similar job on his home turf. The TeleNor job was won by American giant NBBJ and local practice Hus-PKA after an international competition involving Torp and Richard Rogers Partnership.

The office, which has an area of 138,000 m² and accommodates up to 7000 staff, is more than twice the size of British Airway's HQ. It shares one central concept with its British counterpart, though – the office space is divided into several distinct wings that spur off a central spine. The big difference is that Telenor has a pair of spines that curve away from each other in two sloping glass crescents to create a spacious traffic-free plaza raised above a basement car park.

'We wanted a city plaza or public space at the centre, as in Sienna or Florence,' said Jin Ah Park of NBBJ, who designed the complex with Jonathan Ward and Peter Pran. The plaza brings a splash of open air, space and calm into the heart of what might otherwise be a claustrophobic warren of offices. The open space accommodates two key buildings, a learning centre and a customer centre, the latter overlooking the fjord.

All eight wings are sizeable office buildings in their own right. Each revolves around a large triangular atrium, and contains office spaces no more than 16m wide, designed to accommodate several groups of up to 30 staff. Interiors are highly flexible, with relocatable partitions, chilled ceilings and lighting wired up from the floor. The building also has strong green credentials, including natural ventilation, natural daylighting and a heat exchanger feeding off the seawater in the fjord, which together reduce carbon dioxide emissions by 80%.

The building's openness and abundance of casual meeting places, along with the wireless technology, produces what TeleNor dubs *'progressive officing'*, which encourages staff to interact and collaborate, increasing productivity. Chief executive Jon Fredrik Baksaas says:

'The model is built on interaction between people, technology and working environment, exemplified by the fact that our employees can work practically anywhere, anytime with laptops and mobile phones.'

The staff was being gathered together from 47 premises and thus were presented with unfamiliar wireless working methods, they seemed sanguine about this. The model was used extensively, to show the employees their new work place, long before it was built. A couple of months after the building was occupied, a staff survey found that 61% of workers believed the building had achieved its aim of being *'the foremost working environment in Scandinavia'*. An even larger majority, 84%, said they were pleased with it.

The seeds for this success were planted in the open methods of showing the staff the building in the reality centre, which functioned as an interactive cinema. The large screen showed the model which could be negotiated with a joystick, to take the audience from outside in the car park all the way to their individual desks inside.

Text Box 6 TeleNor Project Credits

Client: TeleNor

Joint venture architects: NBBJ, Hus-PKA

Structural engineer: Scandiaconsult

Mechanical engineer: Techno Consult

Electrical engineer: Alfacon Nielsen

Landscape architects: Asplan Viak, Hang Kjaerem

Interior designer: Spor Dark Design

Contractors: Scandiaconsult (structures)

Contractors: Veidekke (M&E)

Contractors: Arbeidsfelleskapet (glass facades and roof)

Contractors: Spenncon (steel and concrete prefabrication)

Contractors: Braathen & Torvaldsen (central plaza)

8.10 Case Study 9: David Ferroussat, BAA Capital Projects, London

Name:

Terminal 5, Heathrow

Location:

Heathrow Airport, London, UK

Project work phase:

The building cost £4 billion and took 19 years from conception to completion and opened in 2008.

Participants:

David Ferroussat (British Airways Authority Capital Projects)

Terminal 5 was a herculean project, not only for the exemplary superstructure itself, but also for the vast infrastructure required to service it. It cost £4.3bn., and even went through 46 months just to come through the longest public enquiry in British history. The Longford River had to be rerouted, there were two new tunnels (of nine), *'HexEx Bored'* and *'PiccEx Bored,'* which were directly under the terminal for the Piccadilly underground line and its station. There was a need for reversible sidings, as well as heavy freight rail provisions close to the perimeter and various other connections to the satellite terminals. It is reported that the Accident Frequency Rate (AFR) was under 25% of the national level (Ferroussat 2008).

Ferroussat also pointed out, that large projects usually go wrong citing:

London Underground with their two-year Jubilee Line Extension delay

That Railtrack missed their deadline to increase slow train paths on the West Coast Main Line,

That the Millennium Dome lurched from crisis to crisis as the bankers were brought in and

That the British Library failed to meet the challenge of the internet age

To correct these imbalances he claimed that processes, the organisation and more importantly behaviours should be designed to expose and manage risk, promote and motivate opportunities and address performances in all relationships. Furthermore leaders were to recognise that change and uncertainty was the new norm and that a different outcome meant doing something, precisely that, differently.

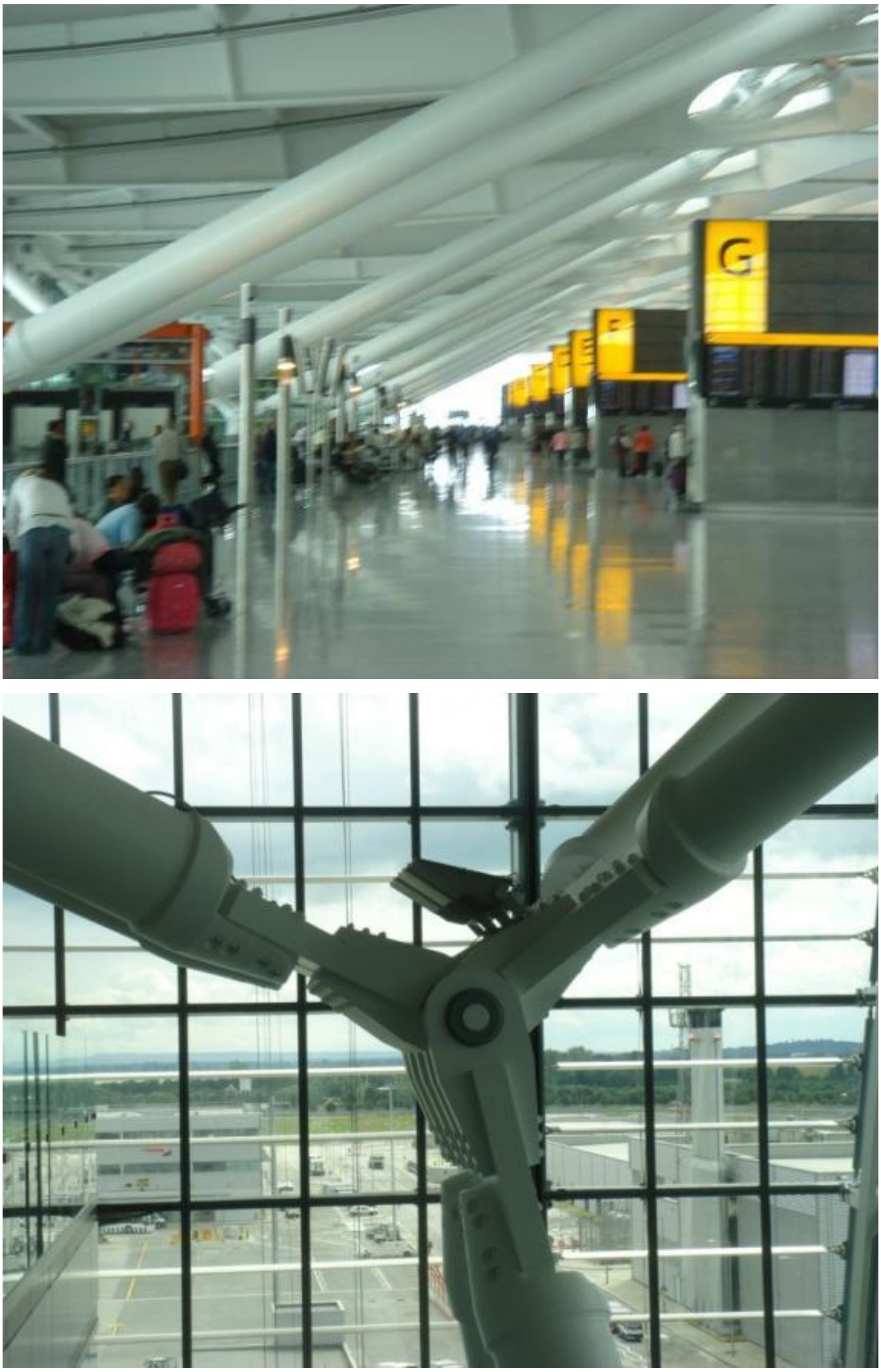


Figure 51 Terminal 5, Heathrow Airport, James Harty © 2009

This was achieved through the special contract (T5 Agreement), vigorous health & safety demands, high standards of quality (behavioural approach) and using milestones to apply handover pressure in the programme. The contract was a unique legal document that managed the cause and not the effect, ensured successes in a very uncertain environment and focused on managing the risk rather than circumventing litigation. There was an incentive fund to replace normal risk payments, which funded shortfalls and provided opportunities to increase profits. Finally, the project, and not the suppliers, was insured against damage to property, injury, death, and professional indemnity.

Because of carefully defining responsibility, accountability and liability, the focus became delivery. Remuneration was based on reimbursable costs plus profit with a reward package for successful completion. This incentive plan encouraged exceptional performance with the focus on the issues of value and time. Value performance occurred primarily in the design phases and was measured by the value of the reward fund for each Delivery Team and calculated as the sum of the relevant Delivery Team Budget less the total cost of the work of that Delivery Team.

The time reward applied only during the construction stages. Here, worthwhile reward payments were available to be earned for completing critical construction milestones early or on time. If the work is done on time, a third went to the contractor, a third went back to BAA and a third went into the project-wide pot that would only be paid at the end (Douglas 2005). There was a no blame culture meaning that if work had to be redone the fault was not apportioned to anybody but the rewards would either be reduced or not awarded at all. This had the effect of applying a kind of peer pressure where it was in the interest of all parties not to fail, which created a place where the vertical silos of expertise were traded for viaducts of collaborative techniques. BAA took out a single premium insurance policy for all suppliers, providing one insurance plan for the main risk. The policy covered construction and Professional Indemnity (Potts 2002).

The overall supply chain was pyramidal with 80 key 1st tier suppliers, c. 100 other 1st tier suppliers, with thousands of 2nd tier and other suppliers. The top ten suppliers were:

Table 7 Terminal 5's Top Ten Suppliers (Ferroussat 2008)

T5 Top Ten Suppliers	Value (£200bn +)
Laing O'Rourke	£950m
Amec M&E	£230m
Vanderland	£220m
Balfour Beatty	£200m
Amec Civils	£200m
Rowen Structures	£190m
Morgan Vinci	£180m

MACE	£110m
Schmidlin UK	£60m
NTL Group	£60m

While the handbook sought to lay down binding guidelines for the whole supply chain during the procurement of the facility, it also went to great lengths to be readable for all involved and understandable in its holistic approach. It clearly defines and sets out the expectations for everyone. It was ambitious with two over-riding standards: *how to deliver* and *what is actually delivered*. Best practices were benchmarked, levels of performances were outlined and expectations were raised across the enterprise. Three levels were identified; *'business as usual'*, which was rejected as a non-starter, *'best practice'* which received an amber light and *'exceptional performance'* which was seen as world class, receiving the green light and setting the bar.

Their mission was to deliver an airport, through teamwork while maintaining and delivering a strong sense of personal identity or achievement for all involved. The teams ranged from client teams through to suppliers and from management to trainees, all identified as an integral part of the supply chain. Emphasis was placed on (pre-) planning the requirements and assigning the best resources to accomplish them. Team building and their environments were cherished in an environment designed to break down (legacy) barriers and divisions. In the longer term, this impacted social and non-work relationships, to which I will return when dealing with collaboration and building interdisciplinary trust.

Appropriate training was tabled as being critical. Responsibilities, and how relationships were developed, was dealt with through ingeniously defining roles and relationships as being open, questioning and non-perspective. There was a desire to match authority with responsibility, empowering people and encouraging delegation. It was essentially a framework that had not been tried before. It was also setting out the limits and parameters to which the exceptional goals could be reached. Under behaviour colleagues were to be treated as customers, personal performance was challenged, initiative and leading by example, was encouraged and pro-active positive mindsets were seen as vital. Problems were to be dealt directly, being flexible while accommodating all contributions. All of this was to be demonstrated with proper documentation and measurement.

Finally, recognition and reward were seen as great motivators, in this postmodern relationship context. This was definitely the carrot rather than the stick driving the changes. In an interview with David Ferroussat, Commercial Quality & Resource Leader at BAA, the implementation of these principles typically saw sub-contractors having to share sensitive information. An example would be if one sub-contractor could source certain materials cheaper or better than another. The set-up meant that the one who could get the best deal supplied all; even if this meant giving a competitor (outside the contract), insight to one's coveted methods and honed procedures.

Often this would lead to an impasse where there would be blatant refusals to comply *(...more than my job's worth... scenarios)*, which could only be resolved by taking each sub-contractor's bosses upstairs, quantifying the risk and potential loss, and paying out on the information, so that the *'open'* dialogue could flourish. This was unheard of in the construction industry before and for such an arrangement to flourish, a longer-term relationship is required. BAA could provide this environment with the lure of further contracts, on account of the size and scope of their organisation. This is significant while a state of transition exists.

Furthermore, when work was rejected or needed to be redone, there was a no-blame culture in place. This meant one sub-contractor could not point the blame at the other, but rather both had to submit proposals to rectify the work and correct it. The quicker and sooner that these things could be accomplished the better, because such extra work was paid out of the golden egg lump sum for finishing the work on time and to date. The longer one bickered, the more of the sum was eaten away. There was no incentive in reducing the bonus.

This was further enhanced with a critical path identifier, in the form of an object, a lump of rock, called a *'milestone'*, which would reside with the current critical deed, like a hot potato. The quicker the owner could pass the object on, the better, as there was a kind of *a peer pressure* culture established, encouraging the completion of tasks successfully to further the job and come closer to nirvana, practical completion.

So much for the management structures, on the technical side Terminal 5 was procured using Autodesk Architectural Desktop (ADT), predating Revit, which meant that the fully immersive milieu of sharing models and data did not happen in large amounts, but there was heavy involvement of NavisWorks to aid this aspect of the project (Lion2004b). The 3D co-ordination used NavisWorks as a process checker to view, review, detect clashes and extract information from the model.

Text Box 7 Software used on Terminal 5, Heathrow

They used 130 copies of *'NavisWorks Roamers'*, 70 *'NavisWorks Publishers'*, and 25 *'NavisWorks Clash'*. There were:

256 licenses of *'ADT'*, 15 or *'Autocad Map'*

70 of *'CAD Duct'* (3D drafting & modelling application for Autocad that facilitates the detailing of a services model)

5 copies each of grounding, highway design and steelwork design *'MX'* (- MX is not officially an acronym, but it is believed to stand for MOSS Extended, MOSS Extra or similar - 'MOSS' stands for 'Modeling Of Surfaces with Strings') (Bentley 2010) & *'3D+'* (- an Autocad based parametric modeling, analysis, design and drawing system for structural engineers) respectively, and

25 copies of *'CADD RC'* (Reinforced Concrete Detailing). Generally, each discipline reviewed each other's models for approval, before issuing 2D plans, sections and elevations.

There was an estimated 10% saving in design time and better co-ordination.

All of the above merely co-ordinated the 3D geometry, with all output being 2D (plans, sections and elevations) extractions. This was to radically change with the advent of BIM programmes such as Autodesk Revit where data could be added to the geometry. 2D extraction is often still a legal requirement but increasingly the model is gaining in stature.

8.11 Case Study 10: Peter Fong, Swire Properties, Hong Kong

Name:

Swire Tower, One Market

Location:

One Island East, Hong Kong

Project work phase:

Completed in March 2008

Participants:

Peter Fong, Swire Properties

On a project that Gehry Technologies Company (GT) was involved with in Hong Kong, the developer has even more positive testimonies. The project was Swire Tower at One Island East and here the technology both aided the building process, while acting and giving feedback, as the lower floors rose above the busy city streets.

'The design and procurement methods being used on the job represent a full integration of information into a single 3D Building Information Model (BIM). This 3D database is being used simultaneously to coordinate architectural, structural and mechanical design information, as well as producing detailed project specifications for cost estimation and construction scheduling.

GT became the BIM process consultant for this project and used Digital Project to create the virtual 3D model prior to construction, discovering close to 2000 clashes leading to a cost saving of close to $13 million. The contractor is updating the virtual model as the building is being constructed, so that the model can be used for operations and maintenance once the construction is completed'.

For the developers it was about project *'certainty'*, knowing what was going to be built and at what cost. While this certainty is giving control back to the architect, the question must be raised about who is providing the service. Gehry Technologies is a self-standing company that Frank Gehry out-sources work to, and this will be an area to be revisited.

One Island East is a new office tower built in Hong Kong. It represents the *'5th Generation'* project for the developers Swire Properties, in that the design and procurement methods being used on the job represent a full integration of information into a single 3D Building Information Model (BIM). This 3D database was used simultaneously to coordinate architectural, structural and mechanical design information. As well as producing detailed project specifications for cost estimation and construction scheduling (Fong 2007).

Figure 52 One Island East, Model & Construction photo © Gehry Technologies

Back in 1883 the then Swire Group moved its sugar business to Quarry Bay, which at that time was undeveloped. During the 1970s, the Dockyard was relocated realising the lands for development. In 1972, Swire Properties was formed which began to create a new urban landscape from the vast dockyard and refinery in Hong Kong's Island East area (Swire Properties2011).

Swire Island East is now Hong Kong's largest privately owned business district, consisting of prime commercial space and high-end hotel accommodation. All of it is managed by Swire Properties, who have a long-term commitment to realise the best potential of Island East as an integrated urban community, adding value and lifestyle benefits for its business and residential inhabitants and their visitors. Therefore, they have a unique situation where they are both client and developer.

They have also utilised the most advanced satellite and fibre-optic technology, Island East Matrix to become Hong Kong's gateway to the world. It is capable of supporting state-of-the-art data transmission speeds, meaning the Matrix is able to address tenants' needs for powerful, fast and reliable communications around the clock. They claim more than providing cutting-edge architecture, the Matrix also connects all of Island East commercial space, creating it is claimed, one of the best-planned and most efficiently serviced business districts in Hong Kong (Swire Properties 2011b).

Text Box 8 One Island East Matrix features

End-to-end fibre optic connectivity throughout Island East

Round-the-clock technical and maintenance support

A free choice of Telecom or FTNS service providers

Full redundancy with dual riser and lead-ins

Full Cat. 5/5e and fibre optic cables

Complete choice of terrestrial, cable, broadband and satellite television channels

This sophisticated infrastructure empowers office tenants to utilise a range of services and applications, including:

Broadband Internet Access

International Private Leased Circuit

High-speed Intranet

PABX interconnections

High-speed data links

Multi-channel real-time video transmissions

Video conferencing

Satellite communications

Gehry Technologies (GT) became the BIM process consultant for this project and used Digital Project to create the virtual 3D model prior to construction. The contractor updated the virtual model as the building was being constructed, so that the model could be used for operations and maintenance once the construction is completed.

Swire Properties plans to use this methodology on all its future projects. While the model was used to do some cladding studies in this project, the focus of BIM was primarily on clash detection, automated quantity extraction, and construction scheduling.

Historically Gehry Technologies grew out of Gehry Partners. The concern there, for the application of this kind of sophisticated technology, (was in the ability to capture and as Frank says to catch the curve), and capture the geometry and configure it such that it could be made buildable, and co-ordinate and execute what otherwise would be extreme complex geometric projects.

In the case of the Swire Tower, the emphasis was on the co-ordination of the elements in the construction. The client's desire there was to make what was an evolving design and delivery process more efficient. So in this case it was about looking at co-ordinating the geometries and quantities of the structural systems, mechanical systems and the lighting systems and so, on into a single model such that any of the greatest possible amount of the geometric complexities could be eliminated in the project.

During the design and development phases, in the 3D model, more than 2000 clashes errors were found, where things were uncoordinated. These would all have created problems if they were first found on site and that would lead to huge economies, and that was one of the real aspects that the client wanted to trap. It is all about project certainty, how it is going to be built, and how much it is going to cost.

Text Box 9 Facts about Swire Tower, in Hong Kong, China

Total area: approx. 141,000 m²

completed: March 2008

Architect: Wong & Ouyang (HK) Limited

Developer: Swire Properties Limited

Main Contractor: Gammon Construction Limited

Structural Engineer: Ove Arup & Partners Hong Kong Limited

M&E Engineers: Meinhart (M&E)

Construction Consultant: Gammon

In 2009, One Island East received Silver Award of IStructE China Award in recognition of its excellence in structural engineering. All office buildings, wholly owned by Swire Properties, have been awarded the highest ratings by Building Environmental Assessment Method (BEAM). One Island East is a Grade-A office development which achieved BEAM's highest Platinum rating.

Table 8 Case Studies: Software Programmes

Table 9 Case Studies: Design, Procure, Build & Manage, where BIM played a significant role through all stages.

9. Questionnaire

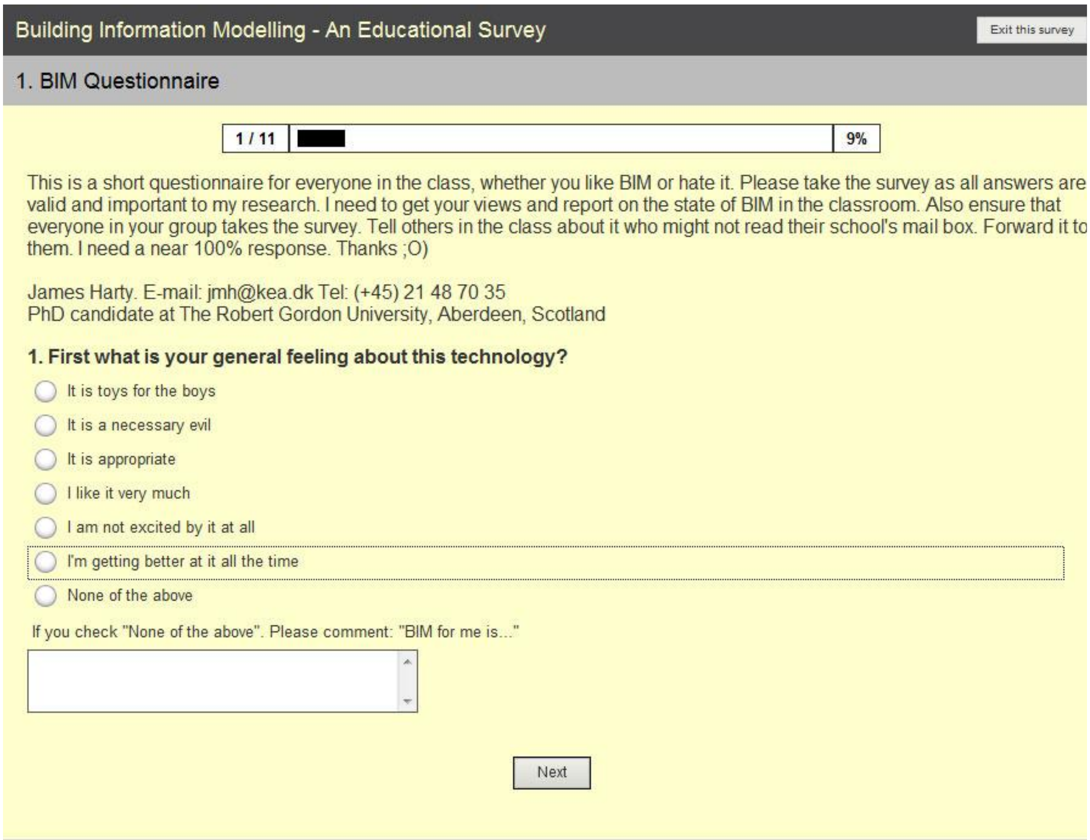
9.1 Introduction

A questionnaire is vital to gather information and to get feedback. It also gathers opinions from respondents, in a form that can be analysed. This questionnaire was confined to the educational establishments, because at the time they represented a controlled situation, where changes could best be monitored and examined. Student classes were chosen where I did not have a direct involvement, for two reasons; it gave me a certain distance from them, which it allowed answers to be uninfluenced by any treat to their marking or grading.

The classes chosen also had the benefit of having a good influx of exchange students, to be bedded into the collaborative methods at the school and a chance to see their impact. This is largely because of the teaching methods at the school, which are group-based project driven. Most exchange students find this quite challenging at first and many hanker for traditional methods that they feel more secure doing. Having said this usually when asked prior to returning home (one or two semesters later), nearly all are well satisfied with the experience and word of mouth suggests that this relayed to the next crop of students who appear the following year.

While it was the intention to run the survey at the start and again at the end of the semester, sadly this did not materialise. This was due to their focus on exams at the end of the semester, and the students' sudden dispersal thereafter. Two supplementary things came out of the process, one was a small control survey that came from Robert Gordon University and the other the preliminary test run survey. Both tended to support the findings of the main survey and they are also included here.

9.2 Questions & Answers


Building Information Modelling - An Educational Survey

Exit this survey

1. BIM Questionnaire

1 / 11 9%

This is a short questionnaire for everyone in the class, whether you like BIM or hate it. Please take the survey as all answers are valid and important to my research. I need to get your views and report on the state of BIM in the classroom. Also ensure that everyone in your group takes the survey. Tell others in the class about it who might not read their school's mail box. Forward it to them. I need a near 100% response. Thanks ;O)

James Harty. E-mail: jmh@kea.dk Tel: (+45) 21 48 70 35
PhD candidate at The Robert Gordon University, Aberdeen, Scotland

1. First what is your general feeling about this technology?

- It is toys for the boys
- It is a necessary evil
- It is appropriate
- I like it very much
- I am not excited by it at all
- I'm getting better at it all the time
- None of the above

If you check "None of the above". Please comment: "BIM for me is..."

Next

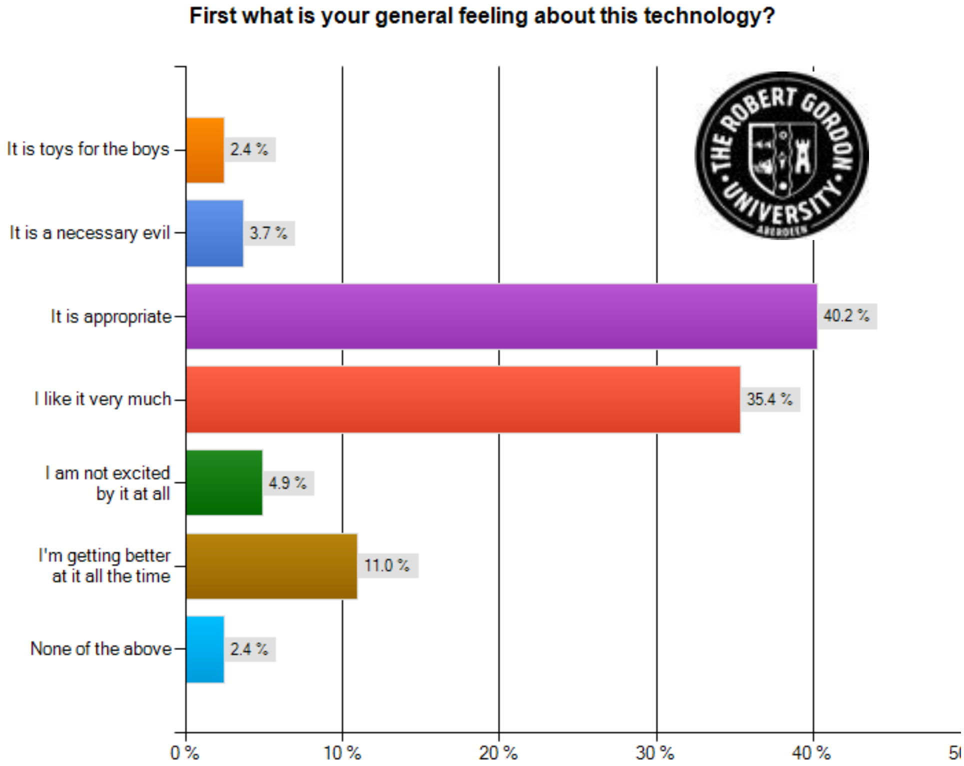
Notes:

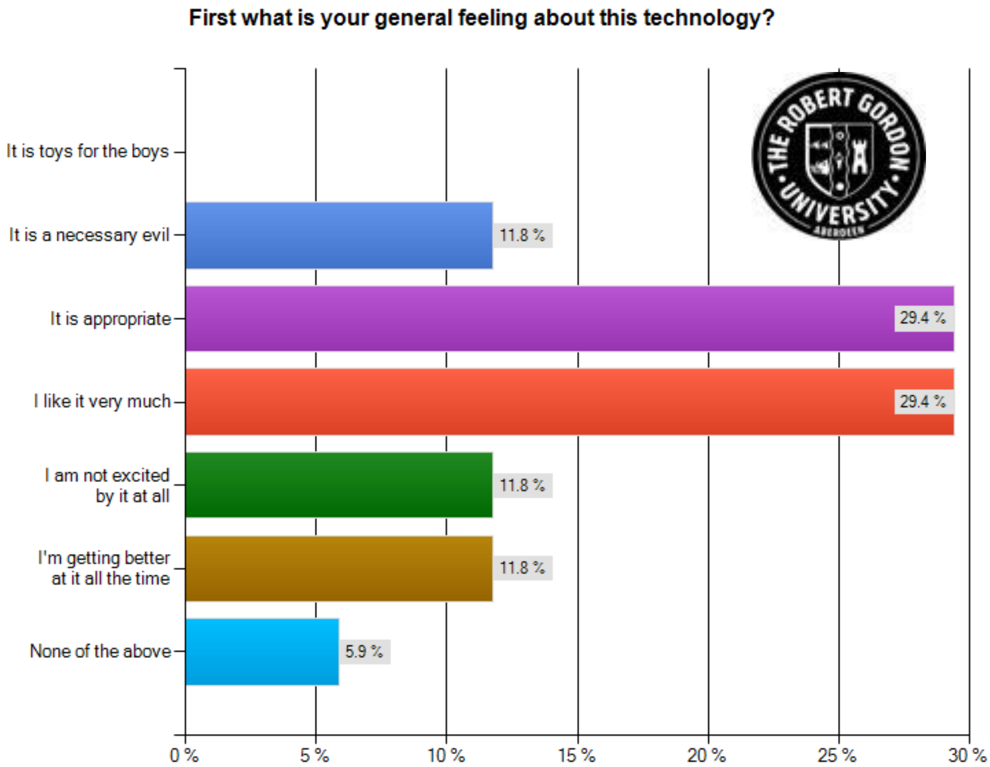
This survey was conducted during September/October 2009. It was primarily aimed at two parallel classes at The Copenhagen School of Design & Technology (KEA). The conditions for the survey were that it should be classes where I was not teaching as this could have a bearing on responses. Furthermore, the mix in the classes was relatively rich, in that they could be broken down into core students from fifth semester who had used Revit since second semester, and an influx of (Erasmus exchange students who had no Revit experience. There were 85 respondents.

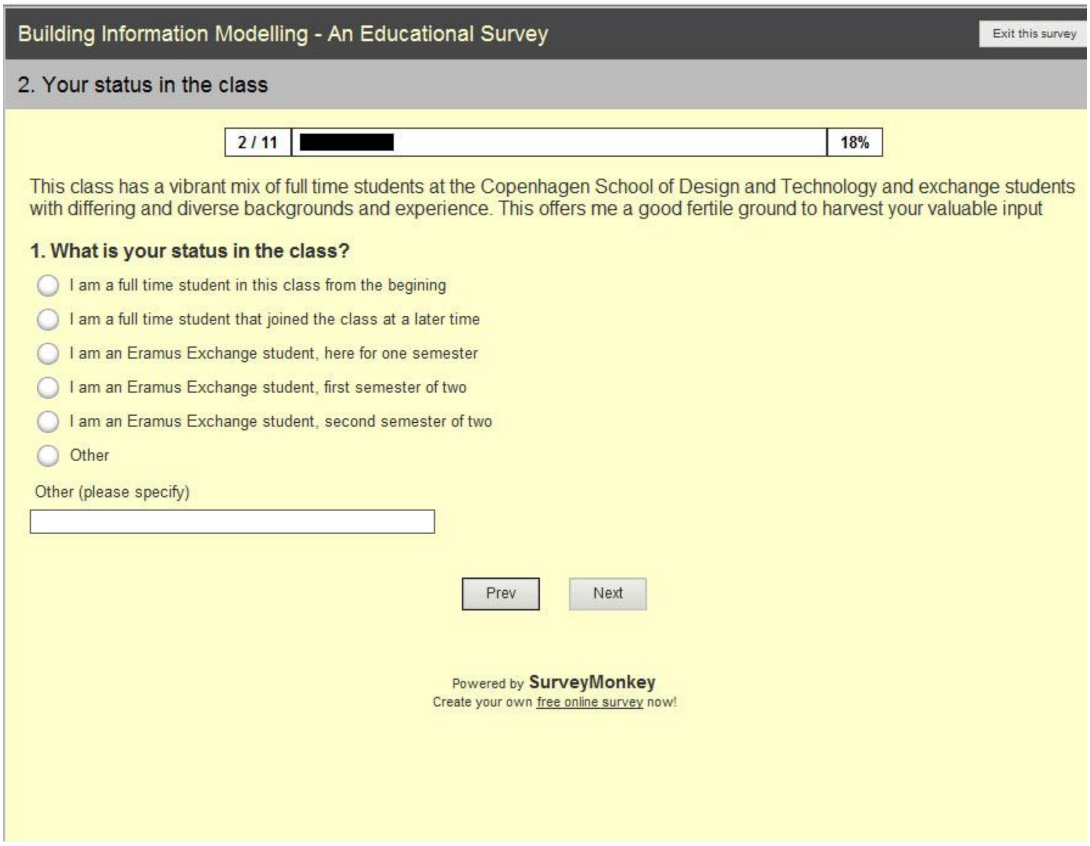
A bonus arose when the survey was also given out to Robert Gordon students, who could be seen as a control group, not having the same exposure to Revit, and being more representative of course content in the UK. This should be seen in this light, where not too much can be read into the answering, because the response rate was not great, being only 15.

Please note, that the difference in numbers of respondents in the two surveys means that the scales along the axes of the charts vary sometimes.

Table 10 BIM Questionnaire; 'First, What is your general feeling about this technology?' (BIM)


First what is your general feeling about this technology?
It is toys for the boys
It is a necessary evil
It is appropriate
I like it very much
I am not excited by it at all
I'm getting better at it all the time
None of the above
2.4 %
3.7 %
40.2 %
35.4 %
4.9 %
11.0 %
2.4 %
0 %
10 %
20 %
30 %
40 %
THE ROBERT GORDON UNIVERSITY
ABERDEEN

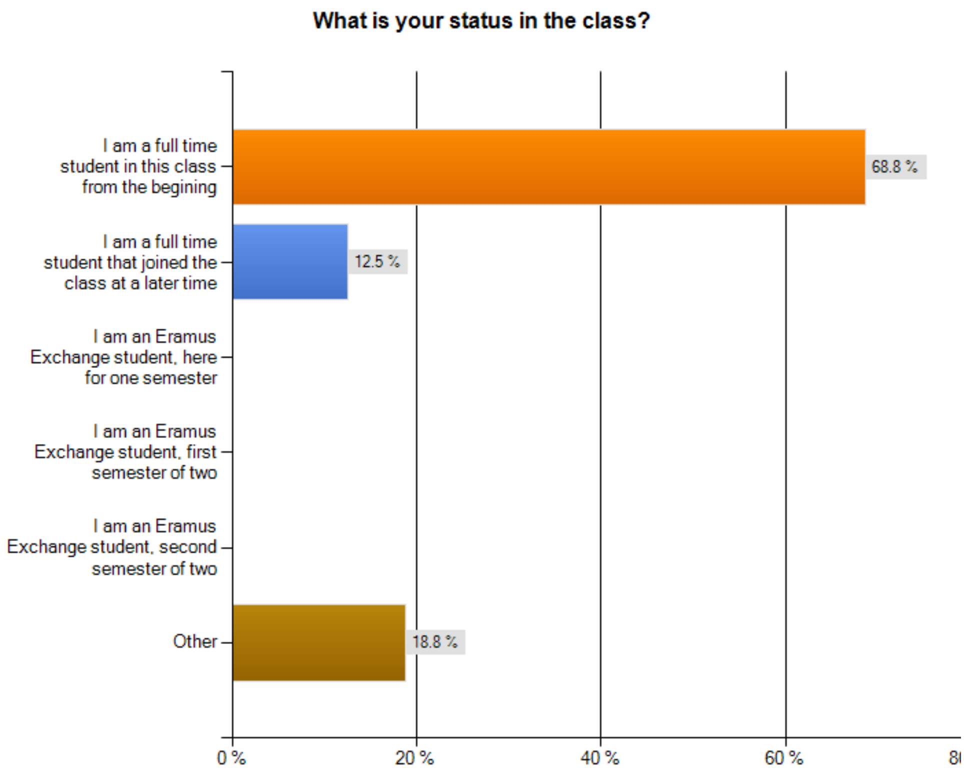

First what is your general feeling about this technology?
It is toys for the boys
It is a necessary evil
It is appropriate
I like it very much
I am not excited by it at all
I'm getting better at it all the time
None of the above
11.8 %
29.4 %
29.4 %
11.8 %
11.8 %
5.9 %
0 %
5 %
10 %
15 %
20 %
25 %
30 %
THE ROBERT GORDON UNIVERSITY
ABERDEEN

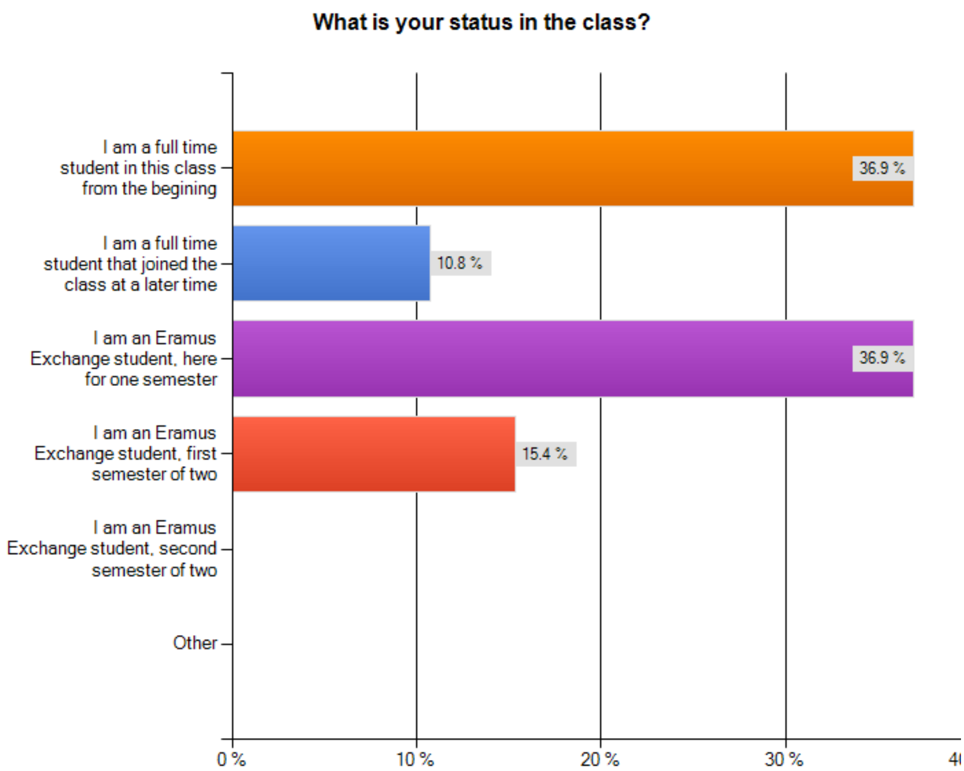


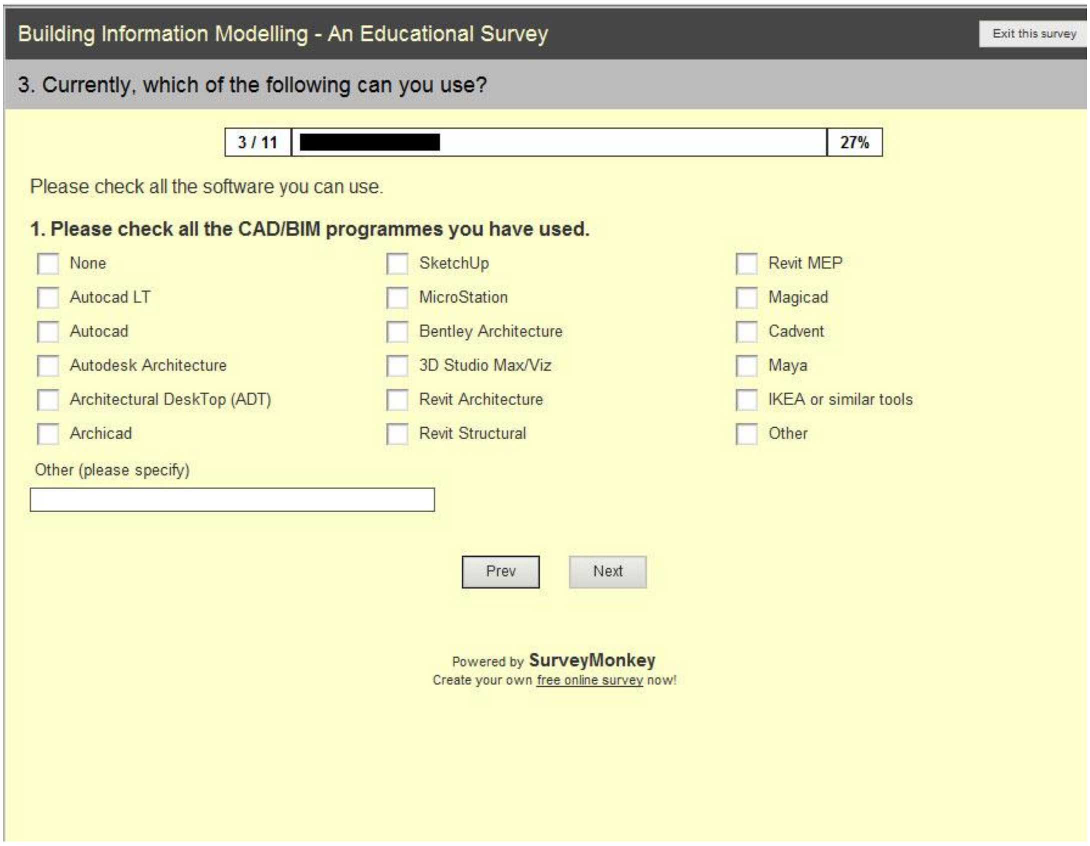
Notes:

This question essentially is to create a profile of the respondents' demographic. It shows that 34 were exchange students and the rest, 31, regular students. The reason for the diminished numbers of home grown students is that many of them were on exchange too (ie at other institutions).

Table 11 'What is your status in class?'


What is your status in the class?
I am a full time student in this class from the begining
I am a full time student that joined the class at a later time
I am an Eramus Exchange student, here for one semester
I am an Eramus Exchange student, first semester of two
I am an Eramus Exchange student, second semester of two
Other
68.8 %
12.5 %
18.8 %
0 %
20 %
40 %
60 %

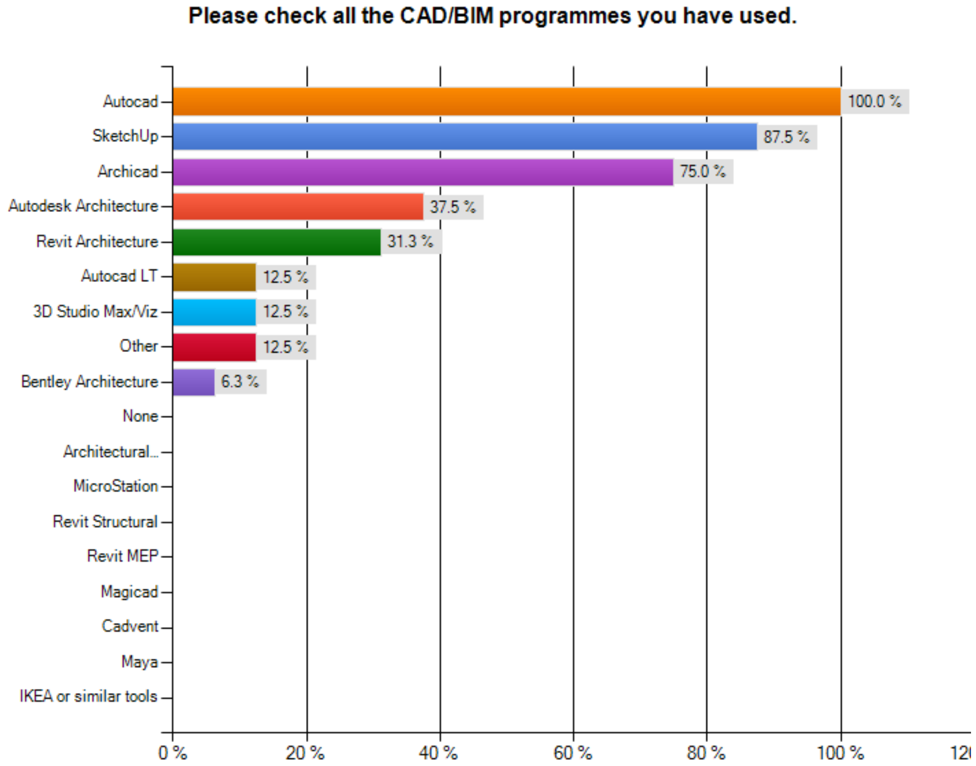

What is your status in the class?
I am a full time student in this class from the begining
I am a full time student that joined the class at a later time
I am an Eramus Exchange student, here for one semester
I am an Eramus Exchange student, first semester of two
I am an Eramus Exchange student, second semester of two
Other
36.9 %
10.8 %
36.9 %
15.4 %
0 %
10 %
20 %
30 %

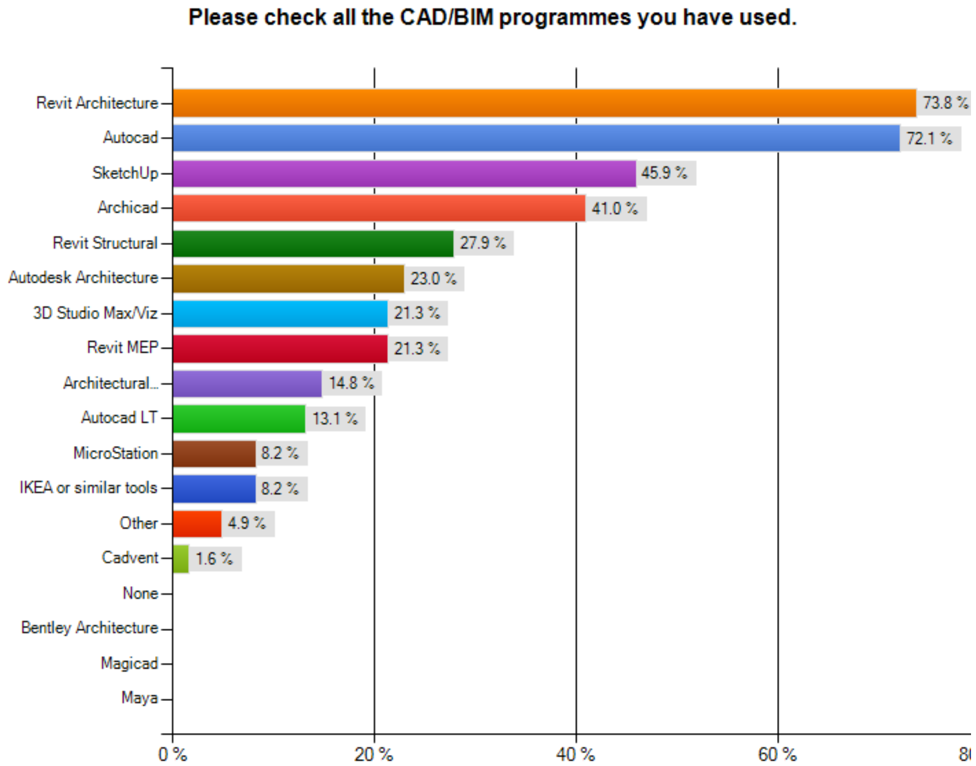


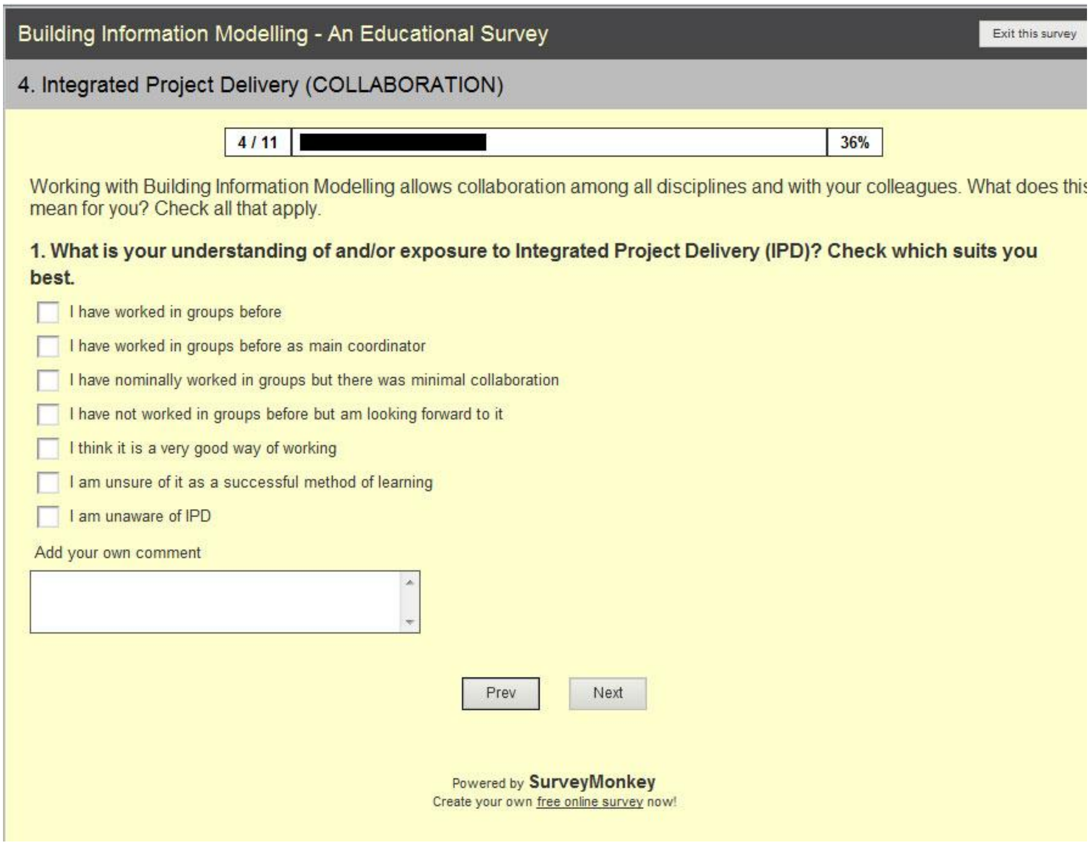
Notes:

This question sets the context from which the remaining questions can be gauged. Understandably enough, AutoCAD features highly. Revit is largely KEA only, while SketchUp and Archicad are mainly exchange students.

Table 12 'Please check all the CAD/BIM programmes you have used'


Please check all the CAD/BIM programmes you have used.
Autocad
SketchUp
Archicad
Autodesk Architecture
Revit Architecture
Autocad LT
3D Studio Max/Viz
Other
Bentley Architecture
None
Architectural...
MicroStation
Revit Structural
Revit MEP
Magicad
Cadvent
Maya
IKEA or similar tools
100.0 %
87.5 %
75.0 %
37.5 %
31.3 %
12.5 %
12.5 %
12.5 %
6.3 %
0 %
20 %
40 %
60 %
80 %
100 %


Please check all the CAD/BIM programmes you have used.
Revit Architecture
Autocad
SketchUp
Archicad
Revit Structural
Autodesk Architecture
3D Studio Max/Viz
Revit MEP
Architectural...
Autocad LT
MicroStation
IKEA or similar tools
Other
Cadvent
None
Bentley Architecture
Magicad
Maya
73.8 %
72.1 %
45.9 %
41.0 %
27.9 %
23.0 %
21.3 %
21.3 %
14.8 %
13.1 %
8.2 %
8.2 %
4.9 %
1.6 %
0 %
20 %
40 %
60 %



Building Information Modelling - An Educational Survey

Exit this survey

4. Integrated Project Delivery (COLLABORATION)

4 / 11 36%

Working with Building Information Modelling allows collaboration among all disciplines and with your colleagues. What does this mean for you? Check all that apply.

1. What is your understanding of and/or exposure to Integrated Project Delivery (IPD)? Check which suits you best.

- [ ] I have worked in groups before
- [ ] I have worked in groups before as main coordinator
- [ ] I have nominally worked in groups but there was minimal collaboration
- [ ] I have not worked in groups before but am looking forward to it
- [ ] I think it is a very good way of working
- [ ] I am unsure of it as a successful method of learning
- [ ] I am unaware of IPD

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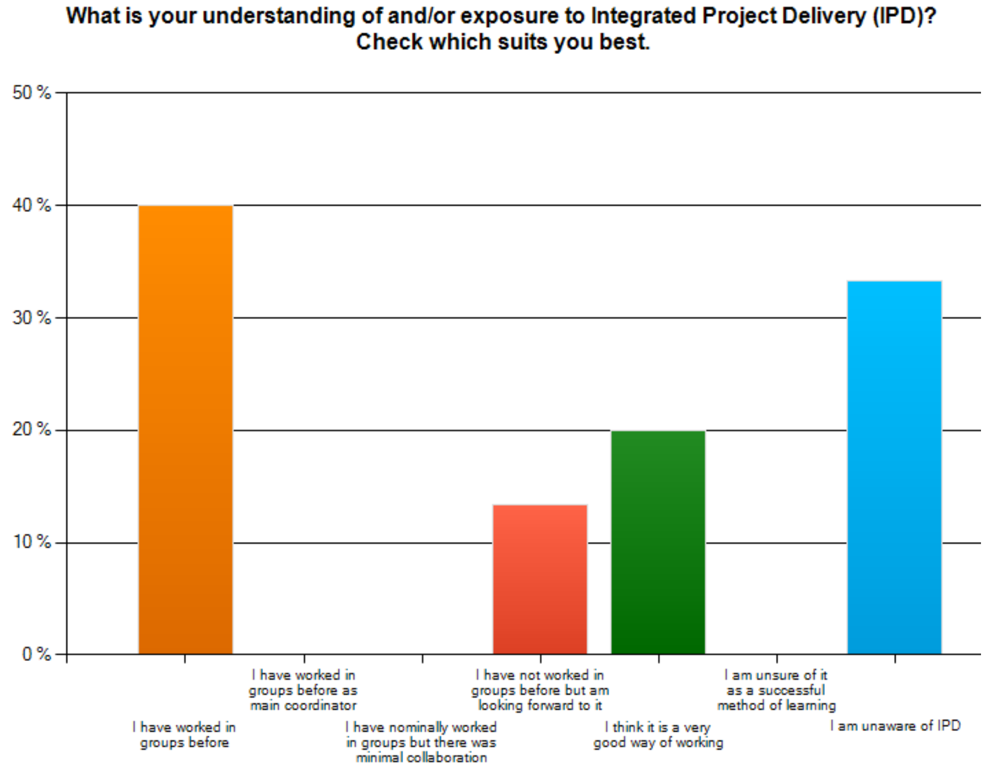
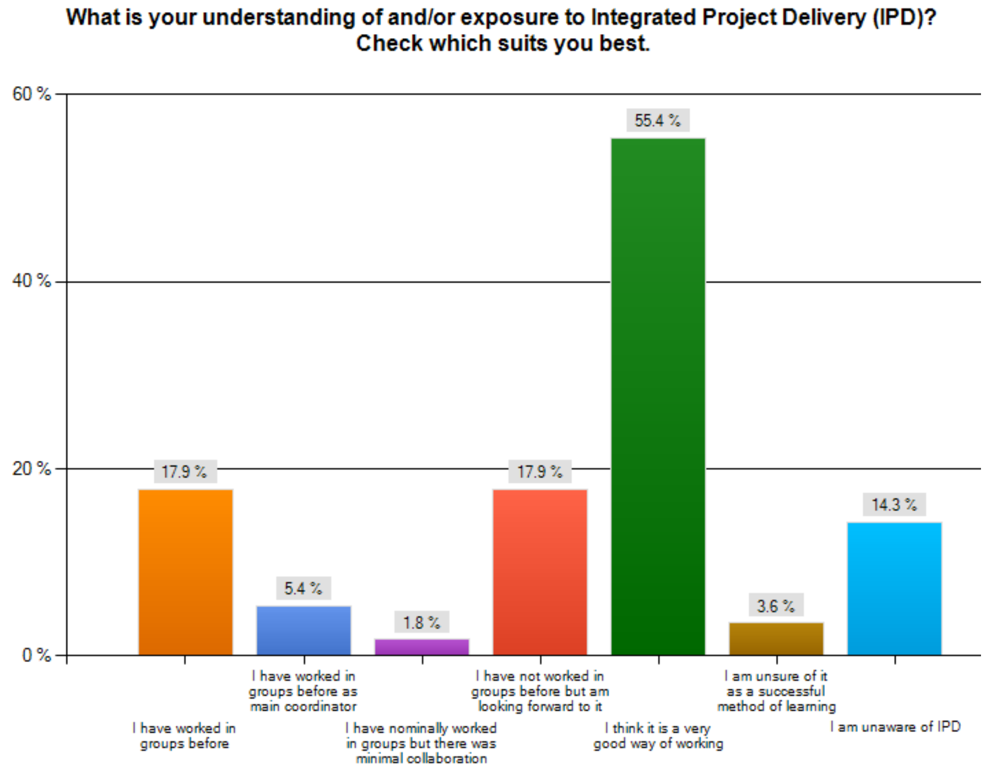
Notes:

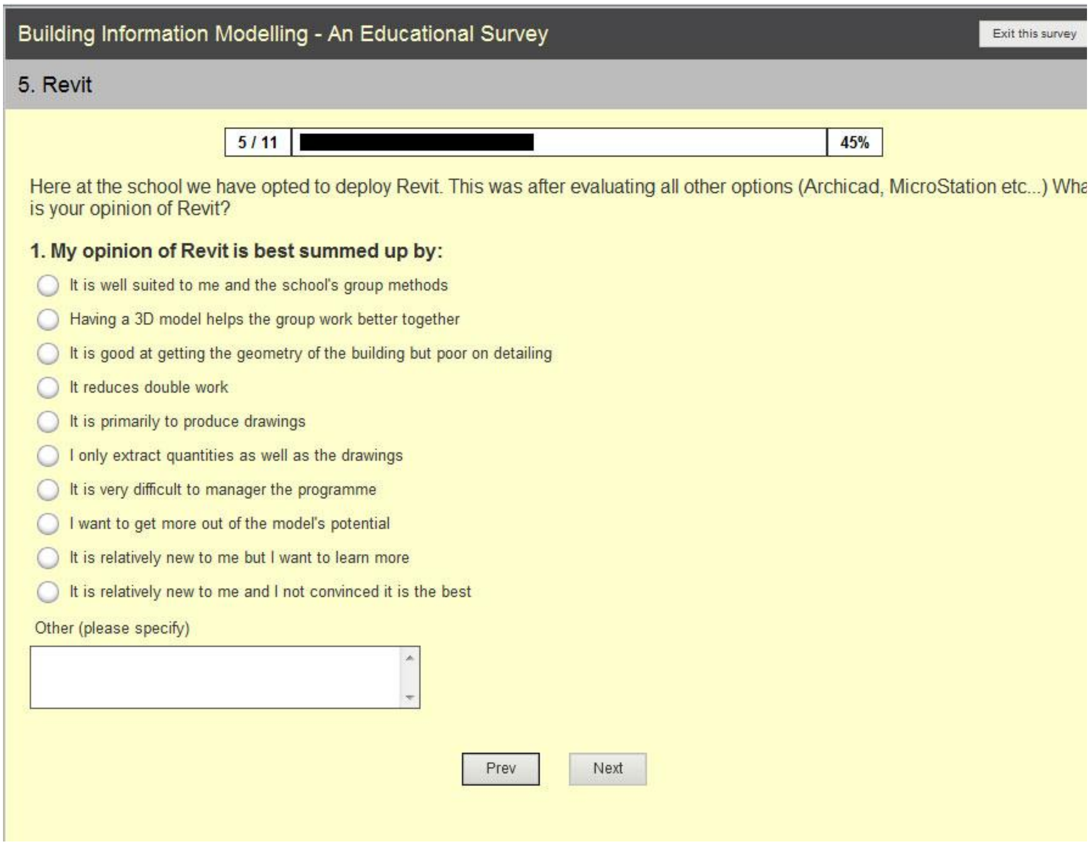
Group work sounds very easy, it mirrors the work place and involves collaboration. But when a whole semester is based on the same group, with inter-dependency for grades and marking, the stakes are high, and this reflects in how seriously home grown students take the matter. This also puts them in a very strong position to collaborate and gives them a better understanding of IPD. It also accounts for the small degree of scepticism shown by those who doubted it of did not know IPD (largely exchange students).

The majority thought it was a good way of working, and this reflects the schools ethos of project driven group work.

Table 13 'What is your understanding of and/or exposure to Integrated Project Delivery (IPD)?'


What is your understanding of and/or exposure to Integrated Project Delivery (IPD)? Check which suits you best.
50 %
40 %
30 %
20 %
10 %
0 %
I have worked in groups before
I have worked in groups before as main coordinator
I have nominally worked in groups but there was minimal collaboration
I have not worked in groups before but am looking forward to it
I think it is a very good way of working
I am unsure of it as a successful method of learning
I am unaware of IPD


What is your understanding of and/or exposure to Integrated Project Delivery (IPD)? Check which suits you best.
60 %
40 %
20 %
0 %
17.9 %
5.4 %
1.8 %
17.9 %
55.4 %
3.6 %
14.3 %
I have worked in groups before
I have worked in groups before as main coordinator
I have nominally worked in groups but there was minimal collaboration
I have not worked in groups before but am looking forward to it
I think it is a very good way of working
I am unsure of it as a successful method of learning
I am unaware of IPD


Building Information Modelling - An Educational Survey

Exit this survey

5. Revit

5 / 11 45%

Here at the school we have opted to deploy Revit. This was after evaluating all other options (Archicad, MicroStation etc...) Wha is your opinion of Revit?

1. My opinion of Revit is best summed up by:

- It is well suited to me and the school's group methods
- Having a 3D model helps the group work better together
- It is good at getting the geometry of the building but poor on detailing
- It reduces double work
- It is primarily to produce drawings
- I only extract quantities as well as the drawings
- It is very difficult to manager the programme
- I want to get more out of the model's potential
- It is relatively new to me but I want to learn more
- It is relatively new to me and I not convinced it is the best

Other (please specify)

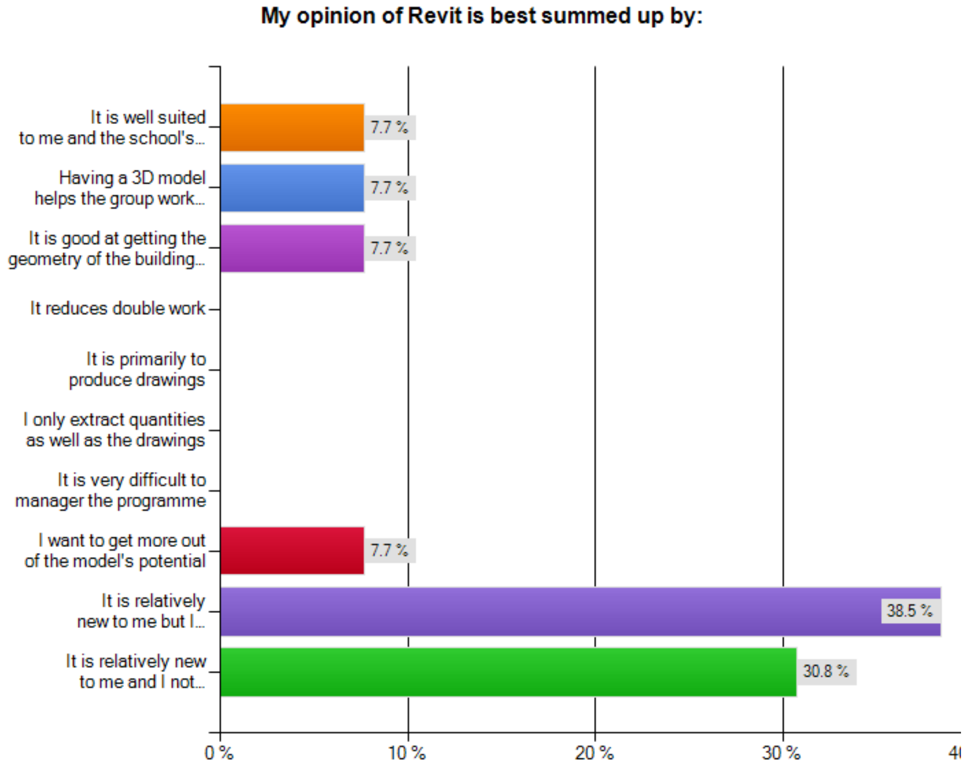
Prev Next

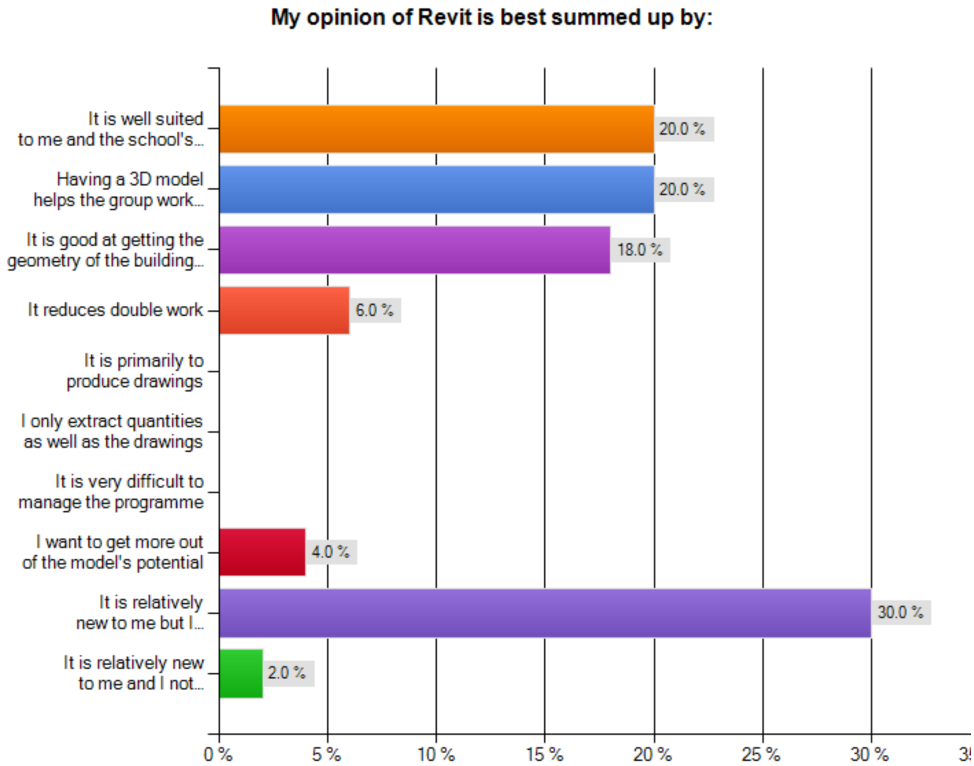
Notes:

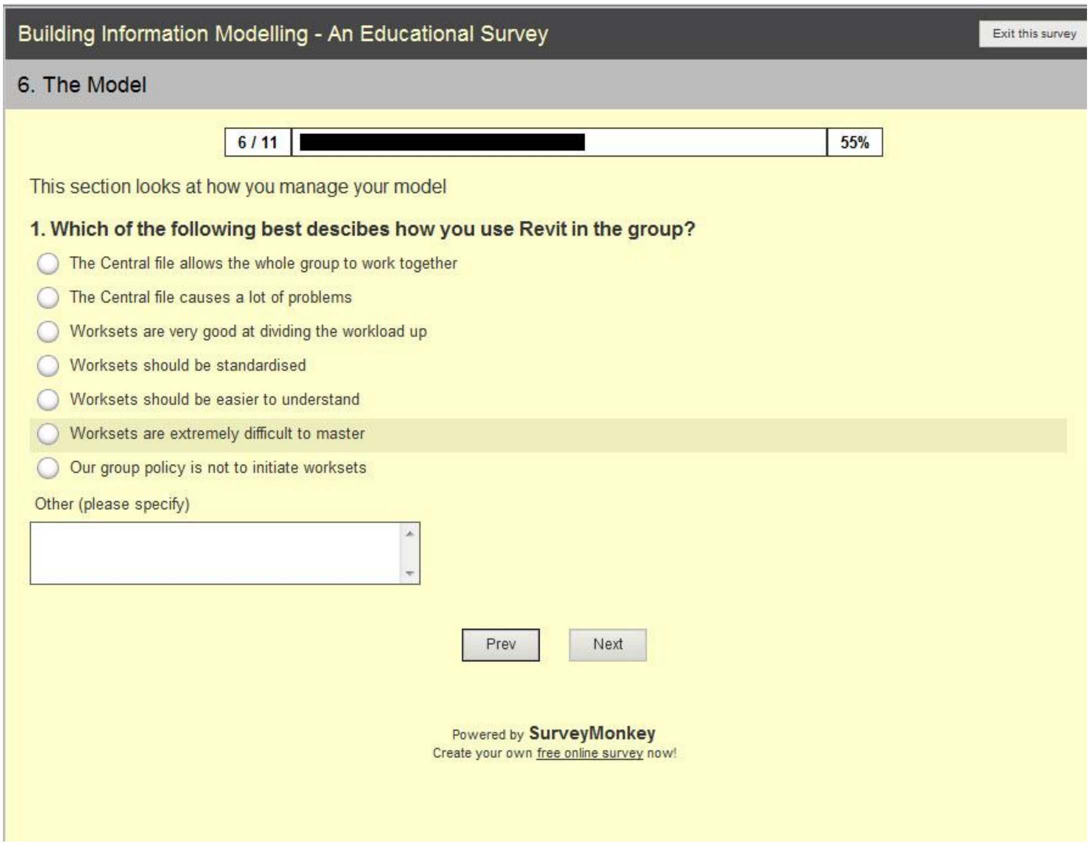
Cutting to the chase, opinions about Revit split along the home grown/exchange divide, telling that there is a threshold to acceptance and adoption, and this is relevant. Once these results were in, there was a desire to run the survey again at the end of the semester to gauge and calibrate the expected difference. This did not happen, because the students were too busy gearing up for exams, or despondent after the exams.

Casual questioning in the class suggested that opinions had been won over but sadly, this could not be captured.

Table 14 'My opinion of Revit is best summed up by...'


My opinion of Revit is best summed up by:
It is well suited to me and the school's...
Having a 3D model helps the group work...
It is good at getting the geometry of the building...
It reduces double work
It is primarily to produce drawings
I only extract quantities as well as the drawings
It is very difficult to manager the programme
I want to get more out of the model's potential
It is relatively new to me but I...
It is relatively new to me and I not...
7.7 %
7.7 %
7.7 %
7.7 %
38.5 %
30.8 %
0 %
10 %
20 %
30 %


My opinion of Revit is best summed up by:
It is well suited to me and the school's...
Having a 3D model helps the group work...
It is good at getting the geometry of the building...
It reduces double work
It is primarily to produce drawings
I only extract quantities as well as the drawings
It is very difficult to manage the programme
I want to get more out of the model's potential
It is relatively new to me but I...
It is relatively new to me and I not...
20.0 %
20.0 %
18.0 %
6.0 %
4.0 %
30.0 %
2.0 %
0 %
5 %
10 %
15 %
20 %
25 %
30 %



Notes:

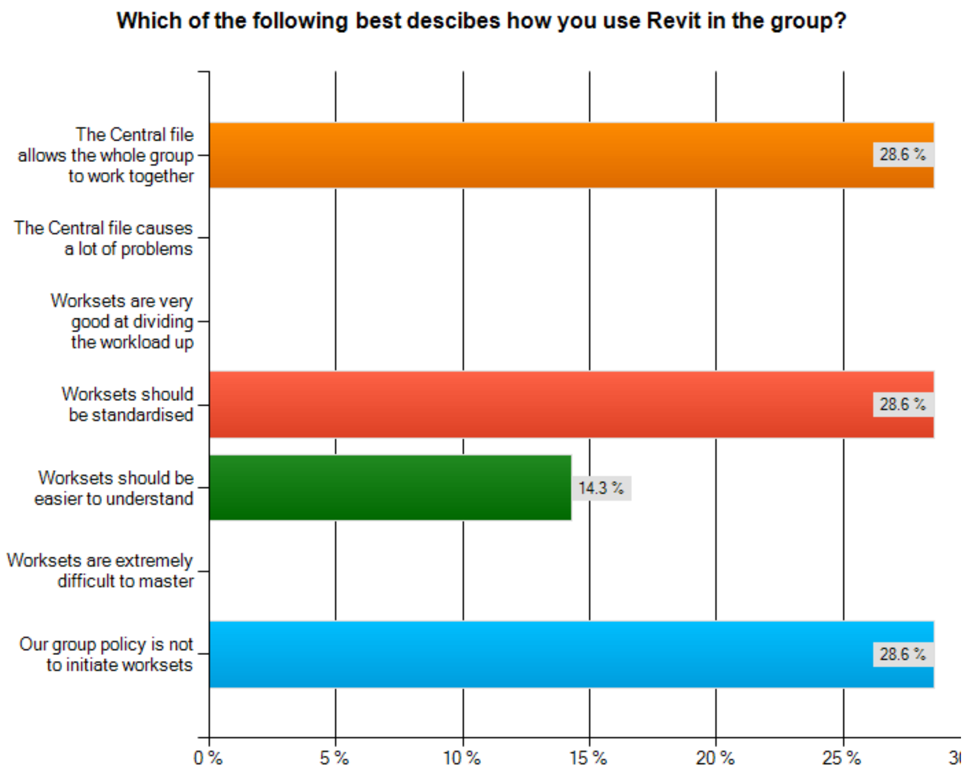
One of the best reasons for group work is the possibility of exercising the student in the vagaries of collaborating in Revit, notably Worksets and Central files. It is very difficult for other institutions to initiate such an arrangement, without strenuous and complicated set-ups, but at KEA, the set-up welcomes it.

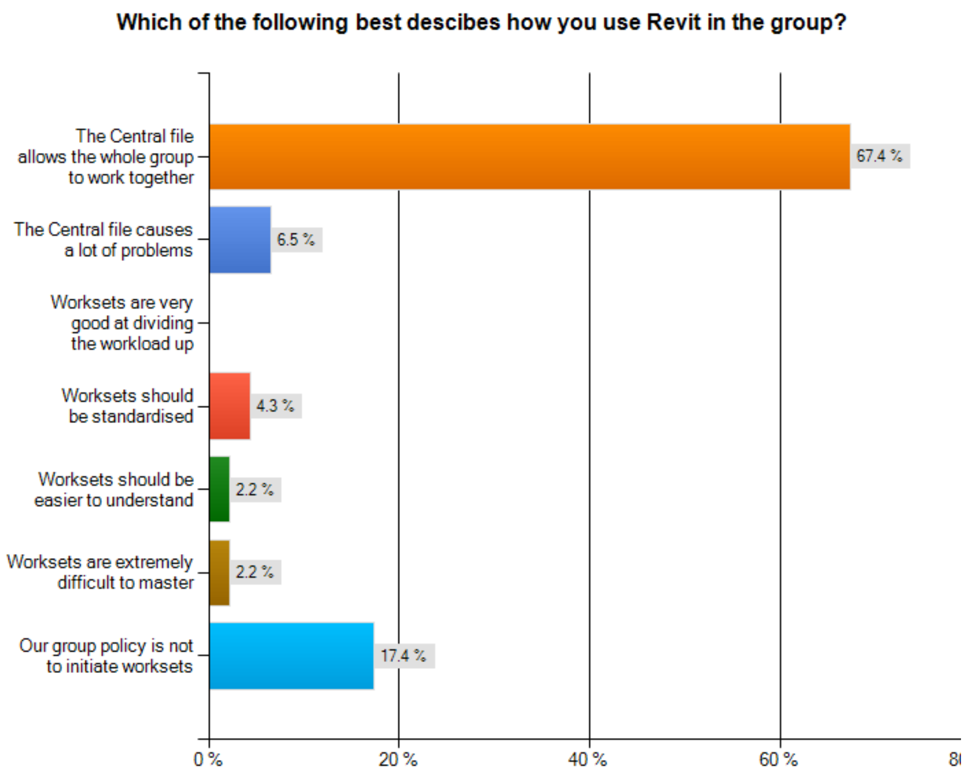
The positive response here was a little surprising, but reflects well on the classes' motivation. There is difficulty in activating Worksets and this can be seen in the small percentage that refrains from initiating them.

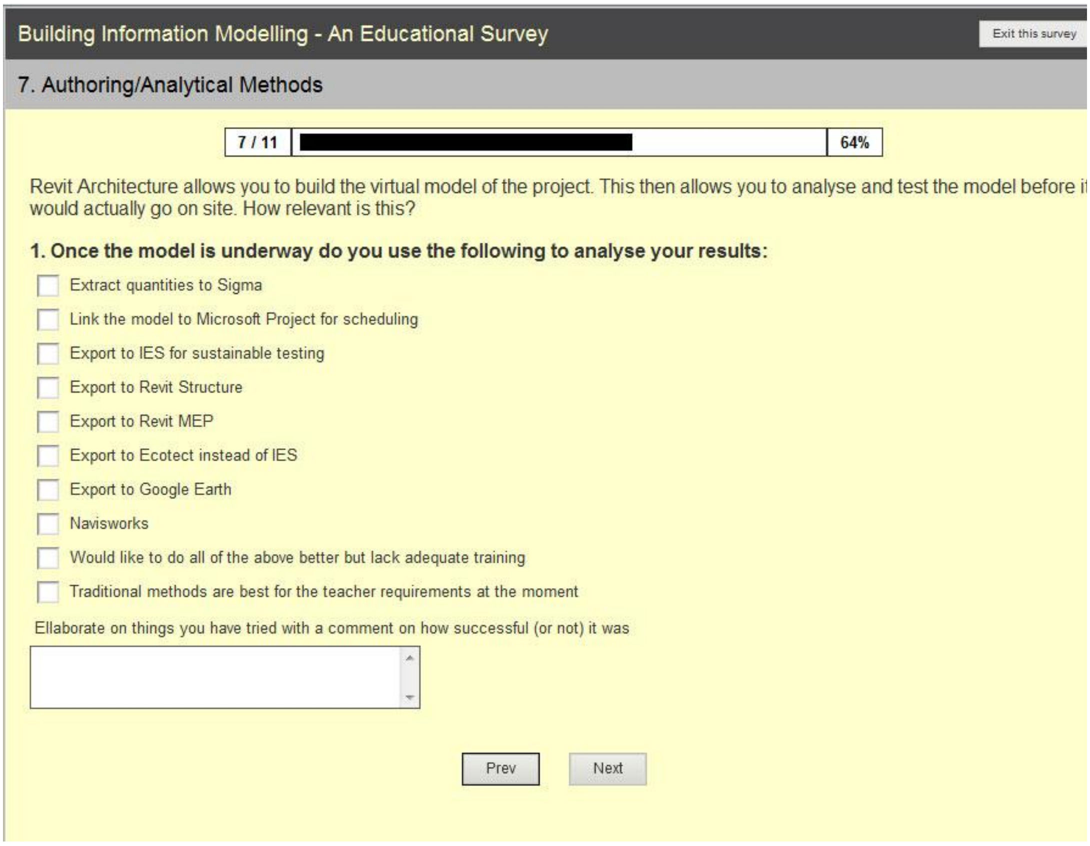
It is worth noting here that the school has negoitiated in the region of 1000 Autodesk Educational licenses, which together with the Subscription package on offer from Autodesk, means that we are a serious user-group with one of the largest pools of both expertise and experience. The educational license means that the school has access to the whole suite of programmes on offer from Autodesk (ranging from AutoCAD light right through to Inventor Fusion and all in-between).

The single license programme allows all programmes to be run from it. Currenlty only staff can borrow licenses onto their laptops, but students can avail of the Educational Community at www.autodesk.com to down load for home use the same programmes with three year student licenses.

Table 15 'Which of the following best describes how you use Revit in the group?'


Which of the following best descibes how you use Revit in the group?
The Central file allows the whole group to work together
28.6 %
The Central file causes a lot of problems
Worksets are very good at dividing the workload up
Worksets should be standardised
28.6 %
Worksets should be easier to understand
14.3 %
Worksets are extremely difficult to master
Our group policy is not to initiate worksets
28.6 %
0 %
5 %
10 %
15 %
20 %
25 %


Which of the following best descibes how you use Revit in the group?
The Central file allows the whole group to work together
67.4 %
The Central file causes a lot of problems
6.5 %
Worksets are very good at dividing the workload up
Worksets should be standardised
4.3 %
Worksets should be easier to understand
2.2 %
Worksets are extremely difficult to master
2.2 %
Our group policy is not to initiate worksets
17.4 %
0 %
20 %
40 %
60 %


Building Information Modelling - An Educational Survey

Exit this survey

7. Authoring/Analytical Methods

7 / 11 64%

Revit Architecture allows you to build the virtual model of the project. This then allows you to analyse and test the model before it would actually go on site. How relevant is this?

1. Once the model is underway do you use the following to analyse your results:

- [ ] Extract quantities to Sigma
- [ ] Link the model to Microsoft Project for scheduling
- [ ] Export to IES for sustainable testing
- [ ] Export to Revit Structure
- [ ] Export to Revit MEP
- [ ] Export to Ecotect instead of IES
- [ ] Export to Google Earth
- [ ] Navisworks
- [ ] Would like to do all of the above better but lack adequate training
- [ ] Traditional methods are best for the teacher requirements at the moment

Ellaborate on things you have tried with a comment on how successful (or not) it was

Prev Next

Notes:

This is very much a transitional question, based in a time-warp, of issues at the school. First of all, there was a desire to offer all the options, but just as in industry, there is reluctance towards implementation and this reflects in the option regarding traditional methods and teacher requirements in some quarters.

Next are the resources to actually teach the analysis programmes (this is improving now, but is still very contentious). Often this is best achieved in a coaching role where the student takes on to find out about it with support from like-minded teachers, and the results and methods are then disseminated through the class.

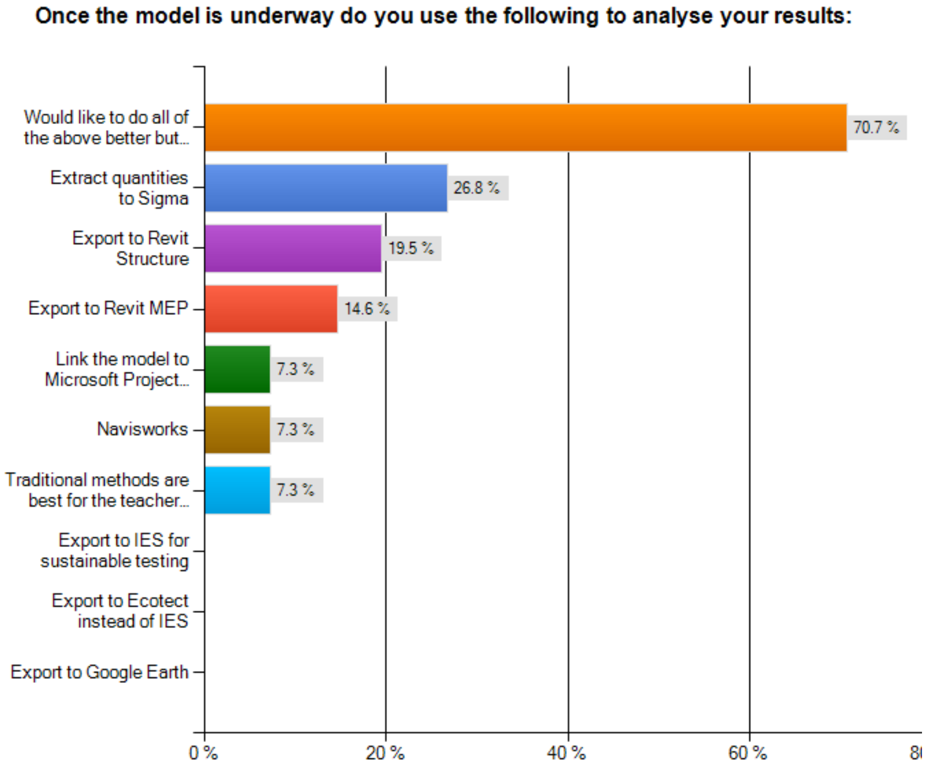
In elaborating the following comments were made:

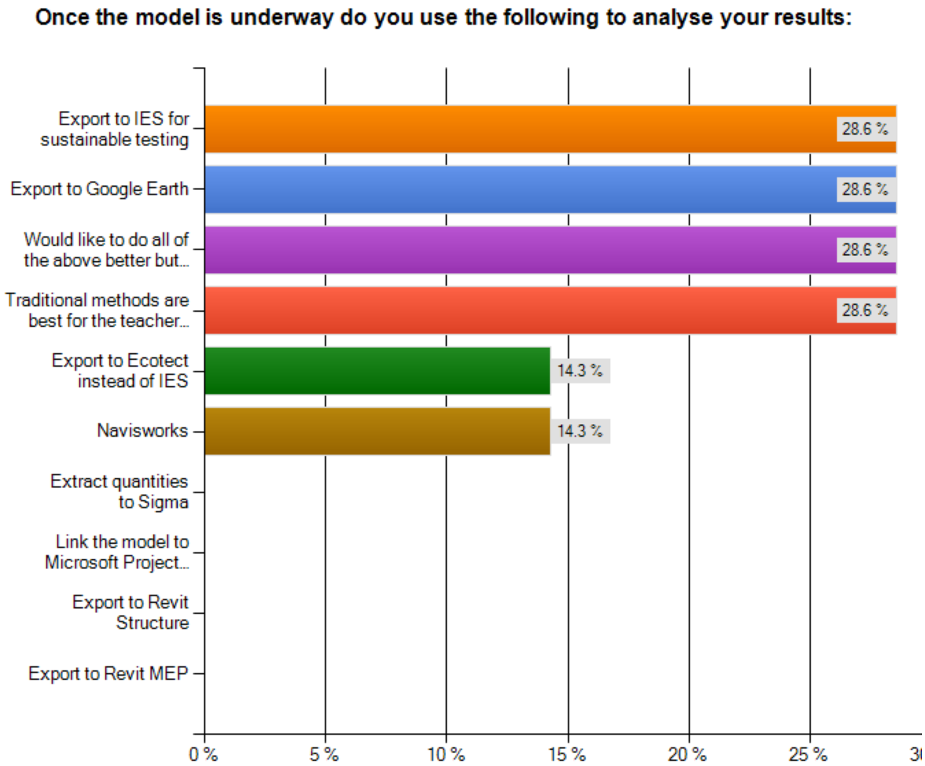
'I haven't tried any of this but I am looking forward to explore Revit as much as possible'.

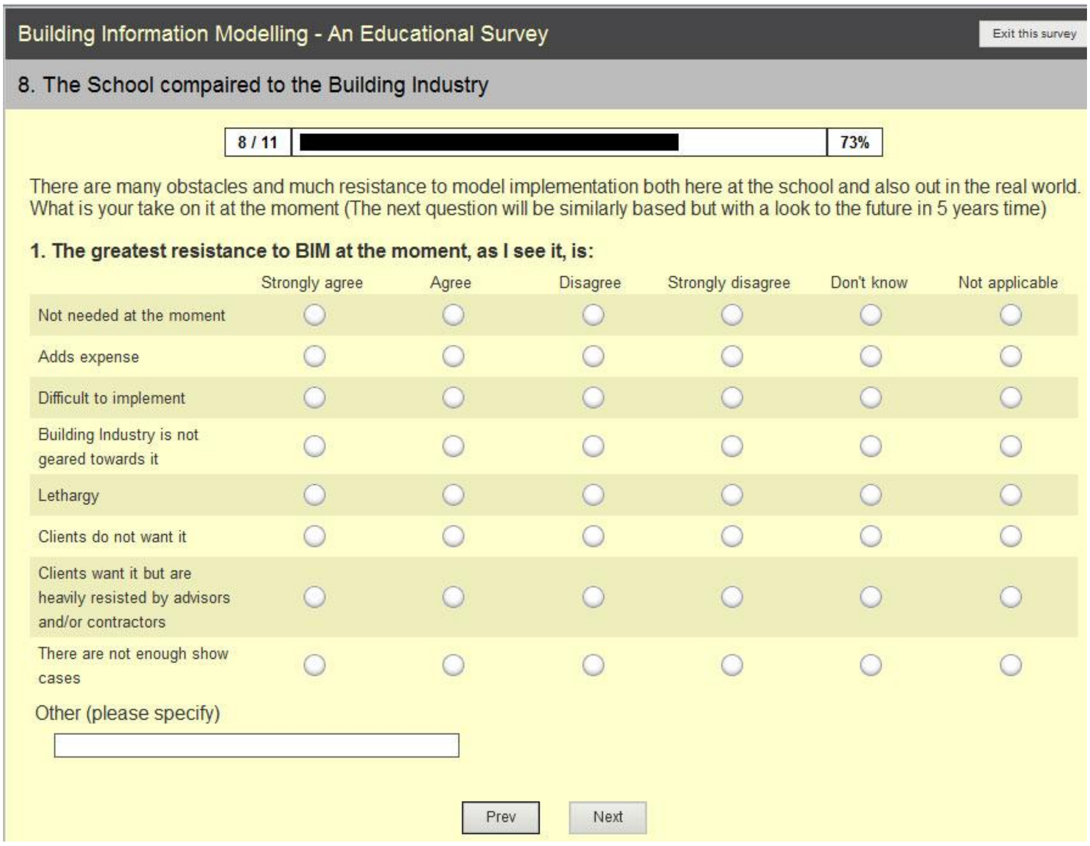
'MEP - I had a really hard time doing it, and it ended up being half-assed. Navisworks - That was great fun. :D'

'We have had no proper teaching in any of this, only a little bit about using Sigma with Revit, that's it'.

Table 16 'Once the model is underway, do you use the following to analyse your results?'


Once the model is underway do you use the following to analyse your results:
Would like to do all of the above better but...
Extract quantities to Sigma
Export to Revit Structure
Export to Revit MEP
Link the model to Microsoft Project...
Navisworks
Traditional methods are best for the teacher...
Export to IES for sustainable testing
Export to Ecotect instead of IES
Export to Google Earth
70.7 %
26.8 %
19.5 %
14.6 %
7.3 %
7.3 %
7.3 %
0 %
20 %
40 %
60 %


Once the model is underway do you use the following to analyse your results:
Export to IES for sustainable testing
Export to Google Earth
Would like to do all of the above better but...
Traditional methods are best for the teacher...
Export to Ecotect instead of IES
Navisworks
Extract quantities to Sigma
Link the model to Microsoft Project...
Export to Revit Structure
Export to Revit MEP
28.6 %
28.6 %
28.6 %
28.6 %
14.3 %
14.3 %
0 %
5 %
10 %
15 %
20 %
25 %


Building Information Modelling - An Educational Survey

Exit this survey

8. The School compaired to the Building Industry

8 / 11 73%

There are many obstacles and much resistance to model implementation both here at the school and also out in the real world. What is your take on it at the moment (The next question will be similarly based but with a look to the future in 5 years time)

1. The greatest resistance to BIM at the moment, as I see it, is:

	Strongly agree	Agree	Disagree	Strongly disagree	Don't know	Not applicable
Not needed at the moment						
Adds expense						
Difficult to implement						
Building Industry is not geared towards it						
Lethargy						
Clients do not want it						
Clients want it but are heavily resisted by advisors and/or contractors						
There are not enough show cases						

Other (please specify)

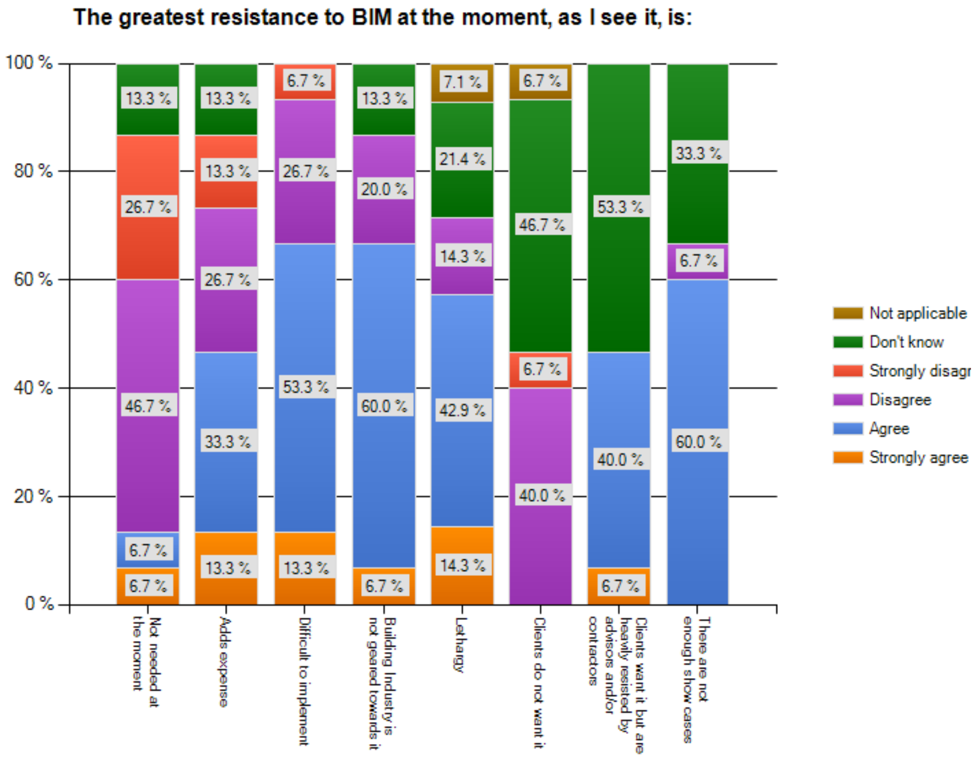
Prev Next

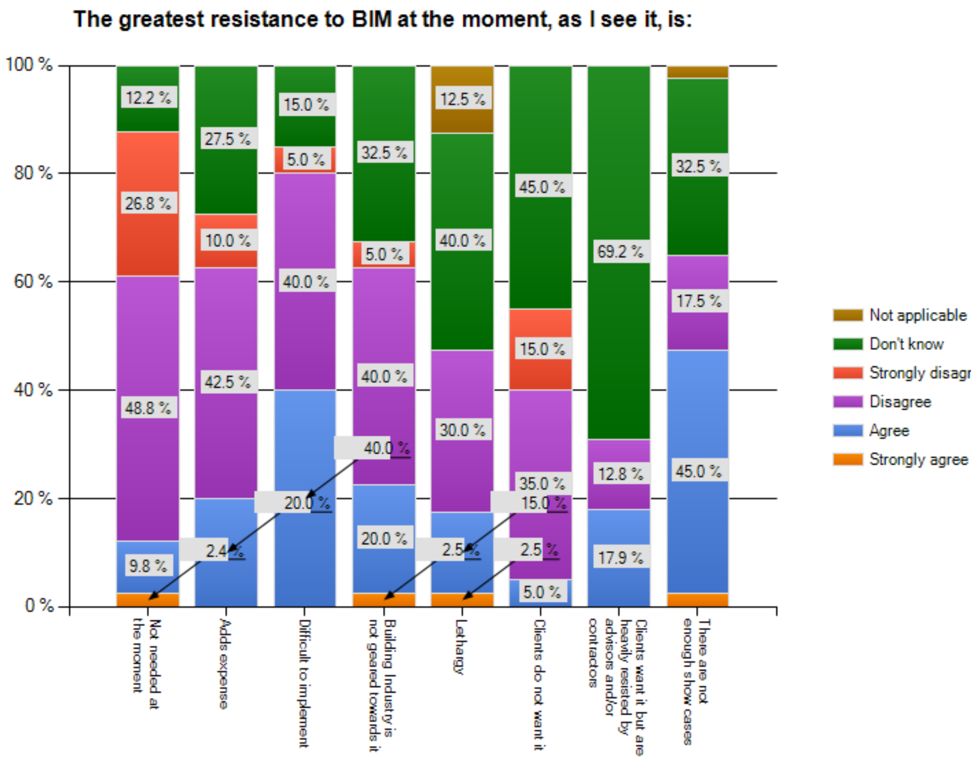
Notes:

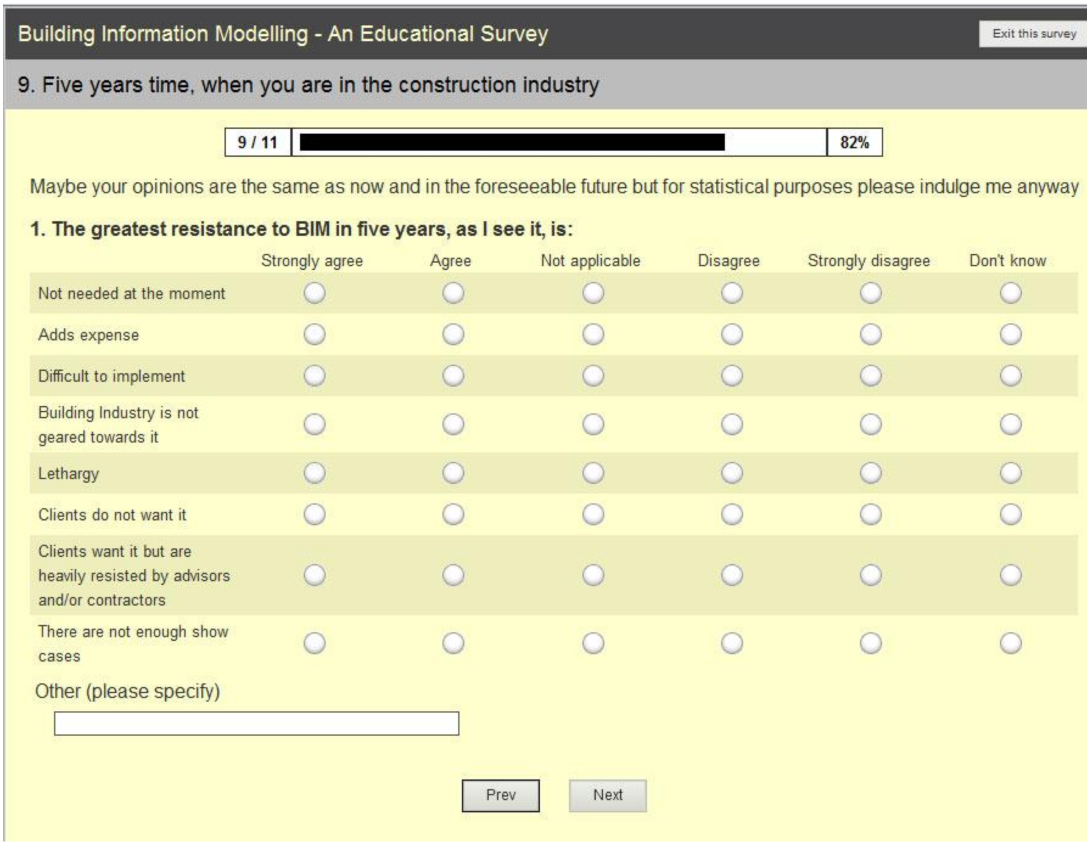
These last two questions are worth data mining. One is asked of the present, while the other is pitched to five years time. It is to assess the student's opinion of where we are now and where we might be heading in five years.

Plotting a line between the magenta and cyan colours shows broadly, where the differences occur. At RGU, it is higher than at KEA, suggesting more acceptance and understanding with those working with BIM at KEA.

Table 17 'The greatest resistance to BIM at the moment is...'


The greatest resistance to BIM at the moment, as I see it, is:
100 %
80 %
60 %
40 %
20 %
0 %
Not applicable
Don't know
Strongly disagr
Disagree
Agree
Strongly agree
Not needed at the moment
Adds expense
Difficult to implement
Building Industry is not geared towards it
Lethargy
Clients do not want it
Clients want it but are heavily resisted by advisors and/or contractors
There are not enough show cases


The greatest resistance to BIM at the moment, as I see it, is:
100 %
80 %
60 %
40 %
20 %
0 %
Not applicable
Don't know
Strongly disagr
Disagree
Agree
Strongly agree
Not needed at the moment
Adds expense
Difficult to implement
Building Industry is not geared towards it
Lethargy
Clients do not want it
Clients want it but are heavily resisted by advisors and/or contractors
There are not enough show cases



Building Information Modelling - An Educational Survey

Exit this survey

9. Five years time, when you are in the construction industry

9 / 11 82%

Maybe your opinions are the same as now and in the foreseeable future but for statistical purposes please indulge me anyway

1. The greatest resistance to BIM in five years, as I see it, is:

	Strongly agree	Agree	Not applicable	Disagree	Strongly disagree	Don't know
Not needed at the moment						
Adds expense						
Difficult to implement						
Building Industry is not geared towards it						
Lethargy						
Clients do not want it						
Clients want it but are heavily resisted by advisors and/or contractors						
There are not enough show cases						

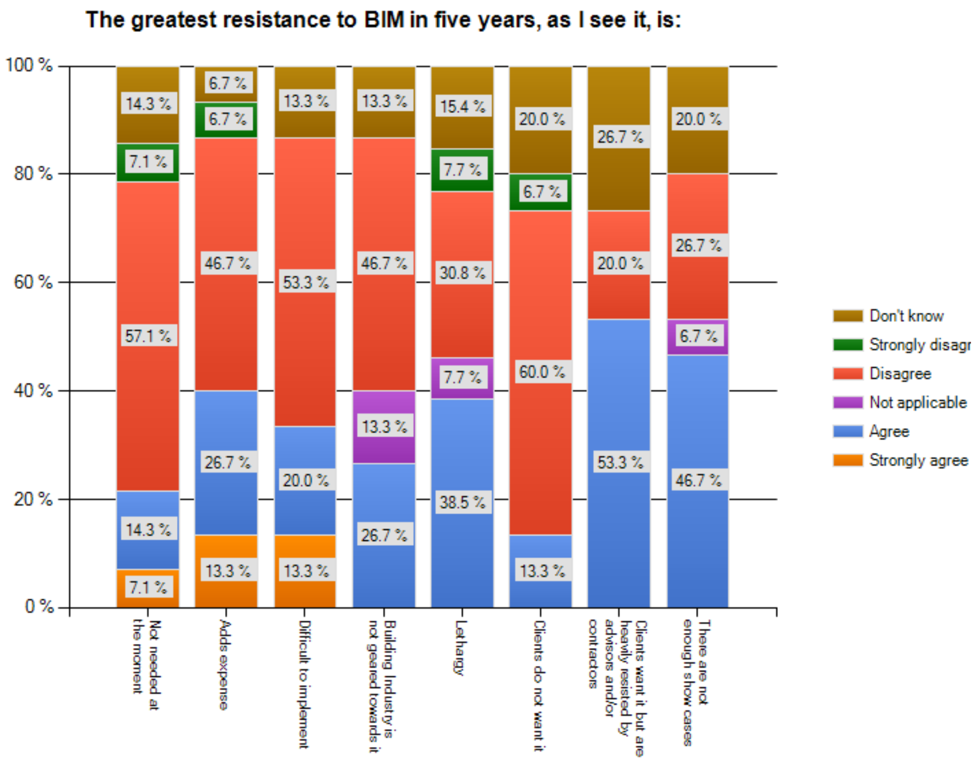
Other (please specify)

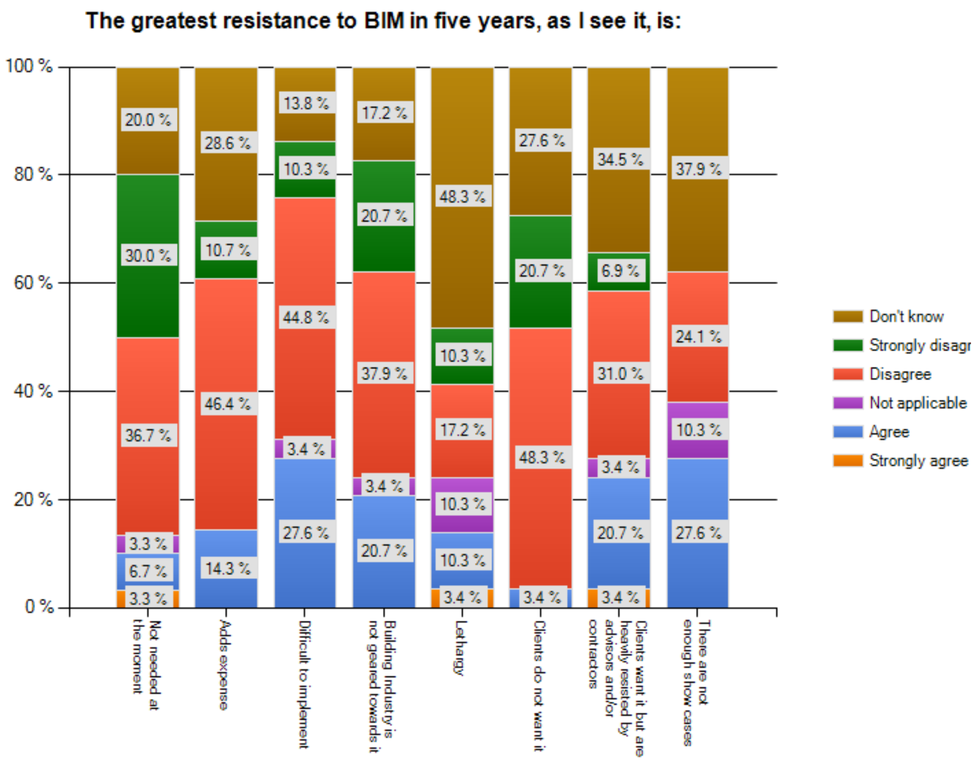
Prev Next

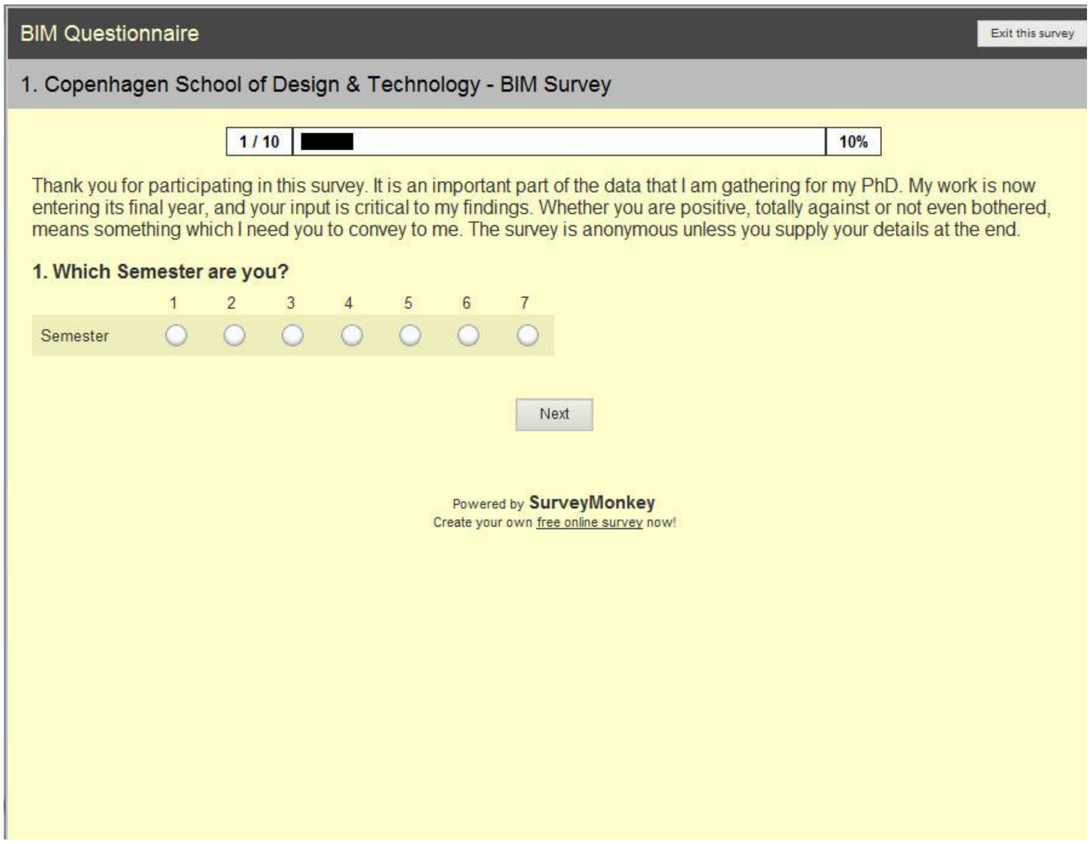
Notes:

In five years the critical line between agree and disagree is the scarlet and cyan colours and again KEA is more positive.

Table 18 'The greatest resistance to BIM in 5 years is...'


The greatest resistance to BIM in five years, as I see it, is:
100 %
80 %
60 %
40 %
20 %
0 %
14.3 %
7.1 %
57.1 %
14.3 %
7.1 %
6.7 %
6.7 %
46.7 %
26.7 %
13.3 %
13.3 %
53.3 %
20.0 %
13.3 %
13.3 %
46.7 %
13.3 %
26.7 %
15.4 %
7.7 %
30.8 %
7.7 %
38.5 %
20.0 %
6.7 %
60.0 %
13.3 %
26.7 %
20.0 %
53.3 %
20.0 %
26.7 %
6.7 %
46.7 %
Don't know
Strongly disagr
Disagree
Not applicable
Agree
Strongly agree
Not needed at the moment
Adds expense
Difficult to implement
Building Industry is not geared towards it
Lethargy
Clients do not want it
Clients want it but are heavily resisted by advisors and/or contractors
There are not enough show cases


The greatest resistance to BIM in five years, as I see it, is:
100 %
80 %
60 %
40 %
20 %
0 %
20.0 %
30.0 %
36.7 %
3.3 %
6.7 %
3.3 %
28.6 %
10.7 %
46.4 %
14.3 %
13.8 %
10.3 %
44.8 %
3.4 %
27.6 %
17.2 %
20.7 %
37.9 %
3.4 %
20.7 %
48.3 %
10.3 %
17.2 %
10.3 %
10.3 %
3.4 %
27.6 %
20.7 %
48.3 %
3.4 %
34.5 %
6.9 %
31.0 %
3.4 %
20.7 %
3.4 %
37.9 %
24.1 %
10.3 %
27.6 %
Don't know
Strongly disagr
Disagree
Not applicable
Agree
Strongly agree
Not needed at the moment
Adds expense
Difficult to implement
Building Industry is not geared towards it
Lethargy
Clients do not want it
Clients want it but are heavily resisted by advisors and/or contractors
There are not enough show cases



Questionnaire II

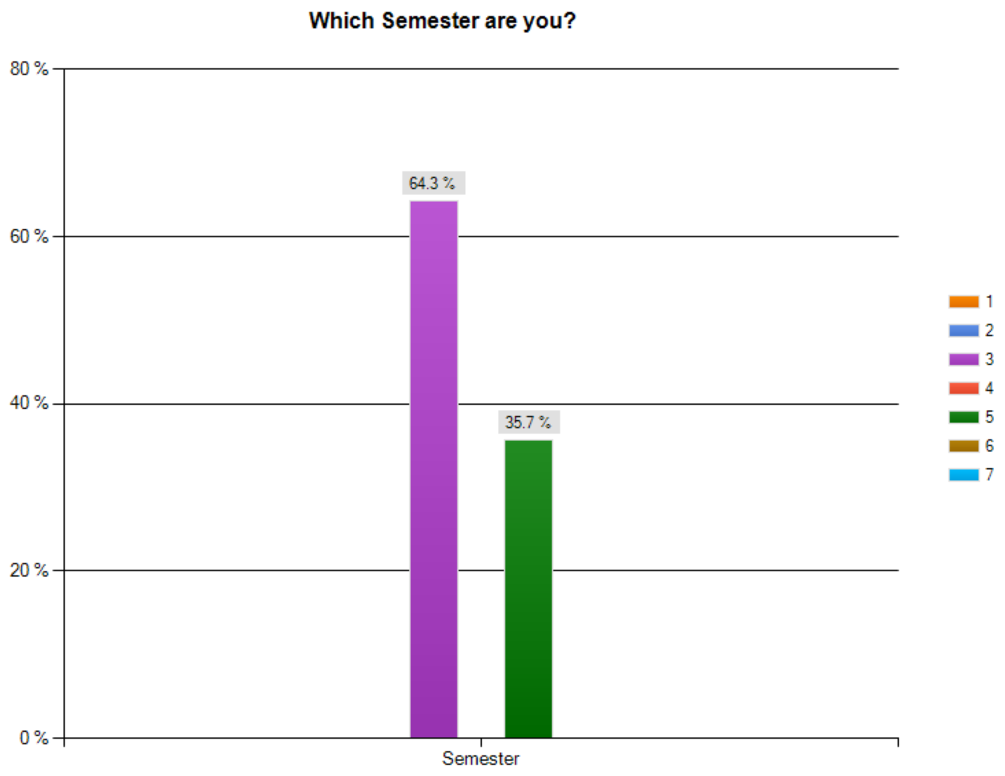
This second Questionnaire took place before Christmas 2008, and was a pilot, precursor, to the first survey. At this time second semester had just been introduced to Revit (they started the semester with a three week introduction course to Revit), followed up with a complete semester project, authored in Revit. This meant it was a good time to collect their responses and hear how they had interacted with the (then) new technology.

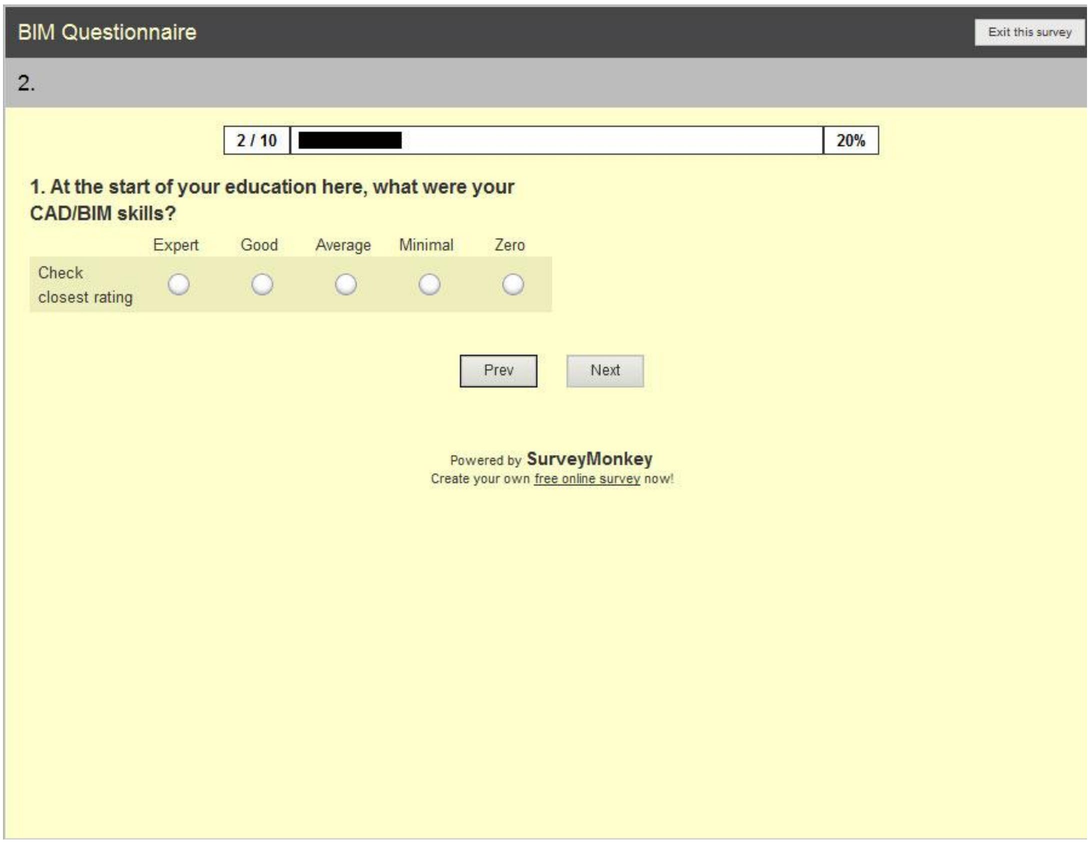
Fifth semester, had agreed to take this survey, if they received tuition in new features in Revit, in order to complete an onerous task, complete an existing building survey digitally. It involved to parallel classes, where two complementary but finally totally opposite solutions emerged.

The survey does not capture this divide, as it was not known beforehand, but in brief one class decided, or more correctly, identified the issue as being, how all elements could be described best for export to Sigma. The other class chose to faithfully capture the existing building before making new work. One method seemed tactical, the other more honest. It was a creditable exercise in capturing an existing building and marking it a existing in the model. The phases then allowed for demolition work and new constructions so that each phase could be presented.

The outcomes were both commendable, largely because both achieved good results. What this demonstrated was a maturity in modelling, and this shows in the results. There were 56 respondents.

Table 19 'Which semester are you?'

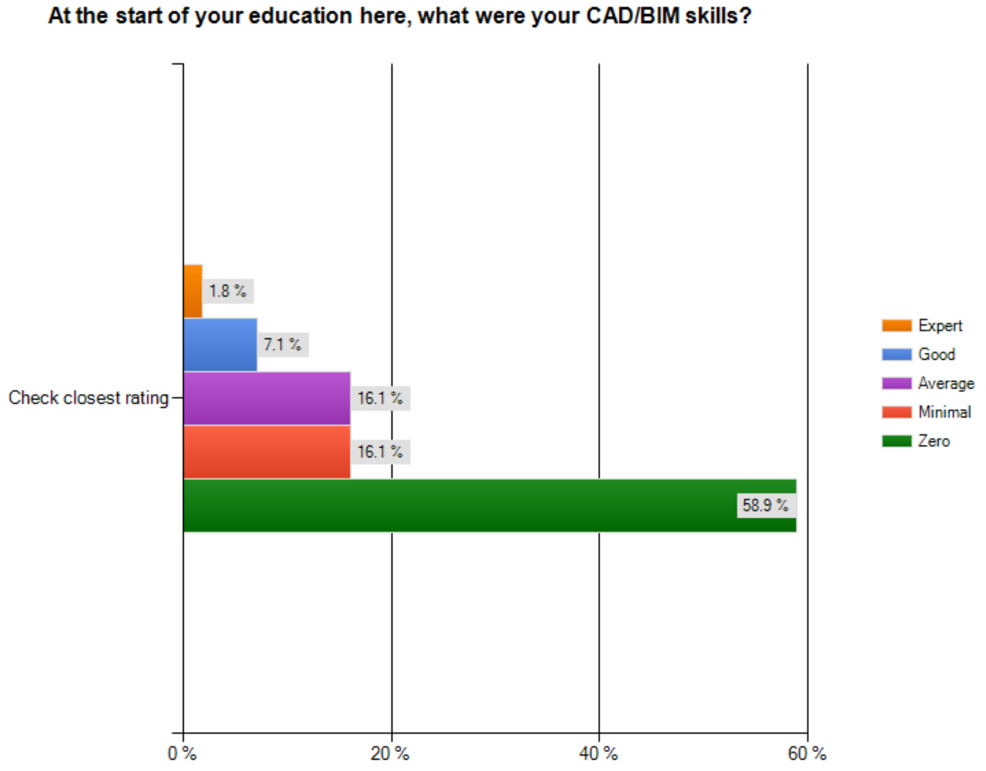

Which Semester are you?
80 %
60 %
40 %
20 %
0 %
64.3 %
35.7 %
Semester
1
2
3
4
5
6
7

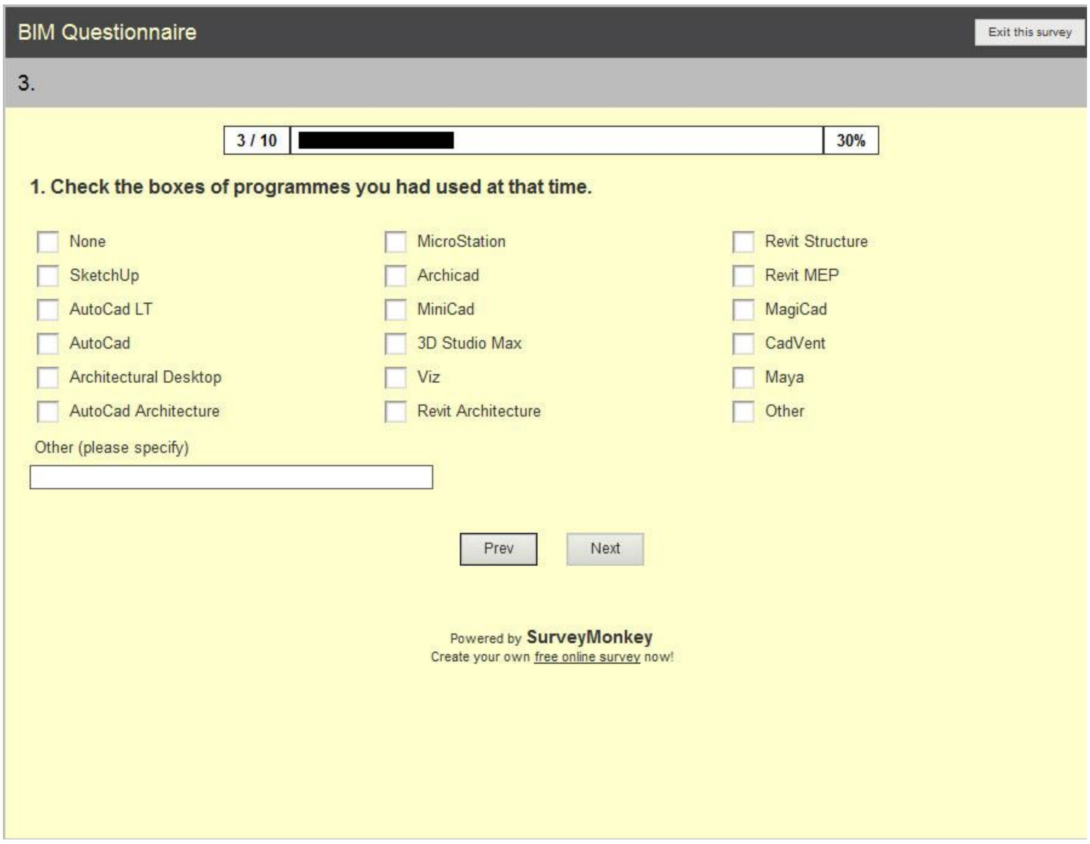


Notes:

Surprizingly, nearly 60% had no CAD/BIM skills at the start of the education,while less than 2% rated their skills as expert.

Table 20 'At the start of your education here, what were your CAD/BIM skills?'


At the start of your education here, what were your CAD/BIM skills?
Check closest rating
1.8 %
7.1 %
16.1 %
16.1 %
58.9 %
0 %
20 %
40 %
60 %
Expert
Good
Average
Minimal
Zero



BIM Questionnaire — Exit this survey

3.

3 / 10 — 30%

1. Check the boxes of programmes you had used at that time.

- [ ] None
- [ ] SketchUp
- [ ] AutoCad LT
- [ ] AutoCad
- [ ] Architectural Desktop
- [ ] AutoCad Architecture
- [ ] MicroStation
- [ ] Archicad
- [ ] MiniCad
- [ ] 3D Studio Max
- [ ] Viz
- [ ] Revit Architecture
- [ ] Revit Structure
- [ ] Revit MEP
- [ ] MagiCad
- [ ] CadVent
- [ ] Maya
- [ ] Other

Other (please specify)

Prev | Next

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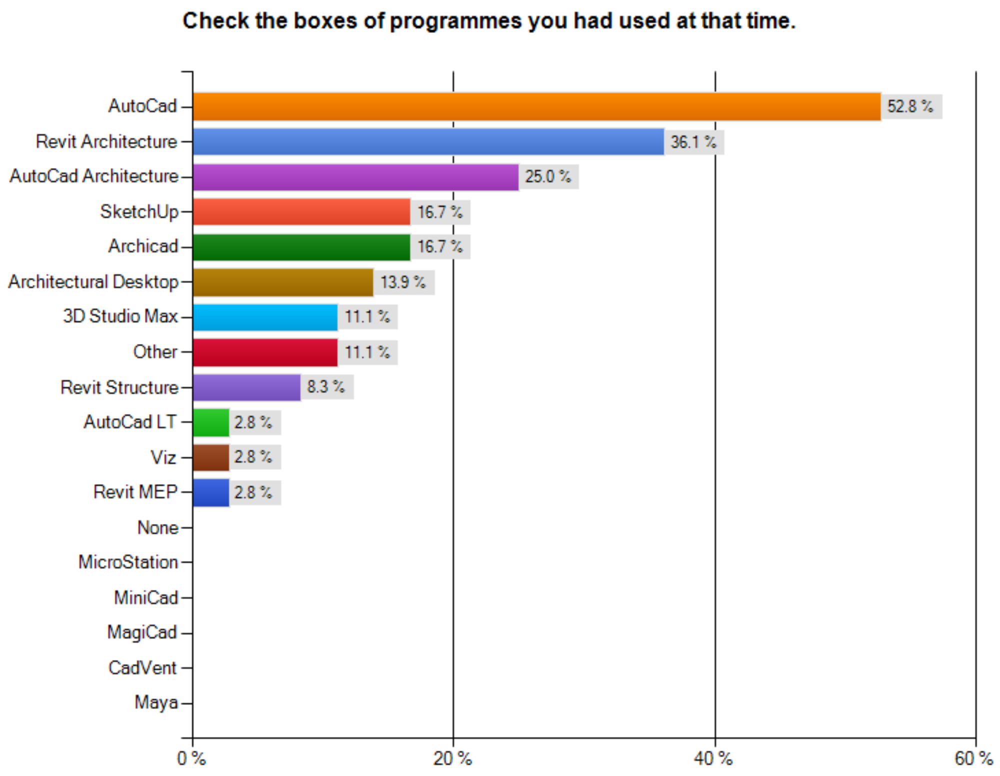
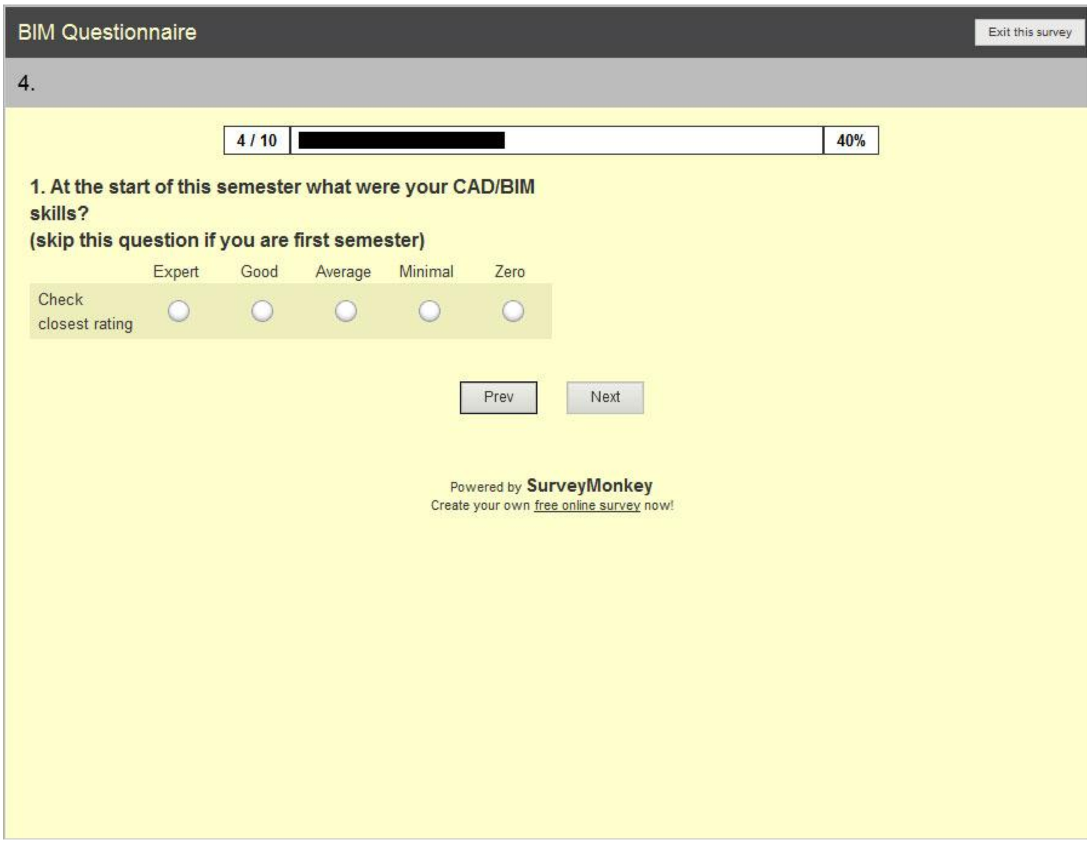
Notes:
Under 'Other' the following were added:
Solid Works
Artlantis, Corel draw, TurboCAD
Artlantis, Corel draw
Photoshop, Dreamweaver
MS Paint
Table 21 'Check the boxes of programmes you had used at this time'

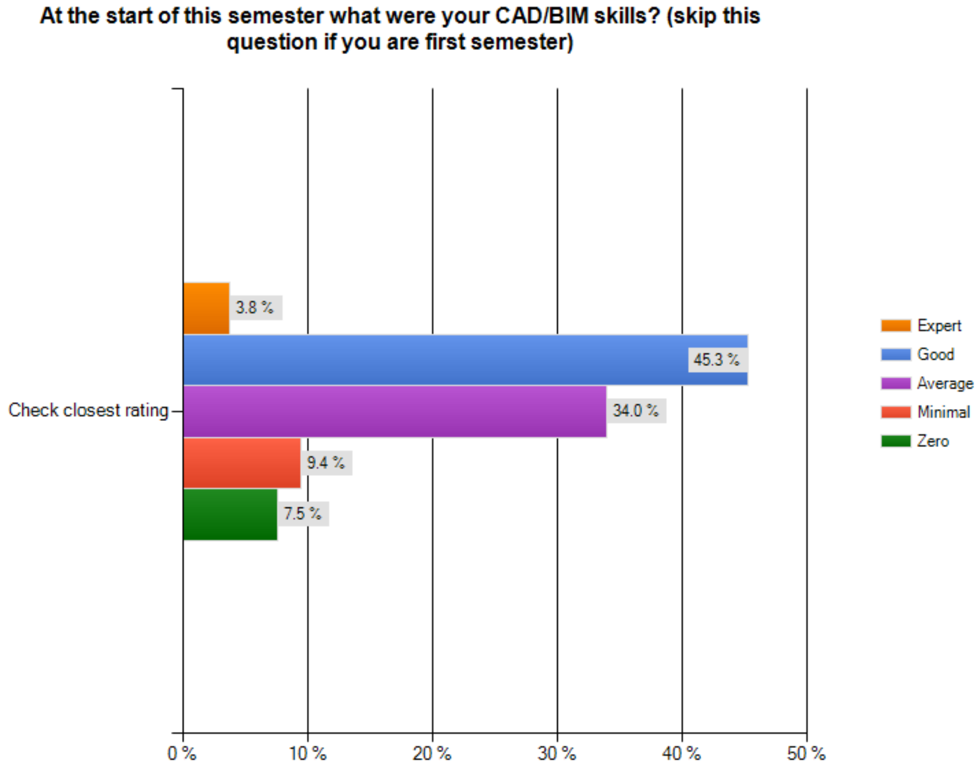

Check the boxes of programmes you had used at that time.
AutoCad
Revit Architecture
AutoCad Architecture
SketchUp
Archicad
Architectural Desktop
3D Studio Max
Other
Revit Structure
AutoCad LT
Viz
Revit MEP
None
MicroStation
MiniCad
MagiCad
CadVent
Maya
52.8 %
36.1 %
25.0 %
16.7 %
16.7 %
13.9 %
11.1 %
11.1 %
8.3 %
2.8 %
2.8 %
2.8 %
0 %
20 %
40 %
60 %

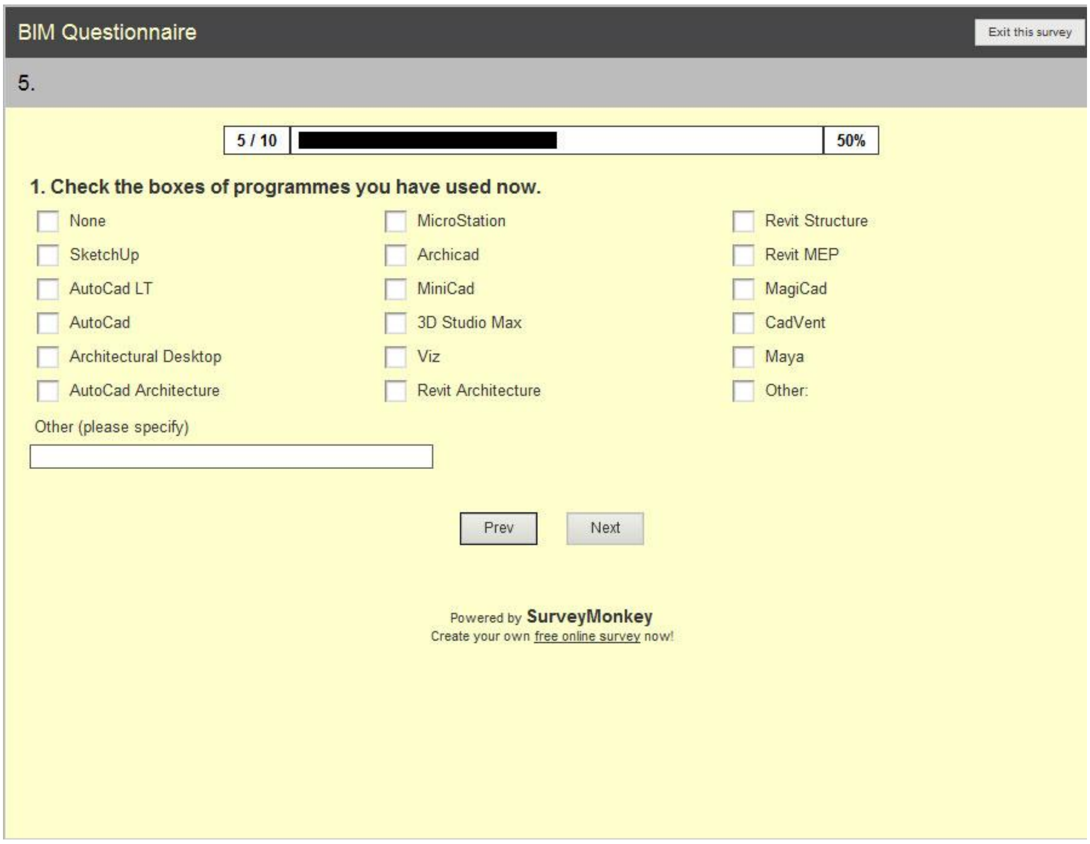


Notes:

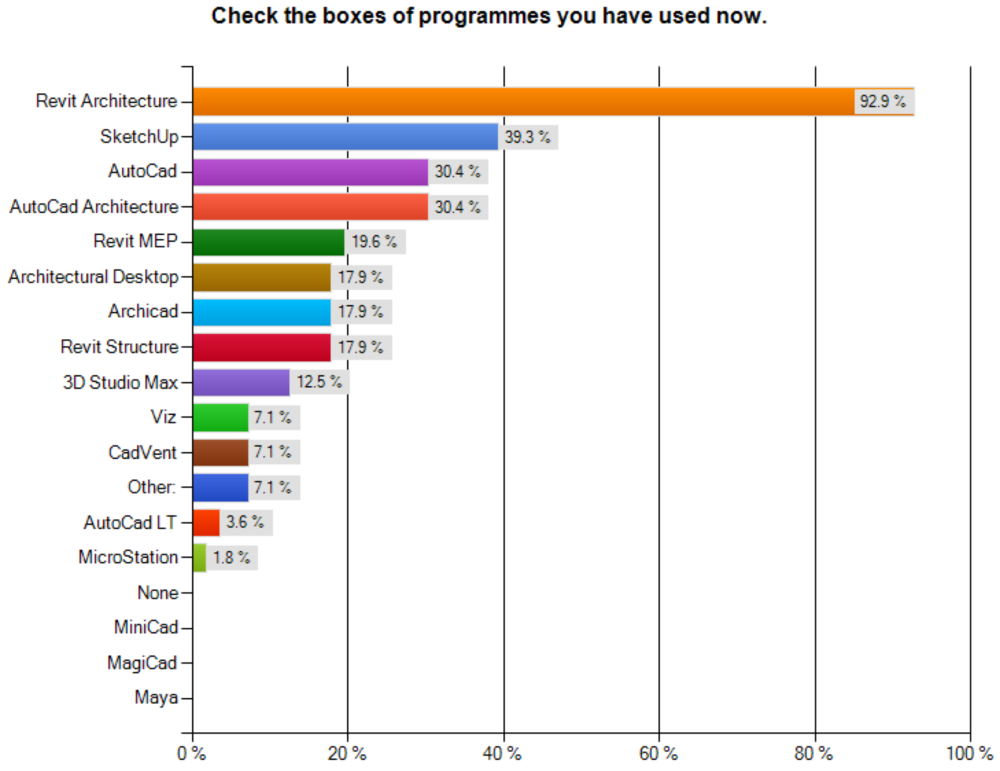
A basis question to build the students' profile and following up on the previous question of their situation at the start of the education. Good and average have grown considerably and zero still has some currency.

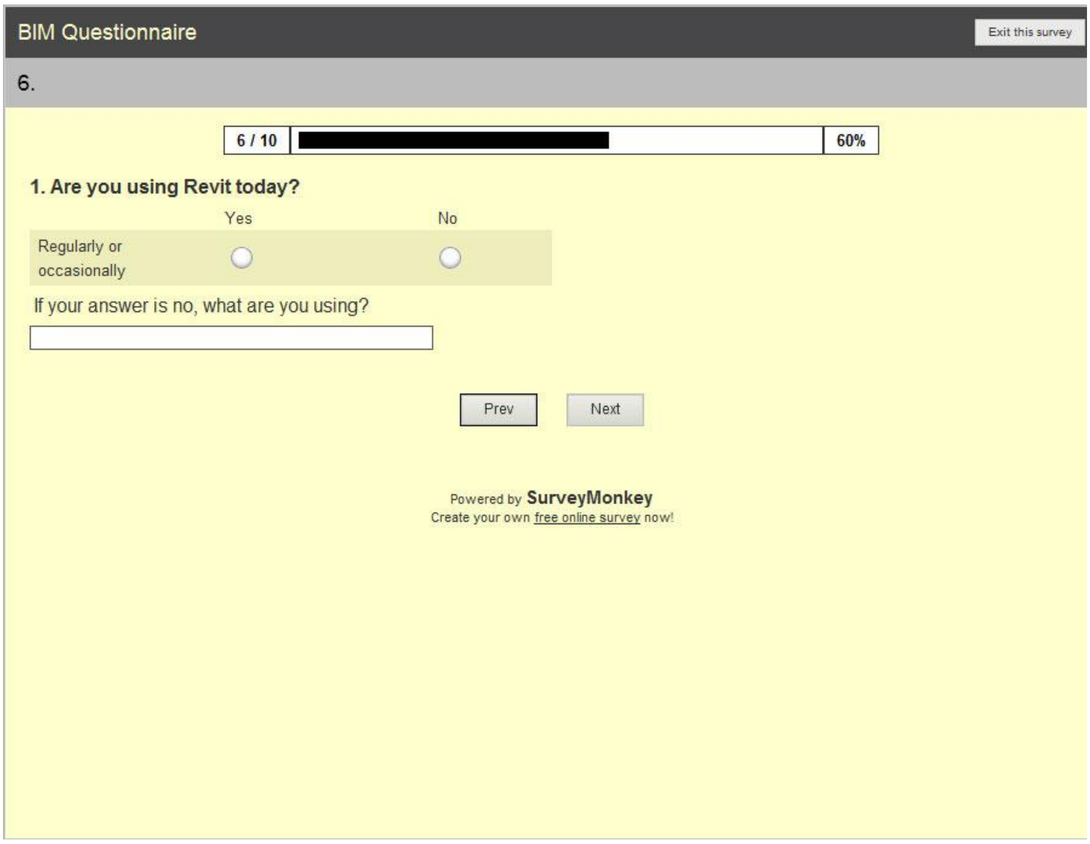
Table 22 'At the start of the semester what were your CAD/BIM skill?'


At the start of this semester what were your CAD/BIM skills? (skip this question if you are first semester)
Check closest rating
3.8 %
45.3 %
34.0 %
9.4 %
7.5 %
0 %
10 %
20 %
30 %
40 %
50 %
Expert
Good
Average
Minimal
Zero



Notes:
Another basis question to see compare their experience was in other programmes.
Under 'Other' the following was noted:
Photoshop
Corel Draw
Corel Draw
Adobe Illustrator, In-design, Photoshop
Table 23 'Check the programmes you have used now'

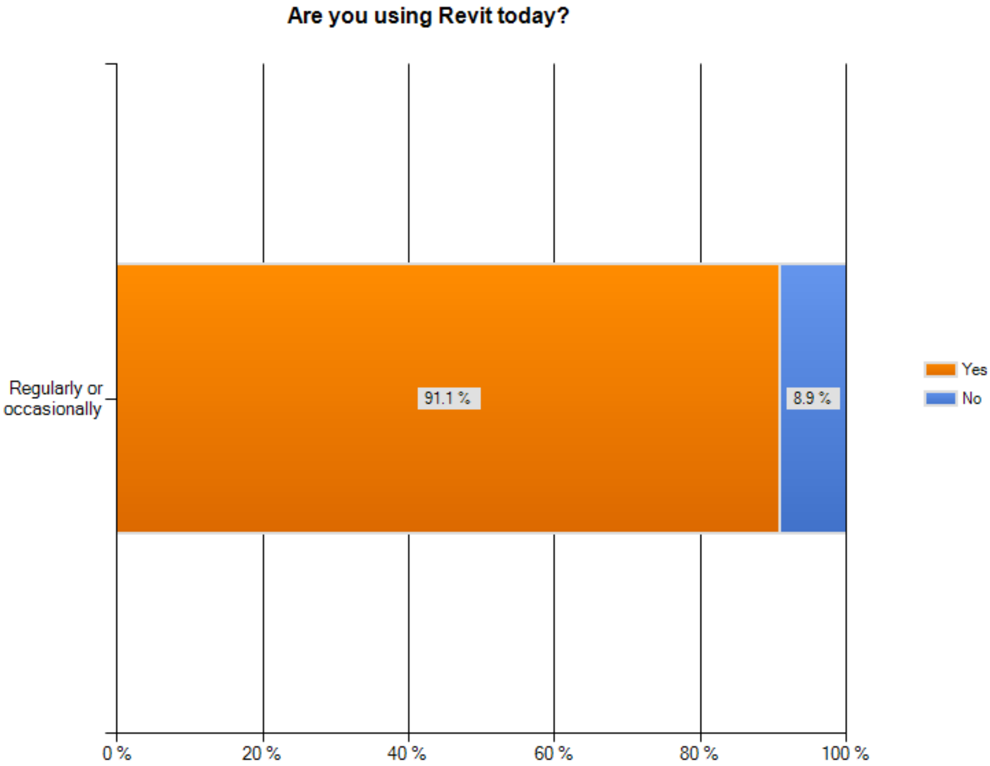

Check the boxes of programmes you have used now.
Revit Architecture
SketchUp
AutoCad
AutoCad Architecture
Revit MEP
Architectural Desktop
Archicad
Revit Structure
3D Studio Max
Viz
CadVent
Other:
AutoCad LT
MicroStation
None
MiniCad
MagiCad
Maya
92.9 %
39.3 %
30.4 %
30.4 %
19.6 %
17.9 %
17.9 %
17.9 %
12.5 %
7.1 %
7.1 %
7.1 %
3.6 %
1.8 %
0 %
20 %
40 %
60 %
80 %
100 %

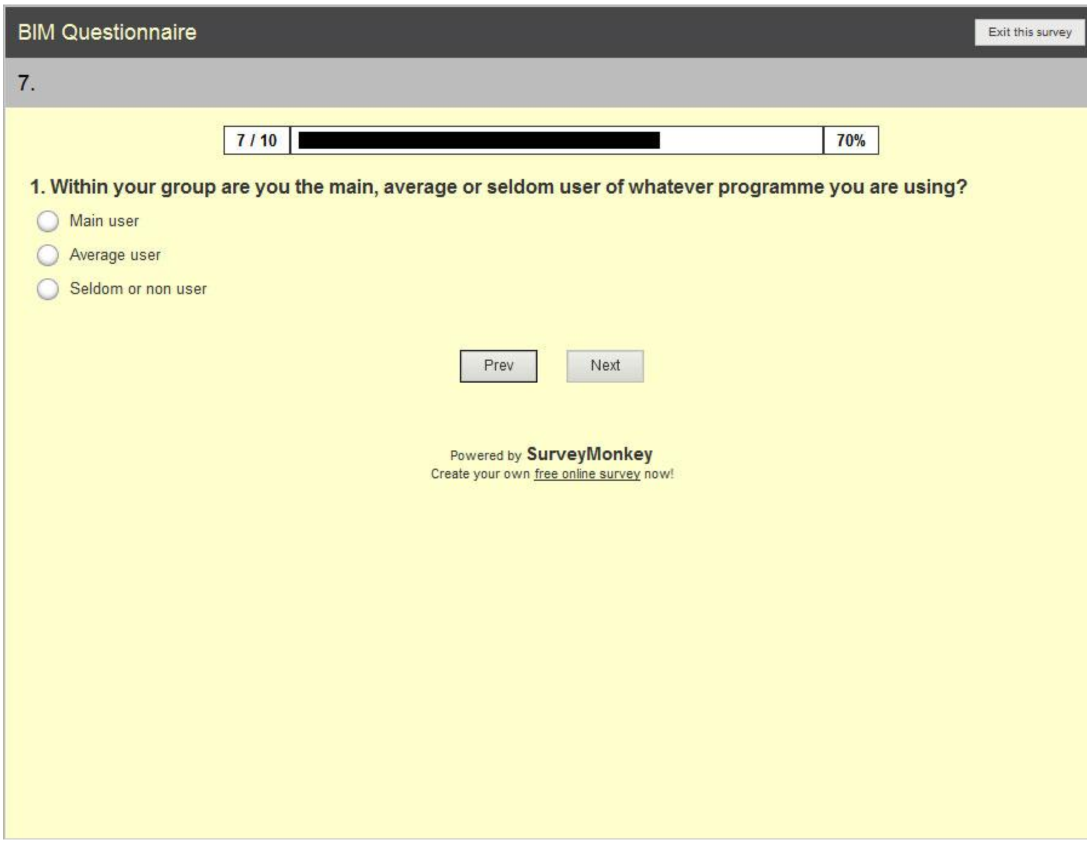


Notes:

Most were using Revit, the 8.9% using other programmes were Polish exchange students, in 5th semester who were using Archicad. They were allowed to do this, as a pilot, to gauge differences.

Table 24 'Are you using Revit, today?'

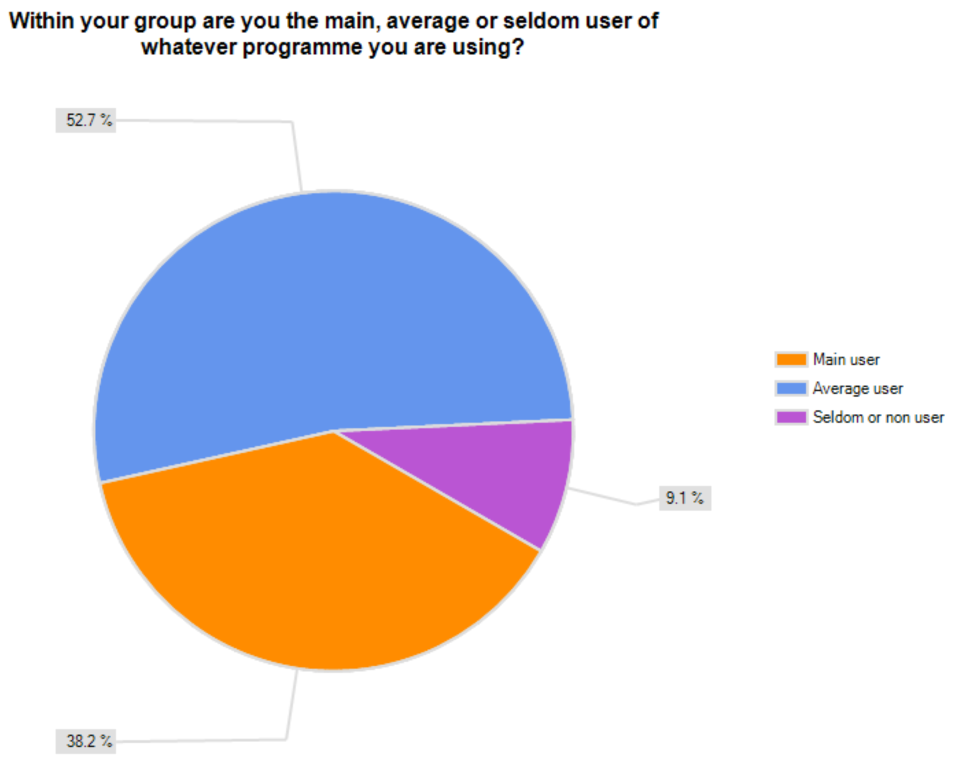

Are you using Revit today?
Regularly or occasionally
91.1 %
8.9 %
Yes
No
0 %
20 %
40 %
60 %
80 %
100 %

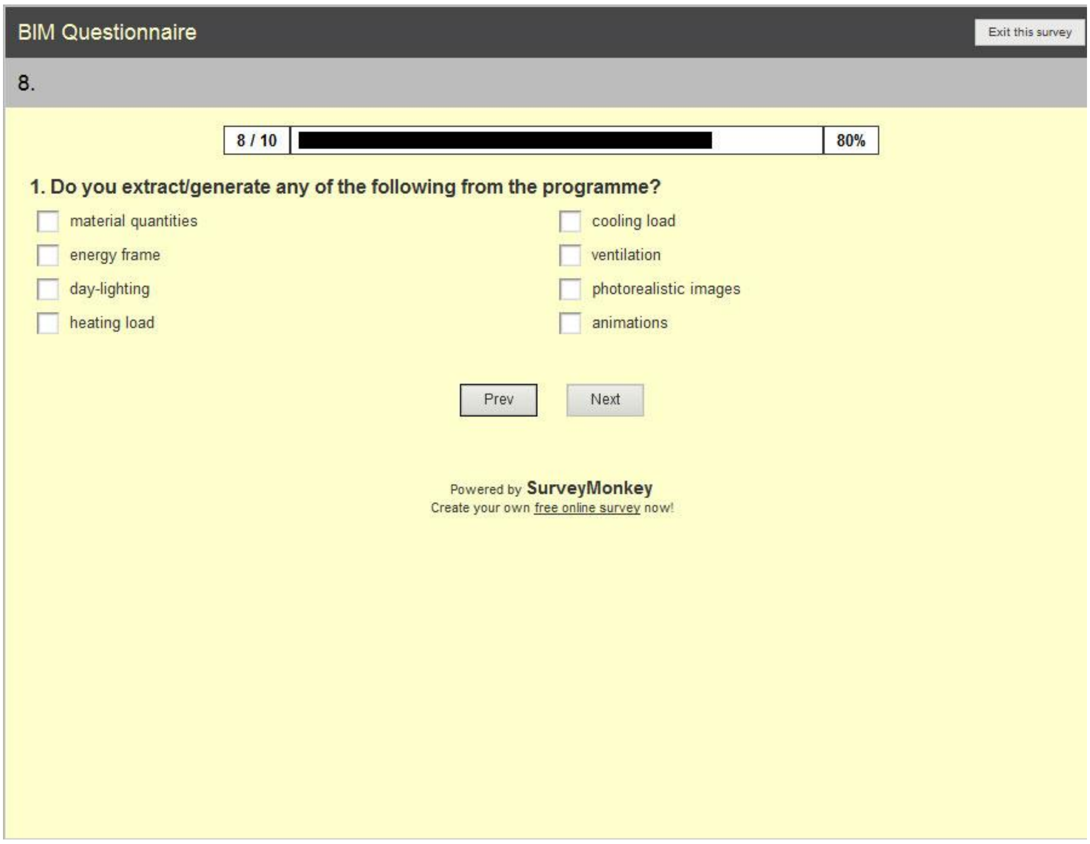


Notes:

This is one of the first questions to examine the roles being played within groups. Over 50% were average users with under 10% being seldom users and the rest main users. This can be explained by noting the work that is done to procure a project. There is much documentation and that is not related to Revit, including the companiies busness plan, letters to the client, municipality and suppliers and some of the tasks can be perfoormed outside the model in traditional methods, including costing, project planning and schedualing.

Table 25 'Within your group are you the main, average or seldom user of whatever programmes you are using?'


Within your group are you the main, average or seldom user of whatever programme you are using?
52.7 %
9.1 %
38.2 %
Main user
Average user
Seldom or non user

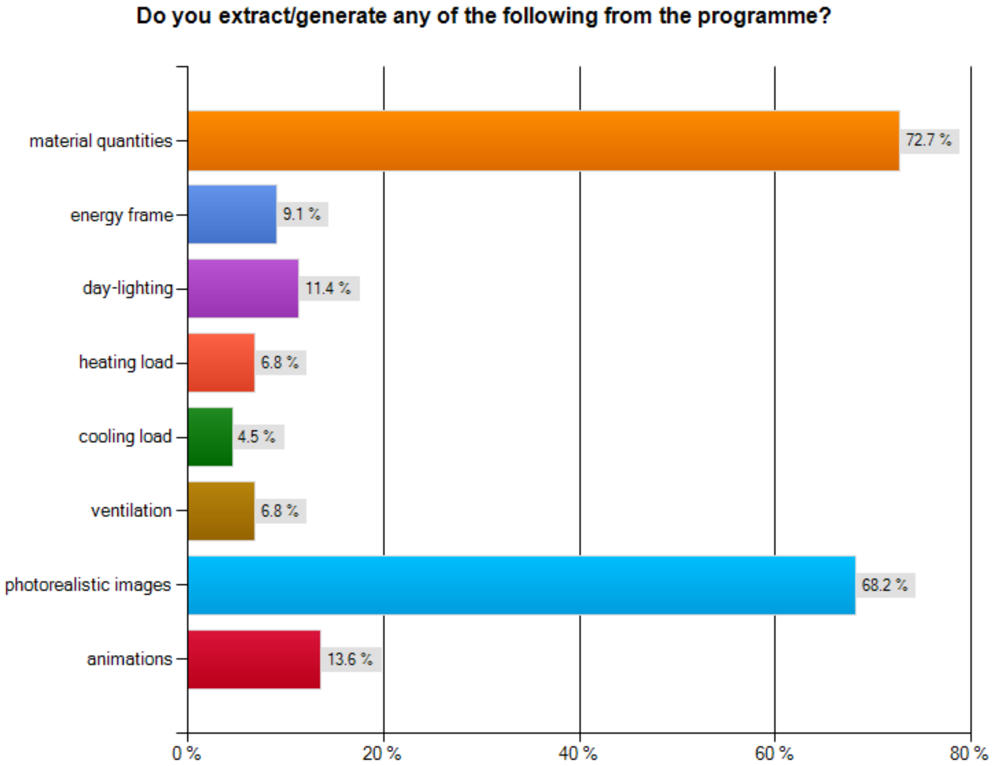


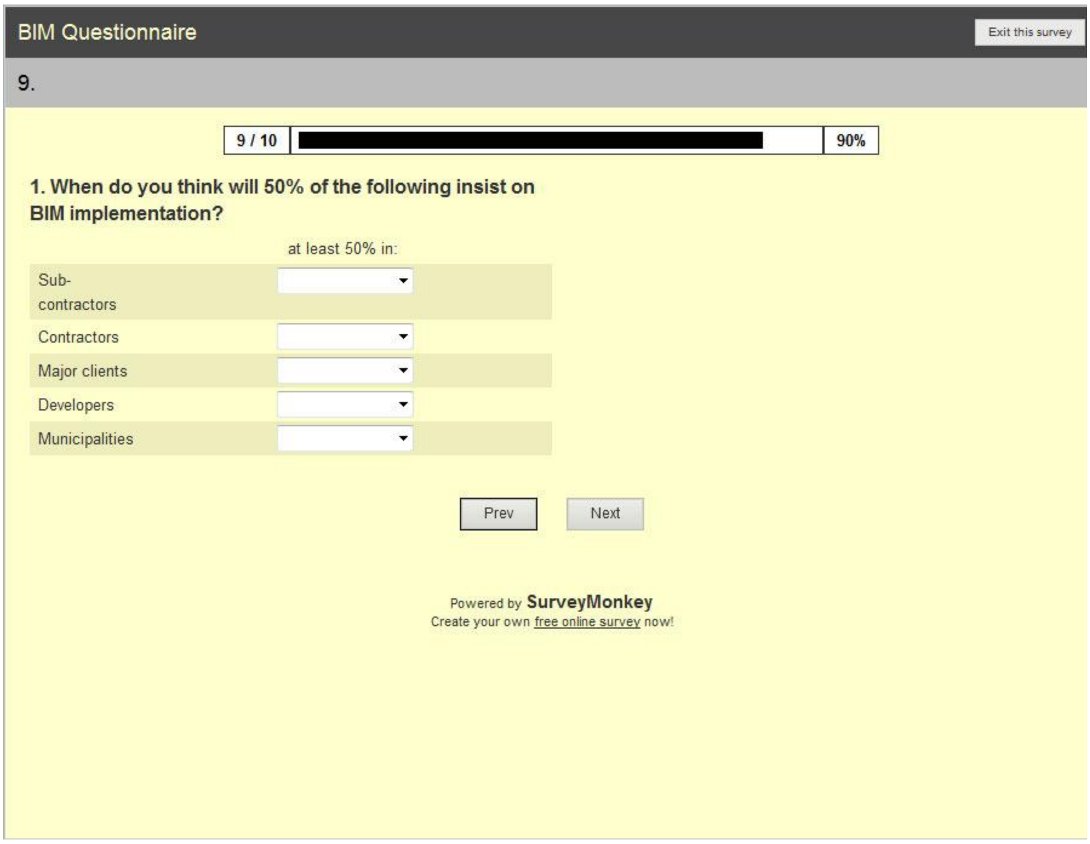
Notes:

At this time at the school, the greatest analysis of the model was the extraction of quantities through Sigma. This allowed linking to a price book for priced Bills of Quantities.

The rendering capabilities came from nowhere. There had not been any instruction in rendering, the students found it out themselves, showing the communicative qualities of the model.

Table 26 'Do you extract any of the following from the programme?'


Do you extract/generate any of the following from the programme?
material quantities
energy frame
day-lighting
heating load
cooling load
ventilation
photorealistic images
animations
72.7 %
9.1 %
11.4 %
6.8 %
4.5 %
6.8 %
68.2 %
13.6 %
0 %
20 %
40 %
60 %
80 %



Notes:

Ironically, in 2008, contractors and sub-contractors were not on the horizon, an interesting point.

Otherwise developers were seen as instigators along with clients to a lesser degree while municipalities were tolerated.

Table 27 'When do you think will 50% of the following insist on BIM implementation?'

BIM Questionnaire

When do you think will 50% of the following insist on BIM implementation?					
at least 50% in:					
Answer Options	5 years or less	10 years	15 years	Don't know	Response Count
Sub-contractors	0	0	0	0	0
Contractors	0	0	0	0	0
Major clients	32	7	2	13	54
Developers	35	3	3	10	51
Municipalities	17	15	2	17	51
					Question Totals
				answered question	55
				skipped question	1

9.3 Summary

Generally, the focus of the survey at the beginning of the semester opened up lines of communication, which in turn generated a healthy debate, in both how to grapple with the physical building survey and how to divide the job up into meaningful segments. It allowed those who were new to the set-up, a soapbox to vent their issues and it allowed the drivers in the classes to adopt leadership roles to get the job done properly.

It was agreed collectively that the building survey would be done collectively and shared to each group. A twenty-point checklist used in Denmark for surveying became a loose control for assigning the tasks to be completed and typically, these would include external wall, stairs, roofs basements, plumbing etc... where each group took responsibility for their own part.

At this time, no mechanism was in place (it was to come later) for grading the quality of the collective work and in some cases there was much peer pressure to step up to the plate and deliver. This was a very interesting phase, in that it showed the drivers in the class in good light. But as said two versions ultimately saw the light of day in the first class everything was recorded in accordance with Sigma (using the Danish price books so that the work would have a relevance and logic later and the other where the building was faithfully recorded, meaning the groups had to implement a handling plan afterwards.

Shortcomings in Revit also flourished, notably that when a window is demolished in the existing wall, Revit replaces the opening with a wall again. This is incorrect and the work around meant having to place both a window and an opening in the existing wall so that the opening was maintained after removal. It could then host a new window or have the opening bricked up and correctly costed.

Secondly, and similarly, a wall could not host new work attached to it. By this, think of how to add more insulation to an existing wall. The entity could not decide if it was new or old wall. The solution was to make two parallel walls and get windows and doors to penetrate both. This annoyed the purists in the class.

These kinds of problems really tested the resolve of both classes and for some the inaccuracies of the existing structure needed to be brought into the modelled building. The cracking and bellying of the existing wall was therefore not recorded, but rather only noted. But the roof was well surveyed because it was essentially made up of elements, which could be sized and placed without the hosting issues of Revit.

10. Discussion of Key Findings

10.1 Introduction

In summary, over and beyond the last six years there have been tremendous developments in BIM and more importantly IPD (Strong 2005). The significance here is the impact a technology can have on process, and intrinsically by extension on a cultural mindset.

Initially, it looked as if it would be architects who would lead the way forward, with the America Institute of Architects (AIA) calling for radical change and implementing methods and protocols for doing so (Jonassen 2006). This was to be welcomed but it has not been adopted in the watershed scenario that was envisaged. The reasons for this are many and varied. We have seen that traditionally the architect led the design team and how through their inability to keep projects on time and to budget, that contractors have gained a foothold in the process. This can be seen in new forms of procurement from Design & Build right through to IPD. Furthermore, their intransience to collaborate in contractual areas like ConsensusDOCS clearly shows a power struggle.

Next with BuildingSMART it appeared that Code Checking would lead the assault (Conover 2008 a, b, c) but to date it has only been implemented in Singapore with on-going trials in Norway. Tests are showing that government legislation, local planning controls and building regulations can be assessed in twenty minutes for specific types of permission and approval rather than the typical three-month turnaround (Rooth 2010a). The only variable not included is the political lobbying and bargaining that can go on in mitigation circumstances. However, planners appear unprepared to consign large municipal planning departments to the wayside.

We saw that the RTPI is currently very reticent in its awareness of BIM. The silence is deafening, as the attraction of such a driver is unmistakable, meaning that the non-adoption must be due to either official ambivalence or planning bodies' self-preservation instincts (Maury 2010). Clearly, this is a political or municipal decision that latently has been successful in lobbying against adoption. Just compare the acceptance of change in the sustainable or carbon lobby and the gulf can be appreciated (see below).

Client demand followed next with the carrot of certainty driving the show (Fong 2007). Once a client has seen how these new methods can bring projects on time and to budget, word of mouth ensures widespread adoption. As more case studies and best practices are aired, more clients will sign up for improved certainty. This is and will have an enduring impact how we procure buildings from now on.

This is being addressed somewhat and will continue to penetrate procurement methods, typically where government portfolios are involved. We saw that Paul Morrell, the UK government's Chief Construction Advisor, wants more accountability from projects while clearly saying that BIM will be implemented.

Software vendors have also been slow to implement across the board standards like Industry Foundation Classes (IFC's) and to adopt or offer better standardisation to users, which would reduce the implementation threshold that discourages acceptance (Pazlar and Turk 2008). The lack of standards also works on another level where not having compliant work necessitates vigilant translation processes with undependable outcomes (Smith 2010). It is also appearing that the lack of open standards clashes against a robust plateau, where confidence could be nurtured and developed (Smyth and Pryke 2008).

Sustainability is being pushed globally and by national legislatures meaning it is being implemented across the board in the developed world and this will ensure its uptake. Following the current recession, those firms who can document sustainable solutions will gain a clear advantage over more traditional operators (Smith 2010). With energy costs increasing and resources being finite, global warming has forced policy makers to implement targets and roll out deadlines to save the planet (Andersen 2009). Having a virtual model allows performance analysis and climatic testing before deployment. Having quantifiable data from a direct analysis tool gets results (Hardin 2009).

As certainty came to the fore, the merits of such a process became more apparent. Showcase projects were on time and to budget, which was virtually unheard of under traditional methods of procurement. Client demands therefore should be driving the implementation of modelling (Fong 2007). This should be the mainstay of adoption but word has not been as widespread as hoped, with contracts in this current recession occasionally reverting to traditional design-bid-build procedures (Erkessousi 2010, Bandurevskaja 2010).

Buoyed by clients identifying certainty as a driver that has influenced digitalisation, a late comer has been contractors and more importantly sub-contractors who now can see that a virtual model allows for better control regarding both collisions and time planning in the procurement process. This has gone as far as the Association of General Contractors (AGC) in the USA recommending that its members build a model before bidding if a model is not part of the tender documentation. This is having a much bigger impact than first thought (Young, Jones and Bernstein 2008).

A follow on from the above is augmented reality where data can be superimposed on situations to give better information in both time and place (Braun 2010). As Global Positioning Systems (GPS) improve in their accuracy the virtual model can be superimposed on the reality, meaning new projects can be assimilated on site before execution and ongoing work can be checked for delays and/or improvements. A deepening of this ability to capture reality can be seen in new technologies such as Autodesk's Vasari, which allows early testing of designs against climatic data including wind, solar and shading. This can be done at a micro level to better inform design decisions. Another programme, Autodesk's Project Photofly, allows a digital camera to create 3D models from photographs using the web. It can use cloud computing to translate photos into detailed 3D models.

A second corollary to this is that soon Bots (a form of virtual robot) can work like search engines to compile and filter product data for different building elements and components seamlessly in the background to tailored requirements (Obonyo 2010). For a designer this can be generic or it can initiate prime cost sums. For the contractor this can compile all products that meet the performance criteria so that when the product needs to be identified a qualified list exists to aid procurement. The potential latency of this is great. It engages push-pull technologies to better inform decisions again, and this must be warmly embraced.

Similarly, to sustainability, Life Cycle Assessment (LCA) is and will have a very significant part in the procurement of buildings (Sørensen, 2010). Even more so, when the initial planning and post operations and maintenance issues are added. Suffice to say that best practice currently has three models running concurrently, one for the strategic policy makers or investors, one for the procurers or supply chain, and finally one for the maintenance people and users who pick up the pieces after practical completion. This is not optimal or efficient, because repeated input of data increases the likelihood or error, and encourages a knowledge drop at each point of the saw tooth knowledge acquisition diagram.

Methods of integrating these diverse methods will improve how we make buildings and how we use them too. Facilities Management (FM) has a critical role to play here and methods of facilitating designers without alienating them will consume many resources before an acceptable solution can be found. The driving force will be collaboration and already we are beginning to see consortia being formed where certain players can work purposefully and profitably together to mutual gain (Smyth and Pryke 2006). Latently, the Bots mentioned above will also fuel life cycle assessments, as this too is data that can be mined.

The major obstacle to this is, how trust is nurtured, how new blood can enter the mix and finally how information, competences and knowledge is shared for the benefit of the team, the project and society at large. Initially there were calls for sharing or giving away data for free, but with contractual obligations and recovery of costs there is a great reluctance to do so by the players and those who have invested so much into the project, to see others in the supply chain capitalise handsomely at their endeavours (Williams 2009). We have also seen in the case studies that contractors, who benefit handsomely from the endeavour, do not see ownership as an issue, but rather that it is the model that is important not unlike the baton in a relay race.

How this can be remedied rests with the client and the appointment of all the stakeholders in the project, as well as contractual concerns. First principles say that work effort must be remunerated, and secondly there cannot be subsequent adversarial disputes about the quality and correctness of the data. A designer cannot and should not be shackled into using binding contractual methods of procurement and application during the early concept phases, just as there has to be development in the process by the time production information is at hand. There has to be a *de facto* acceptance of the state of the data at each stage of the procurement and a method of improving or altering data if and when necessary, and there is, it is called a contract (Miller et al. 2008), but it is a new type of contract, citing trust.

Practically speaking this can occur in two places; either within the model using the model phases property (*single model*), or in a viewer programme, which holds the diverse entities (*federated model*) allowing them to be overlapped, collision tested or time-line compared. The *'within-the-model'* option allows objects to co-exist in time and space without displacing each other, while allowing the data to be shared. This is a paradigm shift.

Within the free viewers option (such as Navisworks Freedom, Solibri or Tekla Viewer), many formats can be assimilated into the same federated virtual time and space, allowing many operations to be completed and reported. Integrity and ownership is not challenged but everyone from planner to environmental activist can access the data for whatever reason. Filters and views prepare the data in optimal sets for the users. This means that neighbouring property owners can check building heights and overlooking from their own homes; that sub-contractors can check if there is room to transport their plant up into the cramped roof space; or that project managers can check that in week 37 that the project is up to speed, that a bottle neck is looming or that, God forbid, that they are ahead of schedule.

The benefits of the model are not lost on some flexible entrepreneurs, already there are stakeholders who are entering into mutual agreements to work together and reap the rewards of completion on time and to budget. The biggest issue here is risk and how much or how well you trust your partner. Building trust in a business environment and especially in a fragmented construction market requires new skills and new procedures. Changing work practices from the adversarial to the collaborative requires major changes in mindsets and even social behaviours. There is no 'I' in TEAM, but there is a mangled 'me' lost somewhere within!

10.2 The Challenge of Managing the Technology

The cultural change required to implement integrated practice delivery is an enormous challenge defining *'true partners and collaborators with a mutual interest in a successful outcome*' (Smith and Tardif 2009). Essentially, it alters the way and amount of time consumed in being adversarial and in expecting litigation. Increasingly, contracts are explicitly saying that stakeholders will not sue each other, that future legal action is a no-value task and that trust with verification mechanisms will become standard, as in banking. The principle cause of a bank failure is often a loss of trust rather than insolvency, there is very little difference between a failed bank and a health one, Smith tells us.

How this impacts technology is principally in the transfer of information and the risk it imposes on the authoring party who could be held responsible for the quality, completeness and accuracy of the handed over data. If a *'no-fault'* policy is in place each stakeholder accepts the data as *'found'* and must validate it, appropriately to their needs. Validation consists of two parts, determining if the data is from a trusted source and confirming the integrity of the information itself. Smith calls this stewardship. Where there are errors or omissions methods will have to be effected to compensate the corrector or rectifier instead of identifying the responsible party or assigning blame. The blame-culture stagnates the process and causes delays. There has to be a hand-off of responsible control.

This greater dependence of stakeholders on each other can cause strain within the working relationship if trust is not present and more importantly earned. In order to minimise and in an endeavour to make the process more transparent standards are invariably required. The National Building Information Modeling Standard (NBIMS) of

America has deployed a compendium of principles called a Capability Maturity Model (CMM) to define goals and offer methods of measuring business relationships, enterprise workflow, project delivery methods, staff skill and training and the design process against an index (Smith and Tardif 2009).

This allows for a form of benchmarking and acts as a quality management control for all those involved. It covers the data richness, life cycle views, roles or disciplines, business process, change management, delivery method, timeliness response, graphical information spatial compatibility, information accuracy, and interoperability support. However, it is only a skeleton, which can offer the stakeholders an index to measure or check each other out, and to bolster their own pitch by giving them the tools to build their own argument and set out their own stall.

10.3 The Potential of Partnering the Business

A compendium of principles as an application allows the stakeholders to value themselves, but value is only added to projects through people (Smyth and Pryke 2008). Therefore, the management of relationships becomes very important. The construction industry is accepted as being fragmented, rarely do the same people work together on subsequent jobs and often they do not complete the current job through either disruptions in the work phases themselves or the sheer length of the project which sees them either replaced of decanted to other projects.

Even a team kept together for more than one project will often meet new players as their opposite numbers subsequently. Even if the same companies remain involved, the personnel often change. In addition, the magnitude of small firms involved and the whole culture of sub-contracting out engenders a state of flux and conversely a vested interest in protecting niches and expertise in the market. The corollary to this can be seen where key team members or personnel are explicitly written into contracts so that they are obligatory involved in the project. This arises usually from clients wishes alone.

But positive relationships do add value, improving project performance and client satisfaction. They also as mentioned induce less adversarial behaviour from the top down, and offer procurement led measures for proactive behavioural management throughout the enterprise. Relationship contracting is best seen in partnering and supply chain management.

One of the best examples is Terminal 5 at Heathrow, completed on time and to budget, which is rare for a building of it size and complexity (Haste 2002). T5 nurtured and encouraged such an environment (Ferroussat 2007). It was based on the principles specified in the Constructing the Team (Latham 1994) and Rethinking Construction (Egan 1998). As previously stated, BAA could have ended up opening 2 years late, with 40% cost over runs and six fatalities (Potts 2009).

Conversely, Eurotunnel had difficulties in motivating the suppliers once the contract had been awarded. Winch calls this *'moral hazard'* (Winch 2002) where the client is somewhat unsure that the contractor will fully mobilise its capabilities on the client's behave, rather than its own interests or some other client. The preferred option he calls *'consummate performance'* instead of more likely *'perfunctory performance'*.

The root to this situation can be found in the negotiation of the contract, essentially between banks and contractors. Here two cultures collide, on the one; the banks prefer to move the contractor to a fixed price, which reduces their risk. On the other, the contractor works on the basis that the estimates have to be low, to ensure that the project gets commissioned.

'In banking you bid high and then trim your margin: in contracting you bid low and then get your profits on the variations' or as another said 'the project price... was put together to convince the governments, it was a variable price, a promoter's price. What it was not was a contract price' (Winch 2002).

10.4 The Enlargement of the Scope to include Facilities Management

As if this was not enough to muddy the waters; beyond procurement, lies both appropriateness and life cycle assessment, both of whom impact outcomes. Operational maintenance and on-going developments have an incredible bearing on how things are presented. The lengthening and enlarging of the scope and the focus and merit of the objective, mean that simple decisions taken in good faith can have a detrimental effect on the success of the project.

Typically the appropriateness of the project when handed over should be exactly as the client desires, but often in the hospital branch for example, operational theatres and highly complex pieces of kit have to be torn out and refitted once they are up and functioning because there has been a total lack of communication when they were being designed. Either the personnel consulted fail to appreciate what is being asked of them, or they fail to read the drawings and presented material well enough to understand what is required of them, choosing to put it off until another day. This day, then happens when it becomes operational and is unfit for purpose.

In addition, if we accept that the first 20% of the design decisions affect eighty per cent of the life cycle costs then the bottom line has to be to accept and moderate this situation (Smith and Tardif 2009, Sapp 2010). The International Facilities Management Association (IFMA) defines FM as:

'A profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology'.

They are seen in a secondary function as supporting the core business.

Out of necessity, FM adopts architectural floor plans for viewing the built environment (Rich and Davis 2010). But with the emergence of Geographic Information Systems (GIS) scaling moves far beyond individual buildings and site maps. Traditionally GIS focussed on the exterior environment and neither technologies ever crossed. But Enterprise Resource Planning (ERP) does not have such boundaries, and this introduces the holistic view that is now required (Wikipedia contributors 2010d).

GIS has now matured and is called a foundation technology that seamlessly provides *'world-to-the-widget'* scalability. This means that it can both drill down to very small scale (from the larger geographic scale) while also bringing layering of data into the matrix. On the one hand, it can tell you how many unoccupied offices are within 500 meters of a parking space. Or how many employees will have to travel more than half an hour to get to an office location. At the other extreme, it can map a property by building, floor, room - all the way down to the equipment and its usage in a Building Information Spatial Data Model (BISDM).

'This spatial data is the primary thread that holds together such functions as project, space, maintenance, lease and portfolio management,'

Rich tells us.

In his critique of BIM, he sees the procurement model as being an ever-enlarging file system, rather than a relational database, and that it works in a multi-user/concurrent user environment requiring highly specialised skills to implement and use. This might be true but what he fails to appreciate is that the entities created in BIM have the ability to hold property fields and property values. These properties can be blank (no value) and beyond the scope of the design team or they can be imported and read-in when making critical decisions.

These decisions might not be relevant or comprehensible to the design team directly now, but the Bots, mentioned earlier (Obonyo 2010), might see fit to implement the data in the decision making process for someone else in the enterprise to use or act upon. The requirement of appropriate tools and software is being negated currently by the use of model viewers, which are similar to PDF files, and can be authored or read-only depending on the need (meaning accessible to all).

10.5 The Intertwining and Dependency of Parallel Models

Six years ago, I saw BIM as a technology, another program like Revit, Archicad and Microstation, or merely a piece of software to be learned, implemented and harvested. While in essence this is still true, my focus has changed dramatically where today it is a process, a method of sharing data and a controller of risk and certainty. Initially it was seen by many as a procurement modeller, but now it is becoming the client's financial model, the design team's construction model and the owner's facilities management model, all bound inextricably together into a BIM pipe.

While previously they were three parallel systems, which at best glimpsed at each other across a boardroom table and at worst never fell into enemy hands, now there is a new culture growing, where how we can best use our models, reuse them and finally share them is to the fore. This is being adopted and propagated to deliver projects on time and to budget, which are sustainable and accountably so.

A model is an incredible concept. Whether it is a pair of leggy pins on a catwalk or the ethereal notions of a mad scientist, it is a representation of a perception or a performance, which can be paraded and tested before implementation. Fashion designers use a model to show off their designs, to mould the minds of the consumer to the next season's offerings and to build prestige. Scientists on the other hand use models to limit their scope, to test their findings and to resolve problems. Both have huge validity, whether it is through authorship or analysis.

In construction and architecture, it is the blueprint for the building, the embodiment of the design and the contractual currency for execution. It is the planning; the drawings, the specification, the quantities and the scheduling required to make a building a reality. But it is more. With digitalisation, a whole new world of opportunity has opened.

10.5.1 The Non-geometric Financial Model

The decision to build usually involves a financial institution or at least a financial plan. What is it going to cost, what is the budget and how is it going to be paid all come into the mix. To appraise these issues a notional building is addressed where occupancy, function, location and their impact is assessed on a spread sheet, where the building's form is not part of the equation, at least not until the money is approved. The people making these decisions are usually not spatial or graphical in their prowess and any hint of form is unwelcome and ill-advised.

However, adjacency and interaction can be an important part of this process and this is often represented in a bubble diagram, for want of a better word. Large bubbles represent large spaces and often are accompanied by notional areas or numbers of occupancy, and these can be overlapping or connected by lines.

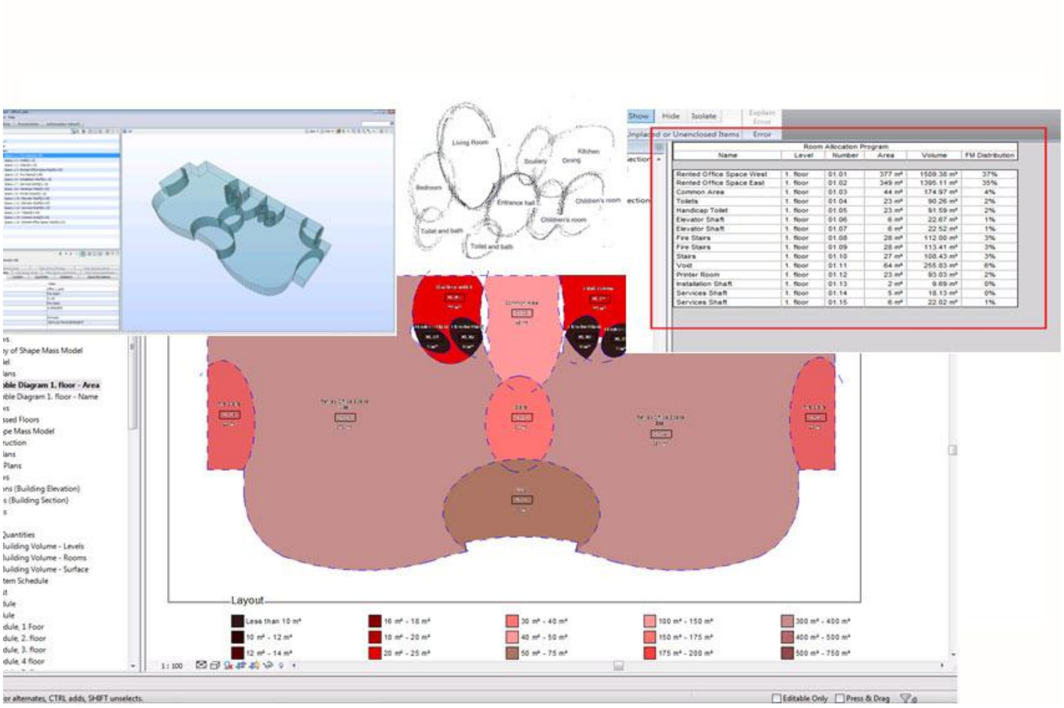


Figure 53 The bubble diagram can be imported into Revit using room seperators as curved lines. These then can be populated with data, extracted as schedules and priced.

As described, this work, (appraisal and brief analysis), lies outside any usable model that can be used for further work. But now it can be done within a modelling program such as Revit which can drive the process right through to procurement. Placing a massing element on the site with the desired height, or placing a parametric volume, which maintains the square metres floor area, room separators can be used to generate circles and ellipses (essentially free forms). This process happens without defining rectangular areas, which can often be misread as definitive spaces so that the abstract nature of the forms can be maintained. Tags are now added, which are as simple as name and size, so that schedules of accommodation can be extraceted. When the correct mix is found, price books can be associated with the data and budgetary figures are determined.

This work is phased within the model as preconstruction work. This means that it can co-exist within the model proper when construction work is subsequently prepared. The benefit of having it here is that specific climatic data can be added to this conceptual form and feedback given, regarding shape, orientation, shading, heat gain, exposure and energy performance. A report can be generated containing all the above data and if several forms are tested, several reports can be generated and cross-referenced in a compare and contrast fashion, giving informed comment.

10.5.2 The Supply Chain Design Procurement Model

Armed with this data the next phase of procurement is better prepared. I know some would say that this is tangential to my design methods or that this cannot, or will not affect my design process, but it can inform it. Designing for large corporate clients often means devouring volumes of standards, branding and methods that the corporation has developed so that a corporate image is presented or that certain prestige is conveyed, which during the Appraisal and Design brief (A & B) can be very time consuming.

As the design progresses the early work is not lost and as each form becomes an entity, the early data is kept and updated and reports can affirm compliance with the initially agreed proposal. For the client this gives a greater amount of certainty to the project, which can be lost in traditional procurement methods. As the project goes through Concept, Design Development and Technical Design (RIBA work stages C, D & E) these can be saved into phases in the model and through filtering of the views in the model, targeted drawings can be formatted to targeted audiences.

Typically, this might mean showing existing, demolition and new proposals tailored to whom the drawings are intended. This means the client gets colour coded legends, the planners code compliant sets of drawings and the contractor location, component and assembly drawings along with the schedules, quantities and specifications, all generated from the model.

Whether the output is paper format (drawings) or filtered sets (views) from the model raises a new situation, the sharing of information. The former (ie paper) is of no interest here as it has caused no end of checking, cross checking, red lining and revisions that eats away the fee and demoralises design teams. But how is the exchange of information handled? Who owns it, who manages it and who is responsible for it regarding errors, omissions and corrections?

If the architect makes a generic wall of 450mm width, does the contractor sue or request further information when it transpires through the designing process that it has to be 520mm consisting of brick, insulation and load bearing reinforced concrete later in the design? Who is responsible for detailing the design, who is being paid for it, or when does it come into the model following the phased work stages?

Architects or those who generally start the project mean their model is a chargeable extra. Contractors or those who take over the project feel it should be free or at no charge as it is part and parcel of the procurement. Initially the call was to give it away as it would come back in spades, but this clearly has not happened.

Under Design and Build or Partnering contracts this is abated by having all involved under the same umbrella, but even here, when the work goes further down the supply chain, vested interests find it very difficult to give away trade secrets or bespoke expertise to erstwhile competitors outside of this contract. So the new benchmark that the construction sector must address is collaboration, with whom and how.

Essential to collaboration is the first line of the contract, that signatories will not sue each other. While sounding innocent this is a major step. Methods have to be found to remunerate work at a fair rate. Competences need to be appraised and rewarded appropriately. Changes and error rectification needs to be awarded to who is best placed to do the work. There has to be an incentive to complete on time and to budget. There has to be mutual respect for all in the supply chain, and this is called plainly and simply, trust.

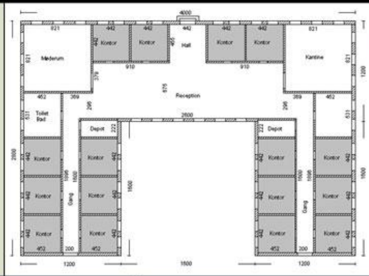
This in turn is seeing the phenomenon of Capability Maturity Matrices (CMMs) appearing, where differing parties tabulate their competences, their bond values and their ambitions or experience, and others compare and contrast it with their own, so that strategic alliances can be formed. This is not unlike speed-dating, and the metaphor does not end there. These collaborations are not for a single project but are related to the longer term. If a team comes together and competes and completes on a hospital (say), then they will try and corner that market and capture all related work.

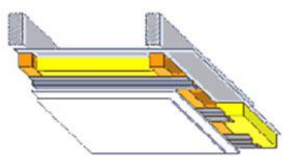
Comparisons can be seen in large legal firms for architects, and also in major contractor/developer firms and large consulting engineers who feel they have the momentum to carry this off. But there is room for small players too and smaller targets but this is ongoing. When it filters all the way down to sub-contractors who can take off quantities from the model then significant progress has been made.

Typically, these consortia comprise a design team (architect, structural and service engineer) who use or plug into the same model. From this a surveyor or estimator can extract quantities from the model and together with a price book or work rates and material costs can price the work. Moreover, once each component is type coded it has a classification, which can be linked to specifications clauses to generate full building part specifications. Following this, a contractor or project manager can begin sequencing the work so that there is control on site with proper manning and resources.

Danogips 2 lag 13x1200x2400 mm på underlag med c/c afstand 400 mm på stål

www.danogips.dk
Link til objektmodel





0. Stamdata
Adresse: Hovedgaden 34, Allerød
Bygherre: Unidanmark A/S
Kontakt: Peter Jensen. mobil 20553266

1. Byggeplads
Skurvogn placeres på adressen.
Hjælpekasse forefindes i skurvogn.
Sikkerhedssko skal benyttes generelt.

2. Planlægning
Opstart: Mandag i uge 44.
Aflevering: Fredag i uge 47.
Materialer er på pladsen ved opstart.

3. Aktivitet
Etablering af byggeplads.
Opsætning af lofter.
Oprydning.

4. Arbejdsmetode
Der opsættes SK 25 vægskinne ved alle begrænsende vægge. Der monteres S 25/85 monteringsprofiler på træbjælker, stålbjælker eller betondæk. Underste (dækkede) lag gips opsættes og der fuges mod begrænsende vægge, dog ikke ved 1 lag gips. Sidste (synlige) lag gips opsætte og skæres tæt mod væggene. Pladeender i det synlige lag gips samles med T-samlestykker. Spartling af plader er ikke indregnet.

5. Materiel
Der sættes stillads op for opsætning af lofter.
Stillads fjernes før maling af indvendige vægge og sættes op igen for montering af loftslister.

6. Materialer

0001007061	Danogips Byggeplade A1 (f) 13 X 1200 X 2400 Mm	M2	524,04
0001006857	Danogips Byggeplade A3 (r) 13 X 1200 X 2400 Mm	M2	524,04
0004844734	Gips lydfuge 0,5 liter	Pos	57,12
0001009216	Gips monteringsprof. s 25/85 3800 mm	M	1179,09
	Gips samlestykker tska	M	262,00
0001008796	Gips skinne sk 25x????	M	336,00
0003790565	Gips skruer f/f13 mm 1000/pk - til skinnesamlinger	Stk	2358
0004281606	Gips skruer ta 35 mm 1000/pk	Stk	3668
0004281614	Gips skruer ta 45 mm 1000/pk	Stk	7860
0003790532	Skrue incl. plugs	Stk	672

7. Mandskab
Byggeleder: Ole Andersen, mobil 33124411
Akkordsum: kr. 32.728,-
Tidsforbrug: 234 timer

Figure 54 This is a Production Card, aimed at the sub-contractor. The plan shows where the work is to be done, the 3D view what is to be done and the table informs the worker where to go, when to go, what the specification is, what materials to bring, what is available to do the work and the manpower. Courtesy of Produktdata.dk

During procurement, packages can be taken off so that sub-contractors can find out how much piping, cabling or materials need to go into the van every Monday, where it is destined for, and how much time and how much money are allocated. This does not require the sub-contractor to have expensive authoring software (like Revit) but to only have a reader (Navisworks Freedom, Tekla Viewer or Solibri) not unlike Adobe Acrobat Reader which is free to the user, meaning they can open the file and interrogate it. This is also indispensible to the project manager in accessing the data.

If a project is authored in Revit or similar, through a process of tagging data, type codes, can be allocated. Using quantity extraction programmes (Code Group, Sigma) a classification system can be selected and applied. This can be CAWS, Omni-class or any internal in-house system. The tagging of elements in the Revit model, when complete, can be exported to Sigma where all the entities can be updated against a price book such as SPONS that recognises the tagging format. This gives a priced bill of quantities, which can be linked back to the model so that any changes are updated in both places.

After this process, the quantities can be exported to a Gantt chart program (MS Project) where all the resources come in with the current day's date. A Gantt chart allows these entities to be placed either through critical path of sequentially so that a start date and practical completion date can be calculated. Currently this is not bidirectional with the previous work (but this is being addressed and is in beta testing at time of printing). An added chart column sequences the construction time line. Armed with the Revit model (3D) the Project chart (4D) and the Sigma schedules (5D) these three models can be imported into Navisworks (or Tekla and Solibri). This is done by exporting the 3D model from Revit and linking it from within Navisworks to the resources and time. A time line feature will sequence the work in a movie or the project manager can move the sliding time line bar to see the progress of the work. Selecting an element brings up when it will be built and other data like delivery and storage can be accessed or noted here.

The added benefit here is that the slider bar can be moved to today's date and the expected work can compared to the actual work, meaning the manager can see if the work is ahead of schedule or behind. Navisworks will also allow him to make clash detections, which can be implemented earlier in the process eliminating many architect's instructions and requests for information on site.

Finally, with regard to this procedure, with better standardisation, there are strong possibilities that this process would be automated, instead of it having to be manually shoehorned as it is at present. If all components and elements were systematically coded whether it is SfB, CAWS, Omnicodes or whatever, then the coding could be smart enough to drive itself. Furthermore, with proper translators the elements could hold all codifications and be interchangeable, depending on the requirements. This would mean they could be anonymous to the user, unless in advanced mode where they would be editable or re-engineerable.

10.5.3 The Life Cycle Extended Facilities Management Model

If the above has been carried out as described then the final virtual model should be a replica of the actual building. This is of significant relevance to the owner or whoever is responsible for running the facility. Previously the Facilities Manager started from scratch building a maintenance model, because often what was handed over bore no relationship to what was initially proposed.

Within the model, each element has a right click properties dialogue box built up of parameters and values. Simply said, a placeholder is identified and a value entered, so that the *'height of a door'* might have the value of *'2100 mm*'. During the early work, stages of the project it is of no relevance to the architect who the manufacturer is, but at some point in the process, it will become relevant, typically when the contractor is placing an order. If the contractor uses the model to enter the supplier, then other data can be added such as durability, colour, model number as well as all ironmongery and key identification numbering. On the other hand, if it is not done there and then, that the ability is there for later or whenever appropriate. This is the beauty of a centralised point of contact.

Although not implemented at time of writing, there is research saying that once a door is placed in a model, that it should be possible to elicit information about it for later use (Obonyo 2010). Just as smart phones use apps (applications) to do things, bots (robots) are waiting to do other things. Search engines are very well advanced today. Enter a word or topic in your browser search engine and a meaningful response is returned based on others who made the same search and relevant to you location. All this happens in the background and without going into the algorithms, we all use it and are relatively pleased with the hit rate and response. That is why we come back.

Imagine a bot placed on a door going off quietly and finding all the doors that meet the requirements demanded for that door. Initially, it might only be an internal single leaf door, with twenty three manufacturers that fit the bill, but by the time it is fully commissioned it might have a gained fire rating, sub-master key with particular hinges, a particular type of wooden veneer, a specific model and price, with a specified life expectancy with inbuilt inspection periods or repair schedules. This data is only relevant to those who need it but at each stage of the process, there is fingertip informed data at the ready awaiting selection.

All-in-all there are fascinating developments happening, and they are happening at a rate of knots. Patrick MacLeamy has engaged us with his 'BIM, BAM, BOOM' scenario where for every dollar spent in the design phase, there are $20 spent in the assembly or construction, which leads to $60 in its operation and maintenance. If clients and users are not demanding this consideration in their projects then we are failing them. If we are not looking at sustainable issues through all phases, then we are falling ourselves.

Initially it appeared that architects would herald the new process with the American Institute of Architects (AIA) thoroughly scrutinising the possibilities while proposing robust models of deployment (Fallon 2007). But the response was middling. Architects are reflective types when designing (Schön 1987) and boxing them into prescribed methods of designing is not easy.

10.6 The Benefits of Adoption to Stakeholders

Parallel to this, financial viability is finding its way into building information modelling where computed area schedules are being mapped in early versions of the model which can be maintained and updated through the procurement of the project. Linking this to indexed price books ensures better cost control and improves project certainty. Facilities managers are also finding ways to map their requirements into the model, which is giving life beyond procurement, making it possible to conduct Life Cycle Assessment (Harty 2010 Chapter 24).

The early massing can also be tested for sustainable comparisons meaning that even at the early stages various options can be tried and tested leading to better-informed designs. Similarly, to sustainability, Life Cycle Assessment (LCA) is and will have a significant part to play in the procurement of buildings (Sørensen, 2010). This is even more so, when the initial planning and post operations and maintenance issues are added. Suffice to say that best practice currently has three models running concurrently, one for the strategic policy makers or investors, one for the designers and procurers and finally one for the operations and maintenance people who pick up the pieces after practical completion. This is not optimal or efficient at all, because repeated input of data increases the likelihood of error, and encourages a knowledge drop at each point of the saw tooth knowledge acquirement diagram.

Better-informed designs are possible, by bringing all stakeholders on board sooner in the process than previously. But while this is a bonus, it is also potentially problematic. Not least is how this collaboration is managed. While there is clearly a need for a manager, there is also a need for bells and whistles, with regard to authorship, quality and level of detail, but this could well be dealt with using metadata.

The benefits of the model are not lost on some flexible entrepreneurs, already there are stakeholders who are entering into mutual agreements to work together to reap the rewards of completion on time and to budget. The biggest issue here is risk and how much or how well you trust your partner. Building trust in a business environment and especially in a fragmented market requires new skills and new procedures. Changing work practices from the adversarial to the collaborative, requires major changes in mindsets and even social behaviours (Sigurðsson 2009).

Methods of integrating these diverse methods will improve how we make buildings and how we use them. Facilities Management (FM) has a critical role to play here and methods of facilitating designers without alienating them will consume many resources before an acceptable solution can be found. The driving force will be collaboration and already we are beginning to see consortia being formed where certain players can work purposefully and profitably together to mutual gain (Smyth and Pryke 2006).

10.6.1 The Issues Involved in Nurturing Trust

The major obstacle to collaboration is how trust is nurtured, how new blood can enter the mix and finally how information, competences and knowledge is shared for the benefit of the team, the project and society at large. Initially there were calls for sharing or giving away data for free, but with contractual obligations and recovery of costs there is a great reluctance to do so by the players and those who have invested so much into the project, to see others in the supply chain capitalise handsomely on their endeavours (Williams 2009).

How this can be remedied rests with the client and the appointment of all the stakeholders in the project. First principles say that work effort must be remunerated, and secondly there cannot be subsequent adversarial disputes about the quality and correctness of the data. The correctness of the data needs to be calibrated and one method is metadata (Onuma 2010).

10.6.2 The Endorsement of Tagging Metadata

Metadata is data about data. It is typically embedded and is only of use to specific persons or things. This might be the size and quality of an image. Its dimensions, colour definition or the date it was created and by whom, the date modified and by whom. From this it can easily be seen that generally, the interest is only in the image but occasionally more is needed for whatever reason, and especially when it is to be used by another downstream in the process (Bedrick 2008).

This too can be applied to modelling and components of models so that the validity of any piece can be verified (Barrett 2008). This is the first step in trusting a collaborator whether known or unknown. It is abstracted information and can be seen or hidden until required. It now makes the virtual element accountable for want of a better word, and it marks or informs the end user whether it is complete or just a holding-place for better-informed data. This allows the authorship to be tagged and any information about amendments subsequently made or commented upon to be archived within the element.

10.6.3 The Practicalities of Applying Level of Detail

The process of architectural design is the moving from approximate information to more precise information (Conover 2008b), But digital model elements tend to be exact, whether or not intended. This can give false indications about the precision of the data. Coupled with its intended use, the author might not be qualified to release or stand over the data in its present form. All this needs a framework defining its precision and suitability, and this is called a Model Precision Specification (MPS).

The framework is essential for two reasons; the first 'that phase outcomes, milestones and deliverables be defined succinctly' so that team members 'understand the level of detail at which they should be working, and what decisions have (and more importantly, have not) been finalised', and the second; 'the idea of assigning tasks on a best person basis, even when that differs from traditional role allocations' (Eckblad, Rubel, et al. 2007). This caveat is purely because procurement is a process, and when the process is most vulnerable is when it is most open.

Five levels are defined:

The first is *'Conceptual'* where there is little geometric data, typically block models, and only notional ideas about time and cost. There can also be analysis about programme, strategies and performance.

Next is *'Approximate Geometry'* where generic elements are shown, duration and cost estimates are better informed, specific functions and requirements are in place and the conceptual design is finished.

'Precise Geometry' as it suggests is a point where quantities can be extracted, the building can get approvals and permits issued and traditionally it can go to tender.

'Fabrication' is where shop drawings and production happen, where building parts are located, and components and assemblies are known. There is a committed price and specific manufacturing is in place.

Finally, there is *'As-Built'* which is the actual building with recorded costs and purchase documentation, where the building has been commissioned and performance can be measured.

10.7 The Next Possible

Carl Bass (CEO Autodesk) in his keynote address to the Autodesk University 2009 conference spoke about five phases of development; the impossible, the impractical, the possible, the expected and finally the required. Focus was placed on the middle phase, the possible, because here, he stressed, was the sweet spot where advantage could be gained over competitors and potential banked in hard currency. Too early and the pioneering spirit was woefully underpaid or unrecognised and too late the ship had sailed.

He noted that the challenge lay in trying to stay competitive but cautioned that work, (as we know it), is really changing. This was outlined in five key areas; *'exploration', 'analysis', 'storytelling', 'access'* and *'collaboration'*. Under *'exploration'*, he described design as becoming more computational. By this, he meant that computers are all too persuasive in design today, whether in construction, aeronautical or car manufacture.

In *'analysis'* simulation is being used to reduce errors and offer a whole matrix of solutions. Tests can be conducted in the virtual world at a fraction of real world testing costs. Prototypes are not required in the same numbers as before and more tests can be conducted in everything from finite analysis, acoustics, lighting, heating, cooling, element costing, U-values and scheduling. All of this means that the model can be tested before it is built

'Storytelling' was pure communication whether visually or orally. But now the model can be an implicit part of the financing of a project, showing investors what they are buying into, or a major player to users showing what they are moving into, or a significant tool to planners checking compliance to building codes or visualising the contextual landscape.

'Access' is a part of the burgeoning growth of web access. This means that new methods abound where data can be accessed from anywhere and everywhere. There is a slow sustainable transfer of having data stored locally to having it stored centrally meaning that it is readily available and not in numerous versions because of many contributors.

Finally, under *'collaboration'* he envisaged a social network using application software where all can contribute. Various types of hardware control where the data is kept and various types of software control how more than one author's contribution can be managed without compromising each person's input in real time. This *'Whole System Thinking'* he told us would lead to better design.

Jeff Kowalski (software evangelist) followed this theme with practical illustrations ranging from point cloud capture, to feature recognition geometry and augmented reality so that there was/is a blurring between the real world and the virtual one. He demonstrated data performing in a kitchen design where the client's kitchen could be populated with differing manufacturers' products, complete with their properties, so that lighting gave true luminosity or appliances appeared in their correct colours or finishes.

This whole process was akin to design and analysis being interchangeable, with the possibility of viable alternatives being added to the mix. But rather than an infinite number of solutions being generated or possible, boundaries could be set so that instead of a trial and error process, an innovative and creative path could be trod. Demands and performance could be set so that a filtering process limited the options available in a smart fashion. This was all due to the properties inherent in the objects used, being able to be extracted in a meaningful context.

In addition, although not yet available he demonstrated or poised the situation where with Geographic Information Systems (GIS) that data could be overlaid on a view to fully integrate and enrich the experience. For example holding a mobile phone or a tablet PC over a terrain the underlying pipes and sewage or cables and utilities could be mapped in real time. Alternatively, that the building model could be overlaid on the actual building in the same manner to check compliance with the proposals or find out how advanced the project was timewise.

He closed by saying this optimised the starting point and likened the process to the *next possible* as distinct from Carl Bass' (plain) possible. It was indeed a choreographed presentation but crucially it addressed how *'work is really changing'*. To relate this back to the building industry and the changes it is currently going through, it is probably best to take Bass' five points of *'exploration'*, *'analysis'*, *'storytelling'*, *'access'* and *'collaboration'* to parallel and elucidate what is happening.

In its simplest form *'exploration'* can be demonstrated in the building information modelling by extending a gable wall of a house out by a meter or two in plan view. Floors, roofs and all related objects both seen and unseen in the view are updated. If roofing trusses are placed at 600 cc's then, as the model grows out, new trusses are added according to the rule set. Exporting to cost extraction software shows the updated scenario and resource software reflects the changes too. This is informed exploration and the *what-if* scenarios can be properly evaluated and judged.

Using *'analysis'* software, these scenarios can be tested, and reports generated showing compliance to regulations or itemising nonconforming failures. Whether it is sustainability, economics, building codes or local plans, certainty and control are in the hands of the designer and the project team. Under sustainability, the building's performance can be modelled with regard to energy use, passive heating and cooling, together with form, orientation and layout. Economy is quite simple, extract quantities and price them. BuildingSmart has already demonstrated that codes can be assimilated into the approval process.

'Storytelling' has a childlike bedtime feel about it, and while it is correctly named, it harks also to the idea of nurturing. In reality, it is about communication, and about how the message is conveyed. Quite frankly since the adoption of BIM over CAD in the

classroom three years ago the stress levels of the students in group work has significantly diminished because all can easily see the model and see what is required or fix what is wrong and does not work. Previously right up to exams there was panic and grey areas where the design had not been fully resolved. While it is not a cure all package, more students can address the problems and assess their impact easier than before.

'Access' is beginning to permeate and perpetrate all areas of work. Anyone who has ever stood as collator for collaborative work knows how difficult that task becomes when the different versions begin piling in on top of each other. As in Worksets in Revit and cloud solutions, like Dropbox, it is much better to control the process and let each have access to their own domain while contributing to the whole. Occasionally there is an editor role necessary to make sure that there is continuity and harmony across the work.

In multidisciplinary projects the same authoring of work and the cross checking of others input against one's own is both time consuming and prone to error. But likewise, safeguarding one's work against accidental or malicious damage by someone else is also very important. A method is necessary to ensure and protect authorship, otherwise litigious warfare would break out, not to mention building failures. So while access in itself is a much-heralded addition, its management too is highly regarded and rightly so.

Building is a process of *'collaboration'*, but the building industry is a fragmented organism. It is made up of many small parts that act together in unique instances meaning that there is much change. Even within the same organisations, different team members regularly line up for repeat work. This means that all players are likely to have their own methodologies and that often it is only deliverables that are specified. Finding a common denominator is therefore not easy and implementing such a vehicle fraught with difficulties.

But that should not deflect nor diminish the task ahead. Neither should it lessen or impact the full adoption of collaboration. Two major obstacles currently blight that course, the first is the entrenchment of the differing disciplines against working together and the other is the talent shortage to implement the venture.

11.Conclusions & Recommendations

11.1 Objective I: Digitalisation's Integration

Text Box 10 Objective I

'To study the practicalities of integrating drawing operations and design processes within database controlled programmes, including a mapping of overall process against individual responsibility, training, data reliability and risk.'

This raised two research questions concerning digitalisation:

'What are the practicalities of integrating drawing operations?'

'What are the practicalities of design processes within database controlled programmes?'

The literary review looked at the situation as it was before BIM with an historical context from Alexander (1964), the design team set-up by Bennett (1981) and Cecil (1989), pre-abolition of mandatory fees scales and the lip service to collaboration in Cicmil (2005) and Cartlidge (2002). The extra work of co-ordination through double work, cross-referencing, checking, and rechecking of each disciplines paper deliverables was documented with comments and proposals to correct them from Eastman et al. (2008) and Eckblad (2007). Resolving issues earlier in the workstages and new interdisciplinary collaborations began showing the development of partnering and other forms of overcoming the poor state of health of the construction industry.

In the next section, the role of databases was examined. Data is information, which can be transformed into knowledge. Onuma (2010) was seen as the synthesis of what cloud computing could provide for the reflective design methods of Schön (1987) and Jernigan (2007). Methods were shown to achieve this integration, because the complexity of procurement involves many resources. The chapter finished with a cautionary tale of OMA's CCTV building in Beijing (2002) and Brunelleschi's Dome in Florence (1436).

This was followed by a mapping of the overall process against individual responsibility, training, data reliability and risk. This entailed looking at the return of investment (ROI) for firms investing in BIM, who should be responsible, and the identification of a BIM manager. The problems of lowest bid partnering against correct pricing, by Miller (2008), who describes collaborative innovation as a means to endorsement. How data input could be verified featured large in this section, as well as the single model and the federated model to limit the saw toothed knowledge drop previously experienced. The section mentioned the Spearin Doctrine and developed the gentlemen's agreements that were necessary to accomplish IPD. It finished with how technologies can change practices especially apps and new digital devices.

11.2 Objective II: Management Structures

Text Box 11 Objective II

'To investigate how the opportunities afforded by a pervasive use of IT within construction, are impacting on design strategies and associated management structures.'

This raised two research questions about management:

'How are BIM opportunities impacting on design strategies?'

'How are BIM opportunities impacting associated management structures?'

The next chapter looked at the impact on design strategies. Crucially, it is the ability to hold data that heralds the new pervasive opportunities. The learn-as-you-go scenario was described and the broadening scope of IT was mentioned. Frank Gehry's situation was used to highlight the difference that sharing the model had on Disney Hall, Los Angeles and Guigenheim, Bilbao, consecutive projects where the first was five times over budget and the latter one fifth under.

The impact of the planning process was assessed with an in-depth analysis of code checking from Conover (2008a, b, c). Next a BIM workshop described how control could be wrestled back, re-empowering architects, together with the power of programmes like Navisworks to leverage procurement.

Chapter five stretched this exploration to associated management structures and their impact across the whole supply chain. There was a definition of integrated practice and a breakdown of the ConsensusDOCS contracts ending with the architects' taking the moral high ground with goal alignment. Bringing FM into the mix opened the door towards life cycle analysis and by extension RFID's and sensor networks, web services and semantic webs (Underwood 2011).

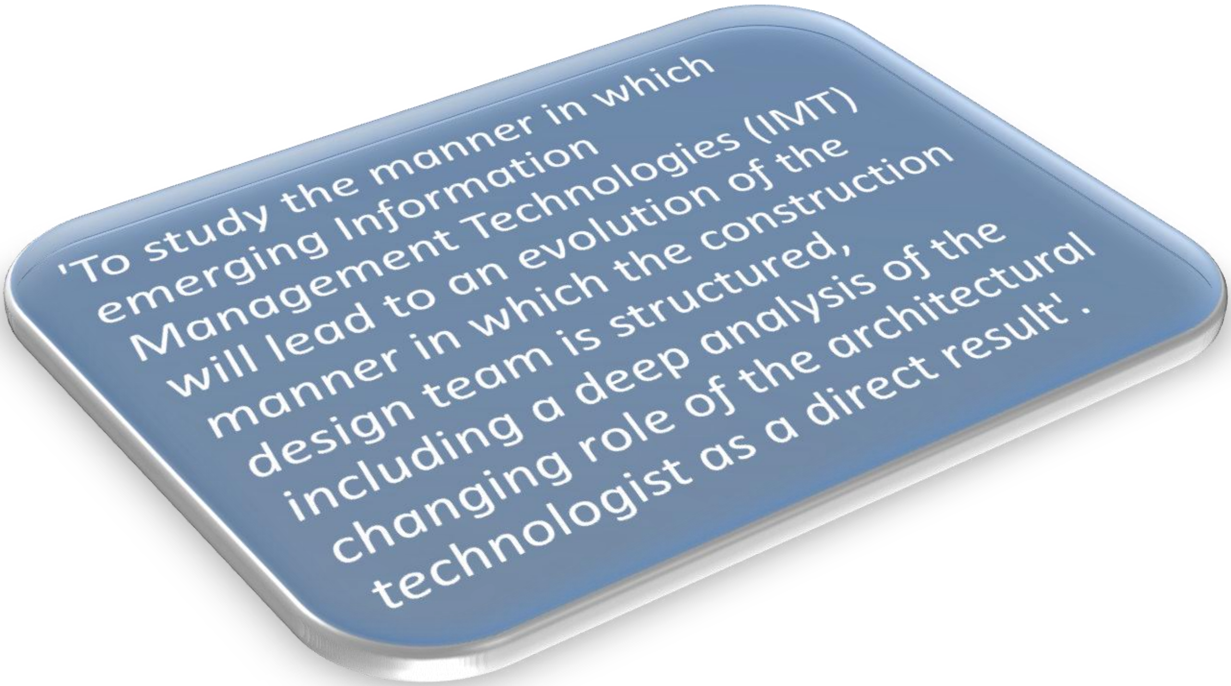
Patrick MacLeamy (2010) expounded his BIM, BAM, BOOM theory, drawing on the $1 in design, translated into $20 during construction, leading to $60 in it lifetime running. General trends in digitalisation were then mentioned to scope the extent they will impact the building industry. The importance of keeping design data in digital form and creating real-time consistent relationships (Bew 2010) brought the relevance of BIM and GIS together by conjoining them (Isikdag 2010). Parametric design in sports' stadia was used to show better informed design as was mentioned by Sheldon (2006). The section ended upbeat that the architect has a holistic problem solving approach and an understanding of broad cultural concerns (Gabrielli 2010).

The next section, structuring the design team, opened with a comparison to a current AIA contract clause and one from Frank Lloyd Wright. The now defunct Office of Government Commerce (UK) presented their methods of engagement before there was an open discussion of a roundtable session at the RIBA chaired by NBS. Morrell, as client representative, was most vociferous that there is a need for a BIM manager and this was borne out by Laing O'Rourke, BSRIA, Hilson Moran and BPD (Waterhouse 2011).

The work of Smyth and Pryke (2006, 2008) focused of people as resources and the role trust plays in their relationships. The chapter finished with a reprise of project certainty (Fong 2007) and mention of Mayne (Strong 2005) who said:

'If you want to survive...'

11.3 Objective III: Architectural Technologists' Emerging Management Role



Text Box 12 Objective III

> 'To study the manner in which emerging Information Management Technologies (IMT) will lead to an evolution of the manner in which the construction design team is structured, including a deep analysis of the changing role of the architectural technologist as a direct result.

Critically, this looked at the role of the technologist with the following questions:

'Will Information Management Technologies (IMT) lead to an evolution of the manner in which the construction design team is structured?'

'Is a deeper analysis of the changing role of the architectural technologist needed?'

The chapter described the technologist' course at The Copenhagen School of Design & Technology, working in dynamic group matrices on whole semester driven project, akin to a real office. Changes to accommodate BIM in the syllabus were outlined and reference was made to DIT (Allen 2009 a, b) where they have embarked on an extended course building up to admission to the RIAI with the recognition and standing of a profession.

The development of a Professional Science Master's was then discussed with its relevance as a hybrid degree building bridges with business and academia (Rosenbloom 2010). There was a call for attention to be paid to lifelong learning and a coaching role. There was also a call for educational institutes to mirror and reflect the paradigm of these changing roles.

11.4 Objective IV: The Significant Contribution within Architectural Technology

Text Box 13 Objective III

> 'To make a significant contribution to an understanding of how IMT's will drive changes within the discipline of Architectural Technology in the next decade'

Finally, in this chapter, there was a look at Norwegian efforts, and how with its impressive infrastructure and cold climate, has initiated a method of code checking, where they will also be the trustees of the national register holding all the accumulated information, so that this will evolve into living archive.

The next chapter addressed the effect IMT's will have on architectural technology. Reference was made to barcodes and SMS technologies, and how they far surpassed any expectations. Similar results can be anticipated here. The *'what-if'* feature will allow different components and elements to be switched in or out, meaning differing constructions, claddings, and assemblies can be tried. Not only that, but as assimilation improves these components can be tested against thermal performance, thermal bridging, ageing even, maintenance, aesthetics and moisture penetration. Reports can be generated.

Coupled with Bots suggestions can be made, ranked and implemented, putting the technologist in the driving seat.

With PIM their reach will extend to larger domains, new materials can be tried, new technologies implemented, new theories explored without the expensive real world prototypes. Avatars can perform fire evacuations, live loading and expected behaviours in a building's performance, and report back. Sustainability can be documented and moreover be accountable.

11.5 Original Contribution to Knowledge

The original contribution to knowledge can clearly be seen in the pervasive use digitalisation across the whole procurement of construction, reaching further into financial modelling at onset, and extending into the legacy of the running and operation of the building, all the way to decommissioning.

There has been a colossal move of the evolving team from an unsatisfactory fragmented team to an integrated well-oiled collaborative organisation, who want to do things once, reuse their efforts and exchange their toil to reap the benefits of delivering projects on time and to budget.

Lastly, the changing role of the architectural technologist has been documented elaborating and elevating their function into management, making them an indispensible cog in the whole building process. Fuelled by this evolution they can see the way forward to being a respected profession within the building programme, with changes in the education system to aid and abet these new fields of work.

The purpose of this work was to examine four objectives with regard to the impact that digitalisation has had on the management role in architectural technology. The journey started with a look at the practicalities involved;

How to effect integration,

What changes in the procedures?

Who has responsibility?

What amount of training is involved?

How good is reliability and

Where and how great is the risk?

There were barriers arising largely due to the fragmentation of the industry. There were differences in management and rank and file operatives, and there were issues of adoption and implementation.

There were drivers too, and prime among them was the momentum of modelling, the pervasive use of IT in general especially in construction, and the need to perform better. Modelling is showing us that there is a new style of architecture, where forms previously impossible are now appearing on the skyline. IT has quietly evolved and is having a huge impact throughout the world. As cloud computing asserts itself, the uptake will follow. Soon not being in the (cloud) loop will be detrimental to how you perform in the supply chain. The interweaving of BIM and GIS will also bring untold benefits, and overlaid with App's and Bot's will reap a harvest of new opportunities beyond procurement and well into life cycle analysis.

Design strategies and management structures are also changing. BIM with better clash detection, better communication and better co-ordination is resolving problems earlier meaning that fee scales will soon follow the money and reduce the risk. This means that more will be done in the earlier stages and ultimately production information might even be fully automated. Management is moving into relationship roles rather than previous hierarchical ones and this is seeing more side-by-side situations where people work together instead of vertically in the same organisation and across disciplines in order to do the job correctly.

This means the construction team is undergoing a transformation too. The right person for the job is improving. The design team is growing with everyone from client and the legal team, all the way to contractors and sub-contractors now having a say. The procurement process is expanding to include the financial model and the life cycle model, meaning the practical completion handover is not the final goal anymore but rather the start of the building's life, in

Figure 55 Timeline simulation

which all stakeholders have an interest and duty to consider.

Architectural technology is also changing, instead of tried and tested details and constructions being applied and modified through time and experience, simulation and analysis now allow for the testing to happen digitally. As stated elsewhere:

> *'We should build prototypes in the inexpensive virtual world, not the very expensive real world'.*

Soon *'wear & tear'* will also be another simulation to be applied, water penetration, and frost action will soon be performed on the model, and the results analysed, reducing thermal bridging, purely because it is analysable. Climatic data can be applied to the site location, the building's forms and compared. This brings confidence and certainty to the project. Novel technologies can be modelled in place and tested to achieve better performance, rewarding the entrepreneur rather than penalising the untested.

The architectural technologists' role is growing too. With their all-round ability and awareness of the other disciplines within the industry, their role is the glue, which keeps everything together. Whether BIM stays as a single entity or a federation of models, to be monitored and controlled, the role of the BIM Manager is certain. As Paul Morrell says emphatically in 2011:

> *'There will be a BIM Manager'*

This corroborates, Jonassen who had championed for someone to manage the sharing, integrating, tracking, and maintaining data sets, which requires overall leadership as far back as 2005.

11.5.1 Inductive Methodology

The research creates new knowledge about what works and what does not. It is audited with questions about, whether we are following best practices that are measured against standards. Research is concerned with discovering the proper thing to do, auditing with ensuring that it is done correctly. Research is concerned with creating new knowledge, knowledge about whether new methods work, and whether certain procedures work better than others do. Research forms the basis for guidelines and standards, that determine best practices.

From an inductive point of view, the methodology has been demonstrated and examined in chapters three, four and five. *'How the opportunities afforded by the pervasive use of IT within construction are impacting the design strategies'* looked at the situation with reference to design strategies and their scope, with reference to Frank Gehry and then seen in context of local authorities ending with BIM's need to empower architects.

'How the opportunities afforded by the pervasive use of IT within construction are impacting associated management structures' assessed management and the process, looking at IPD, ConsensusDOCS, creating real-time consistent relationships to encourage collaboration. *'The manner in which emerging information management technologies will lead to an evolution of the manner in which the construction design team is structured'* looked at erosion of the architect role at the helm of the design team and the emergence of the stakeholders and their supply chain, to make buildings perform better. It included looking at the team, collaboration, trust and the cost savings that can accrue.

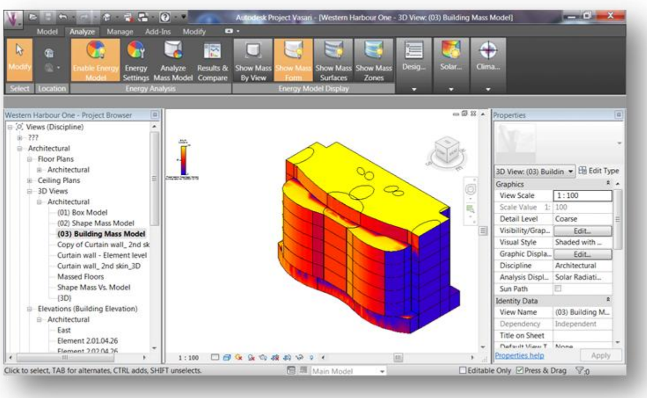


Figure 56 Student model analysis using local climatic data and night-time rendering

Quantitative Measures

Both the case studies and the questionnaire brought an element of reality to this virtual world. It is one thing to hypothesis but testing and analysing what is out there brings a modicum of authenticity to the proceedings. The case studies were wide and varied and this was their intention. They ranged from the small to the large and from the design phase to the on-site phase.

The questionnaire tested the perceived view of BIM, and both reported back on its penetration and its overall awareness. Along with expected results, it also threw up some unexpected ones too. The communicative value of the model was one that comes to mind. While accepting that, yes, it would, this is something that the students manifest repeatedly. It is also borne out in their demeanour coming to evaluations and exams. Previously there was uncoordinated work that the examiners had to spend time crosschecking and thoroughly analysing, in order to satisfy themselves that it was buildable. It also showed that examinaters' expectations from the model were limited to their own spheres of influence.

Finally, this work can make a significant contribution to the understanding just of how IMT's will drive changes within the discipline of architectural technology. There are those who will become the equivalent of CAD jockeys, implementing the new technology within the same structures that prevail today. There are those who will embrace the new technology and transform the work places in which they find themselves, making it better in which to collaborate, building trust across the disciplines and bringing certainty and better control to the proceedings. There are also those who will grasp this new phenomenon and change the way we build. new consortia, maturity matrices, financial models, procurement models and facilities models, all will be rolled into one, where life cycle analysis will see the embeddedment of sensors reporting back on use, maintenance, which builds an enterprise where the embedded data is working for the better good.

Figure 57 Office Building, Western Harbour, Malmö

11.5.2 Summary

The purpose of this thesis was to assess the impact of digitalisation on the management role of architectural technology. Within this statement, four objectives asserted themselves. First was to study the practicalities of integrating drawing operations and design processes within database-controlled programmes, including a mapping of overall process against individual responsibility, training, data reliability and risk. This was viewed with an assessment of both education and the construction industry, primarily because schools seem to be moving faster than business for whatever reason.

Next was to investigate how the opportunities afforded by a pervasive use of IT within construction, were impacting on design strategies and associated management structures. Where modelling was happening and collaboration was to the fore, both clash collision and time line procurement were showing that more was being achieved earlier in the project phases. Consequently, this had both remuneration and responsibility issues involved.

Finally, there was a need to study the manner in which emerging information management technologies (IMT) would lead to an evolution of the manner in which the construction design team was structured. This included a deep analysis of the changing role of the architectural technologist as a direct result. With collaboration increasing in its importance, having somebody with an intimate knowledge of all the disciplines and a technical background to dovetail and interact with them left the technologist with a unique prospect of claiming this new role, giving ultimately prestige and professional recognition, not widely accepted today.

This last objective was central to the PhD phase, and had the potential to make a significant contribution to an understanding of how IMT's would drive changes within the discipline of architectural technology in the next decade. While this research started out examining the technology and how it can/will be implemented, increasingly the work became one about how we can collaborate and trust each other, or the other stakeholders in the overall supply chain. This includes methods to benchmark handed over work and protocols allowing interaction without defacing integrity or authority.

The chapter on the practicalities of integrating drawing operations, has considered prior work concerning the evolution from draughting to modelling, together with the collateral that is necessary to implement such a shift. Draughting has always been a formalised procedure allowing a creative person a method to capture thoughts and to convey them to another for implementation. It blossomed in the Renaissance bringing abstraction in the form of proportion into buildings. In the modern movement of the last century, it brought a new life to '*form*' in its absolute meaning. It is constantly balancing these two concepts of form and formality.

With the complexity of modern life, this process has evolved into a collective operation. The size of buildings invariably means that it is a team that prepares the documentation for the building and another team that executes these instructions on site. It was this process that attracted my attention here; it had nurtured a whole industry that acted as a barometer to the national economy.

Elaborating on this objective, it was my intention to look at the practicalities of realising building projects today and in the future. The context would be set into perspective with an historical review of technologies leading to this situation in time, pinpointing the main protagonists and charting their developments. The potential of the new technologies was then assessed, and applied to procurement models with a view to rationalising their adoption. Within this phase, attention was also paid to the capabilities and shortfalls both from the technology and the user's perspective.

Finally, managing this phenomenon included assessing leadership, personnel, training, deployment, and the issues of responsibility for ensuring quality management of the whole process. Experience needed to be factored into this especially when it had been learned or gleaned over time. Consequently, a degree of protectionism could creep-in to the procurement process.

If the whole financing of construction is closely related to property prices then this could artificially inflate building costs. When the economy is good construction is good, when the economy is poor construction suffers. The extent that cost overruns and general unproductively are nascent in the trade needs to be addressed and commented upon. Whether removing property prices from the equation would herald a whole new trade and change the life span of the product is for debate. What is the life cycle of a building? How do we become more productive? There are lessons to be learned and there is great interest both within the industry and from developers at large to get feedback and move on to the next loop of the cycle. It is a most exciting time to both appraise and to draw attention to such issues.

The chapter on the practicalities of design processes within databased controlled programmes found that BIM was having a significant effect on educational establishments in construction related fields, and would continue to have a profound effect both in academia and in the industry at large. One of education's mandates is to produce and prepare resources for deployment in the industry. BIM has the ability to involve all the design team, the wider design team, everyone in the procurement chain and everyone from inception to demolition of a building both as a project and as a managed facility throughout its life (-cycle).

This was not the situation before in Computer Aided Draughting (CAD) days and certainly not the situation in manual draughting days of old. Moreover, BIM is here to stay, it will not be replaced in the next wave of innovation. The closest you can get to a real building, that is not a real building, is a virtual one, and BIM is that situation. Before a real building exists, it has to be modelled in some matter or form.

This is precisely what happened in the head of a gothic master builder, or on the parchment of a renaissance architect or in the machinations of a modern elaborate design team but it was never fully modelled as we are beginning to see as possible now. Sure, it will develop but the fundamental concept of a virtual building is here to stay.

In mapping the overall process there are many things that needed work to become both known and used. There was also many things to which we need to say good-bye. Prime among them is the versioning, checking and rechecking of paper organised documents and drawings. The time and effort spared here more than compensates for the threshold that needs to be crossed in the new regime. But as seen here the benefit in kind is three to four times better for those (experts, per se) who have made that jump, over those novices still to do it with reservations and doubts in abundance.

But the process is being helped greatly by the parallel development in Smartphones, applications and digital knowhow in general. Slowly their influence is creeping through all vestiges of life. Also the reliability, relevance and presentation of the data is becoming better suited to purpose and easier to adapt, adopt and interpret. Best of all, it is happening at a rate that encourages adoption, both from a need-to-know basis and through peers. Often it is by seeing something on someone else's phone that starts the process of claiming the same for oneself.

In looking at the opportunities afforded by a pervasive use of IT on design management, there was inductive reasoning that implicitly states that the need to empower architects and managers is happening. If this is so then they can regain the overall command in the design process. There appears also to be a pattern emerging that begins to establish that there are new opportunities to be had from the persistent use of information technology, and that they are impacting design strategies.

Critical in this too is the threshold resistance to adoption where those who are yet to embrace the technology have both reservations and hard-earned investments to defend. Whereas those who are experiencing the benefits are reaping the payback of the decision with better co-ordination, better-informed decision-making processes together with the ability to comply with ever more stringent methods of procurement. There is also the rider that those who now move into the expert bracket also see the benefits clearer and starker than those who are yet to try it out.

The corollary is well summed up by Rory McGowan, Arup's Project Director for CCTV, who was asked that after working with architects for so long, did he have any advice for the future generation of architects. Something he felt architects do not yet know about themselves? He replied:

'Architects are becoming more and more deskilled. At the same time, building design is becoming more and more technically driven. Many architects are giving up their stakes in the design by allowing engineers to pick up the slack in technical knowledge. For example, you see façades that architects used to do now being done by façade engineers. Architects are retreating from of a lot of these issues. A key question is if architecture is really just about ideas. When you deskill, you lose the detailed knowledge that informs the big idea. You can sell the family jewels for so long but you will run out of them one day.

Architects need to understand and grasp this, because if they don't, a consultant will do it for them. The part that is even more scary is that they have to pay for the service and, in turn, wind up losing the creative control. A same critique could be applied to our work: in our practice in Beijing we aren't allowed to do construction drawings on products yet. We can do concept and schematic design for a number of years, but as the graduates come up through the ranks, they might not know what concrete looks like, and that will impact our ability to do our job'.

Finally, these impacts are changing the way we design. The traditional work stages followed the workflow and remunerated it proportionately to the risk and quantity of the work supplied. Nille Juul-Sørensen, an associate director also at Arup, recently foresaw a situation where most of the design procurement fee will be paid for the early stages of the appointment and that the production work stage will actually be free. This is a very radical thought but one that should shortly be feasible.

Summarising the opportunities afforded by a pervasive use of IT on associated management structures, there are many forces at work to discourage collaboration (Porter 2007) including the threat of new entrants, the buying power of both suppliers and buyers, rivalry among existing firms and the fear of substitutes. These strong entrenched attitudes (Walker 2002) in the design construction divide were addressed in the procurement of Heathrow's Terminal 5 (T5), delivered on time and to budget (Haste 2002), where such an environment was nurtured and encouraged (Ferroussat 2005). It was based on the principles specified in the Constructing the Team (Latham 1994) and Rethinking Construction (Egan 1998).

But likewise, there are many encouraging signs to herald new approaches and develop new potentials. What is abundantly clear is that with the correct attitude these opportunities abound, typically in IT generally but also within specific threads of BIM and GIS. There are also great prospects with other emerging technologies in areas like smartphones and the cloud. These are also gathering a momentum, which make their implementation obvious and this is to be admired.

Conversely, where entrenchment perseveres, it limits not only progress but hinders any advancement or improvement for the ailing industry. Gradually clients and contractors are beginning to implement these technologies. All that remains is that the other stakeholders join the surge and not hamper its flow.

The impact of emerging IMT's evolution on the design team acknowledged that it is just that and not a revolution. While IMT's are technological, they are instrumental in the cultural change that is happening. They facilitate it and they encourage it, especially in their omnipresent status as witnessed in the adoption of smartphones, and their driving impact in so many facets of today's life. In this chapter, we saw how the evolution had been heralded by the new type of client, especially in government contracts, and this is to be welcomed. This will filter down through contract sizes and spread right through the spectrum of the building industry, as better examples and case studies show the benefits in kind.

With stakeholders entering into collaborative relationships, new possibilities presented themselves and this reduced risk and put the best person to do a job into pole position. As these roles expanded and the participants became more familiar with them, trust was nurture and grew. This galvanised working practices with more over-forties personnel sitting with under-forties personnel, working in collaboration and sharing their competences for the better good.

Costs should tumble in this new scenario. Whether these savings will be pumped back into the infrastructure or be taken out in profit is too early to predict. Those on the leading edge are currently seeing an overspend, but are seeing more data is being made available, beyond the procurement envelope. The major benefactor here will be the client and facilities management. The market, in regulating this, will see where remuneration goes, and this will develop and stabilise.

It could be argued, that the architect's inability to adequately recognise teamwork across the whole supply chain, led to the litany of cost overruns, late completions and technical problems that undermined the profession's status historically. Increasingly, contractors or PFI consortia who are now in the driving seat, have a simple, if misplaced, logic; appoint a world-class concept architect to wow the planners, but get someone sensible to execute the details. To reinstate architectural integrity the *creative* architect needs to be the orchestrator, collaborating with like-minded colleagues within the same team, if it is to be secured.

BIM is an enabler, with potent offerings. It is getting better by paying attention, where relationships are becoming vital in the procurement process and this might bring the architect back into the fold. Federated models can also reduce exposure where there is a tendency to withhold information or data, because of its quality. Finally, insurance might become more project-based, rather like Terminal 5 where who manages the model and who owns it (the client) becomes better clarified. The accuracy of the content and the issue of information liability needs a mechanism to stifle fears and encourage up-take.

In the changing role of the technologist a deep analysis of their role is firmly based in their education, and the metamorphosis that it is experiencing. There is a balance between what is required and what is expected and this is understandably so. Education has begun to make changes to spawn the next generation of technologists and this is to be welcomed.

There are also measures afoot to enhance the technologist's status and prestige. This can be seen in the form of the new curriculum at DIT in Dublin, and to a lesser degree the changes in the syllabus at CSDT in Copenhagen. Clearly, there is a requirement and a need for these changes and this is best summed up with the IATGN group in Dublin fighting for the right to sign-off work, and ultimately gain recognition from the Architect's body in Ireland, RIAI.

With regard to the new technologies, great ground has been covered and the changes in procurement are slowly asserting themselves. Prime here is the role of BIM Manager. There is also acknowledgement of the changing work practices, especially learning to be flexible and adaptable. This is also evident in extrapolating what we know and applying it to novel situations. There is a need for *'lifelong learning'* and this can be seen in some of the changes mentioned.

A Professional Masters Degree has potential to merge the practical nature of the technologist's course to be responsive and relevant to industries needs where there could be a win-win situation for all. This needs to be looked at as educational institutions have a duty to mirror what is required in the construction industry, as has been mentioned with ongoing moves in Norway.

Several significant points were made in next chapter, (how IMT's will drive changes), ranging from the impact of PIM on IMT's, to the influence of the cloud in driving the needed changes, and also from the rising pressure of sustainability in effecting the new tomorrow to the enabling power of augmented reality. Starting with the entrenched view that there is traditionally resistance to change and that the lessons of the CAD era stress that management must be kept on board, the technologies are patently showing that there is a way forward and that the pervasiveness of them are making it easier to adopt and adapt.

There is a suggestive and symptomatic thread here that leans towards an idea that as the technologies become more honed to the users' needs and demands, that there is in parallel an opening up and responsiveness from the user to trust and accept their new capabilities. In a sense there is a meeting at halfway from both camps, and this is a relatively new phenomenon, to be cherished.

While acknowledging that some of the IMT's are nice-to-have others are need-to-have. Sustainability and the need to curb carbon emissions will focus the next generation immeasurably. Legislation and cultural change will drive how we live, whether it is the price of fuel or the availability of fuel, the *nouveau riche* will be the people who use least energy. Merely addressing heating and electricity in buildings, accounts for nearly 25% of greenhouse gas emissions, according to the 'World Resources Institute'.

Producing buildings where *'certainty'* is to the fore makes sense. As more examples become mainstream, word of mouth should exponentially accelerate adoption. Life cycle analysis has been accepted into the argument and this enlarges the procurement phase to the life cycle. The next step has to be looking at the impact the choices made in design have on the overall life of a building, from cradle to grave, or rather cradle to cradle (to include recycling).

Summary of Case Studies

The case studies documented a range of situations that are current and real. They covered the internal BIM situation all the way up to full IPD integration, and also beyond procurement to FM and semantic sensors. The progression served a purpose for others in the industry to rate themselves and place themselves into a matrix. This provided an important mechanism to find out how far or how little had been implemented and also gave feedback on how implementation has progressed so far.

These levels could be seen as such:

Internal independent BIM, where there is no collaboration, only better co-ordination of the traditional procurement methods.

External independent BIM, where there are several models and they are analysed and checked through traditional methods. There is no attempt to exchange models, only extracted material.

One-way BIM, where the internal work is qualified with reports from outside. The data is sent out to a consulting engineer who reports back that such and such should be implemented in order to achieve the stated goals. This is short term and is quickly acquired in-house.

Two-way BIM, where the work goes in each direction, but in limited bundles. While there are bi-directional workflows, there is little or no collaboration with regard to a single model, or models which can be superimposed in Navisworks or similar.

Full integration of the design team, where there is cross fertilisation and better collaboration, leading to better IPD. This has two facets, one where the contractor is not involved and the other where design and build measures are in place.

Full integration of the supply chain from concept design to handover. All stakeholders are involved and work towards a golden egg bonus system. There is no litigation as this emptied the pot.

Full partnering through either PPP or PFI, where the team continues to have a holding after handover. This ties the contractor down to maintenance after handover for an agreed period of time.

Finally, a total lock down where major parties to the agreement continue to have a critical role in the lifecycle and decommissioning of the facility, from a involvement from the beginning where demands and requirements were first tabled, and the financial decisions first taken.

Summary of Questionnaire

The survey supported many things. First and foremost it showed that the students were happier using BIM than traditional methods or CAD. Not surprisingly, but very gratifying was that collaboration and reuse of data scored better than might have been expected. With regard to the questions about the greatest resistance to BIM at the moment, only 10% thought that it is not needed. Only 20% thought that it added expense, 40% that it was difficult to implement and 20% that the industry was not geared towards it. 15% were lethargic but 30% thought that clients wanted it but were poorly advised. Nearly 50% wanted more and better showcases.

In five years time, not needed still sat at around 10%, expense has dropped to 14%, while implementation to 30%. 20% still thought that the industry was not geared towards it, and lethargy remained around 14%. Only 3% thought that clients still would not want it and 24% thought they were ill advised. Showcases were down to 28%.

The other interesting point was that no one saw contractors or sub-contractors implementing BIM. Clients, Developers and Municipalities featured as would be expected, but the other side of procurement was not seen as ready yet.

Figure 58 The electronic site hut

Summary of Methodology

Just as in design and build or partnering, collaborative consortia will go through a process of pre-qualification but not necessarily or singularly project driven. It will be for a longer haul and over or through many projects. This pre-qualification will see the various members of the consortium indexing themselves with a view to both internally establish their own worth and externally finding a compatible niche or setting the rate or level of engagement desired with the other stakeholders.

Central to this process will be the expectations of the collaboration and this will be built on faith and hope (Smyth, 2008), giving rise to confidence and resulting in trust. The characteristics of trust were derived from the work of Lyons and Mehta, Smyth tells us, bringing the economic and social analysis of trust to relationship management. There are essentially two elements involved, the first is the self-interest part and the second is the socially orientated part, which demands certain obligations in a social network of relationships. This introduces reputation and advocacy into the mix and it is prolonged through experience.

Already in the United States the National Building Information Modeling Standard (NBIMS) of America has deployed a compendium of principles called a Capability Maturity Model (CMM) to facilitate this process, but where the National Institute of Building Sciences (NIBS) see problems is how to bring the strategists and the operations and maintenance people on board the grand coalition of consortia. Essentially, there are three pipelines and each has a different model and a different purpose (Harty 2010). But they all serve the same client and there is a need now for the client to step up to the plate and knock heads together.

Legislature has also a role to play here and as we have seen with sustainability, it can be done. Those authorities with clout, like the major agencies in the States such as the military or the state agencies in Norway who actually commission work and have a portfolio of properties to maintain are beginning to set demands which require a broad response possible only through consortia.

The strategic alliances made through these consortia will see like minds using the same tools to use, reuse and exchange data. There will be an acknowledgement of each stakeholder's worth and expectations for each stakeholder's input. The rewards will be significant and in proportion to each stake. There will also be continuity as the same methods and processes are honed and improved with each project. It will transcend procurement, involving the strategists and developers at start-up, the procurement team through construction and the facilities managers through operations until decommissioning and demolition.

11.6 Suggestions for Further Work

Many would say faced with this evidence that it is unbelievable that it has not been adopted in greater numbers. However, there are questions of ownership, which latently must be having an effect. IPD outlines that the collaborative process demands full commitment from all parties but there is a certain amount of entrenchment from the professional disciplines towards engagement. Before each stakeholder in the supply chain makes their contribution, there can be a stand-off, with the misconceived view of avoiding abortive work.

It is seen as a baton passing exercise where there are sign-offs at each work stage so that there is a finite body of work to be tackled by the remaining team members. It harks back to traditional methods and without a custodian or manager, it is stagnating. Confidence has not been established and more showcase projects are needed. With a defined role of adjunct manager, the situation can be reversed.

This coupled with the work that educational institutes are doing to produce technologists, leads me to believe that they will be the custodians of this new idea. This can be seen already with Frank Gehry who has established Gehry Technologies, an independent holding company that provides an indispensable service for him but who also act on their own as can be seen with Swire properties in Hong Kong.

Project certainty was an issue for the Swire Tower. GT became the BIM process consultant for this project and used their expertise to create the model prior to construction. The contractor updated the model as the building was constructed, so that the model could be used for operations and maintenance when the building was completed.

Finally, sustainability with its need for indicators is fostering a Code Checking environment to deem compatibility in the carbon neutral race. Coupled with Code Checking of building regulations and all related laws which can be codified or enumerated, this is leading to a beach head where clients will demand the *'today'* building permit over the typical three month turn-a-round often experienced by the conventional method. Clients like certainty and will drive this cause. The latent uptake by the professionals can be alleviated by the adjunct manager, a role that can be fulfilled by the technologist, who has the unique ability to understand the professional languages of all or most of the stakeholders, together with the know-how gleaned from an intimate knowledge of the model. They are trained to know what each profession does and they are trained to know what each project needs from the other professionals.

11.6.1 Finally

BIM will empower technologists to make better buildings, better constructions, and better environments. But bridges need to be built to align Facilities Management and financial modelling with the procurement (design) phases. Collaboration and sustainability demand this. This lengthening of the model's life cycle makes even more demands of the model and the modellers.

One option would be to establish the model on an independent plane, with an adjunct role of BIM manager emerging. This removal from the coalface to a more robust position, would steady the ship and offer a more consolatory arrangement. This would have the effect of making the adoption of and transition to BIM less risky. It would standardise the format and it would remove the technical obstacles, which are perceived as a barrier to many at the moment. Three levels of competence are envisaged:

the first where there is a hands-on approach where resources are required to physically integrate the various programmes and process together in the project

next there is a need for managers to control access to the model across the board ensuring indemnity and safeguarding the various stakeholders stakes

finally there would be consultants who are required to advise both clients and professionals on strategies and short, medium and long term paths, to massage the model adoption through the differing disciplines, as seamlessly as possible

Jim Jonassen, managing partner at NBBJ, one of the largest architectural firms in the world, has stated that:

'…the management of sharing, integrating, tracking, and maintaining data sets that make up the total project model is a new and rather awesome endeavour. While it will be done in collaboration with many modelling entities, it requires overall leadership' (Jonassen 2006b).

I firmly believe that the discipline best suited to that role is the technologist. But they need help. Educational institutions need to provide the resources to equip them, both at undergraduate and graduate level. New roles are evolving and the need to adapt and change needs fostering.

If they can establish a beachhead, then the rewards can be immense. Changes to the workplace will then see the BIM manager establish a holding role in effecting project realisation. This can eventually give the discipline professional recognition and redefine the whole procurement process.

James Harty, Copenhagen, May 2012.

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Appendices

Publication arising from the Research

The Impact of Coded Digital Design of Architectural Process and Management

IV08

International Conference Visualisation

VIS 2008

Visualisation in Built and Rural Environments

9-11 July 2008

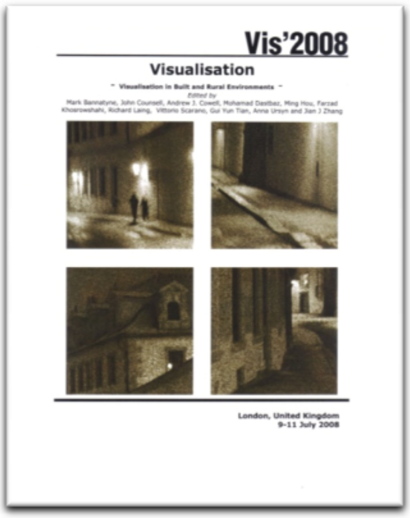
London, United Kingdom

IEEE Computer Society Order Number P3271

ISBN 978-0-7695-3271-4

Library of Congress Number 2008926131

BMS Part # CFP0843E-PRT



The impact of coded digital design of architectural process and management

James Harty, Richard Laing
Copenhagen Technical Academy, The Robert Gordon University
{jmh@kts.dk, r.laing@rgu.ac.uk}

Abstract

Building Information Modelling (BIM) is only a tool in the procurement of a building, but it is changing the way the process is achieved.

Having a single model which is used by all disciplines requires a different management structure and by consequence a restructuring of the resources required to complete a project.

These changes are encompassed in Integrated Practice and more recently Integrated Project Delivery, but professionals are not adopting them in great numbers.

It appears that it is clients and code checking that will herald the changes, and that these catalysts will drive and impact the building industry in a greater role than previously thought.

Keywords— **Building Information Modelling; IPD; code checking**

1. Introduction

The persuasive benefits of Building Information Modelling (BIM) are well documented and widely heralded across the construction industry. Nevertheless the next step in this process, their implementation and the adoption of Integrated Project Delivery (IPD) does not seem to be happening in equal measure (Eckblad, Ashcraft, et al.).

At last year's keynote lecture (IV07 in Zürich), Bob Spencer maintained that we could "Forget the Technology" meaning that it was no longer the lowest common denominator in any development. Rather, we could all look forward to delivery of end product. Interestingly at about the same time Integrated Practice (IP) moved onto delivery (IPD) (Eckblad, Rubel, et al. 2007) with a well formed set of criteria, procedures and guidelines to achieve this nirvana. But as I write, any enquiries to firms if they are implementing integrated practice are met with polite denials. Internally many are reaping the rewards of a central file but few if any are sharing it with other disciplines. This raises the big question, why?

The debate also encapsulates who will force this issue and this paper seeks to address this by naming "Clients" and "Code Checking" as the catalysts that will hasten the implementation of IPD within the construction industry (Young, Jones, et al. 2007).

The role of the client cannot be underestimated; many would claim that they were instrumental to Autodesk and DWG file formats becoming the de facto standard twenty years ago. Developers made it a requirement that all deliverables from a project had to be handed over in DWG (AutoCAD's file) format and in so doing they limited the scope of rival software packages.

Code checking will impose its impact in a more subtle method. Just as in net banking, most people can check their mortgages and go through exercises of something known as "what-ifs". Here they can see the effect of differing rates and repayment periods. This is generally taken for granted now but it is relatively new phenomenon. Previously a financial consultant or broker would make the calculations and present their version to the consumer. Objectifying the process allows people to easily and frequently check their liquidity and to way up their options. Many lending institutions offer this service free so that they can monitor the situation. So it has opened a whole new vertical market.

Figure 1 BIM's Matrix

Likewise Code Checking in the building market involves the writing of code, in XML format, of all building regulations, byelaws, local plans, municipal, federal and national statutes into computer binary code. Once this is incorporated onto a server users can then submit their proposals to check compliance against specific issues or ultimately for full building control approval. For this to happen two thing are necessary, the first is a model and this is provided by Building Information Modelling (BIM) and secondly a method which is being provided by such bodies as International Code Council (ICC) where their work on BuildingSMART (Conover) has been presented and demonstrated to great acclaim.

2. Historical Overview

Computer Aided Design (CAD) since its inception has merely automated the draughting process of drawing. Where a pencil previously laid a line on paper, CAD plotted that line on paper. Over the last ten years this process became more intelligent but essentially the common media traded between design teams, clients and authorities was a paper format (or a digital form of a 2D representation), from which ownership and authorship could be legally documented and claimed, or signed off and remunerated.

What computers are good at and where they get their name from is computing or number-crunching masses of data. As CAD became more complex and the virtual world expanded its boundaries, building 3D models of the building naturally grew as well. This 3D model could be sectioned, elevated and cut into floor plans which duly saw the light of day in reams of drawings which could be issued to the relevant parties in the contract of building procurement.

So what is the essential difference between a CAD model and a BIM model? Both are related and in many ways being familiar with a 3D CAD model is a good introduction to a BIM model. The big difference now is that CAD becomes a subset of BIM. The drawings are an automated subset of the model. Lines can no longer be placed on sheets of paper by the user. Indeed as the process grows, paper will probably experience a slow demise. But the reality of the paperless office is still in the middle-distance.

BIM is a collection of meta-data that has relationships and reactions with other pieces of meta-data. In other words it is a database; a collection of facts; true or false; yes or no binary operators. It can have a visual aspect of the CAD model, it can simulate acoustics, U-values, in fact any relationship that can be codified. The model can tell how many bricks are in the building, and if I index it to a cost model it can give me a price for the brickwork.

But the paradigm in modelling came when an acceptable method was found for sharing data. It allowed ownership to be retained of the various design team members' work, while allowing them to remain stakeholders in the project. Its motto is to do the work in one place and only once, no more checking, cross checking, and red-lining other consultants' drawings in the traditional method, but rather having an open source know-how which is not compromised with fears of one expert being undermined by another or lumbered with finding component collisions later in the procurement process, on site for instance.

Of course there is still checking but now the machine draws the operator's attention to collisions or inconsistencies, and requests a response. This response can be to make an alteration or to reject the proposal, but either way the problem is dealt with earlier in the process and not on site as was oft the case.

3. Building procurement

Building procurement is not like buying a car. It is a process, because there is a timeline from inception to completion which is outlined in work stages. This breakdown of the process means that each parcel can be billed and each party has expectations and rewards for successful conclusion of the stage. All architectural institutes have a phased plan of work stages and they all resemble each other with minor differences.

Whereas in a traditional model the most effort and hence the most resources are to be found in Work Stages Detailed, Final, Production and Tendering, there is an obvious shift in the process where things are being resolved earlier while production is becoming semi automated. This is pushing the bell curve chart of time over effort to the left. This tendency will be another chapter in my work.

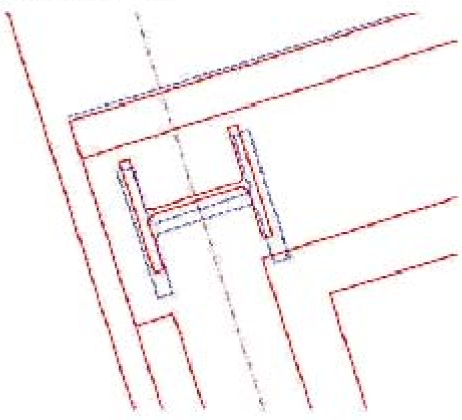


Figure 2 Differences in size and location of columns. Electronic overlay comparing two different drawings that had been approved for construction (architect's drawing – red, structural engineer's – blue). Source: www.productioninformation.org/images/final/FigS12.gif)

This is also manifest in RIBA's Plan of Work 2007 where the key work stages Outline, Detailed and Final, have been replaced with Concept, Design Development and Technical Design. On top of this it also draws attention to differences in tradition type contracts to more modern 'design and build' and partnering types. These moves are significant in the management role that I have incorporated into my title.

4. Design team operation

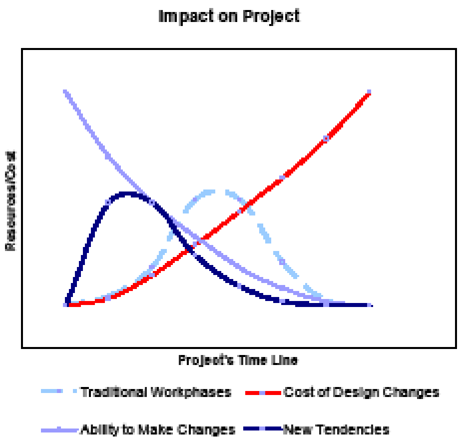


Figure 3 Bell-curve of Impact of Resources against Time

Coupled with this is another shift in how a design team functions and how the approved building work stages are defined. Traditionally the meatiest portion of any job would be developing the design to production stage and this is reflected in the fee distribution. If as is increasingly happening, all building parts are components and as the design becomes fixed, so too is all production, the fee scale will have to change to mirror this, meaning that the biggest chunk of the work is occurring in the earlier stages of the job.

Also the traditional procurement process is prone to errors on site which should now be significantly reduced, leading to savings in the building industry. The knock-on effect for wastage, sustainability and better production are endless. The industry has a very poor name to date in this regard but this is an area in which I do not intend to get too involved. Establishing a common set of standards is important for all of this to work.

Two options are available; to base everything on a lowest common denominator, so long as it is robust and comprehensive, or to allow major players to capture the market. It appears that although the latter option normally wins, in this case good sense might have prevailed and that Industry Foundation Classes (IFC's) are becoming the code that all can write to.

IFC's are common code that the various programmes are signing up to read/write. They can be seen as similar to DXF file formats in the CAD (old) days. DXF meant Drawing eXchange Format and although championed by Autodesk, the world's largest CAD vendor (some estimates claim 65%+ of the market) the other programmes had to follow suit, in order to facilitate data transfer, and to match deliverables required by developers.

DXF's shortcoming lay in the fact that each time the common standard levelled the playing field, a software upgrade raised the ante and new code was required to restore the balance. Such a situation was open to abuse and rarely could the latest features of any programme be transferred to another without cost, or penalty. There was, one could say, a vested interest in maintaining an imbalance and addressing that imbalance was never top of the aggressor's priorities.

IFCs' seem to have avoided this scenario, and are controlled by an independent authority. This is in part because the amount and variety of simulation and modelling is so broad that no one-solution provider has the where-with-all to offer a complete package. It also means that there is cross platform compatibility and an opportunity for customising different packages. In some of the demonstrations that I have seen, the same results in code checking can be achieved using completely different vendors and solutions. Whether the situation remains like this, remains to be seen. Currently there is a certain novelty about the product that has seen things develop openly.

5. Overall Control

Who will engineer these changes, and who will effectively manage them are major issues. This is where the technologist comes into the frame. Back in the eighties Philip Bennett writing on "Architectural Practice and Procedure" for the Mitchells Building Technology range of books (Bennett, Philip H. P. 1981) painted a wholesome picture of the architect in full command at the helm of building procurement. If you wanted a building you appointed an architect. The architect established the design team, tendered the work and administered the contract.

At that time most architectural institutional codes of professional practice (RIBA for example) forbid competition between architects for work. This had the professional ethic of presenting a solid front to the public that once a member, professional capabilities were guaranteed and certain standards assured. The market (in the mid eighties) in challenging this alleged monopoly forced the introduction of competitive fee tendering for appointments. While appearing straightforward in its consequences it also had the effect of polarising practices into specialisation and niche markets. For example if a firm had several hospital designs under its belt, it had earned a reputation that it could use to its advantage when fighting for the next contract. The image of a pipe smoking man on a high stool behind a mechanical draughting board, being able to switch from a house extension to a hypermarket master plan was over.

Ray Cecil in "Professional Liability" of about the same period (1980's) bemoans the carving up of the architect's cake by the "proliferation of consultants, each of whom has created an institute or association to protect and promote their interests" (Cecil 1989). At that time these included quantity surveyors, various engineers, landscape architects, town planners, differing designers, as well as sanitary, security, fire, space, acoustic traffic lobbies etc… not to mention energy, environmental impact and health and safety that we have today. He ends his work shrouded in gloom as to the prospect of the architect's role in the future.

Parallel to these developments has seen the emergence of project managers and technologists (as distinct from technicians) who have also identified a wedge of this architect's rich fruit cake as being fair game. Differing forms of contract from Design and Build to Partnering have also reinforced this situation. A traditional contract is becoming rarer and some would go so far as to say that architects might become marginalised, being hired in a sub contractual role for a limited design package, removing or managing a them as a perceived risk. So where has this shift come from and where is it going?

6. Integrated Practice

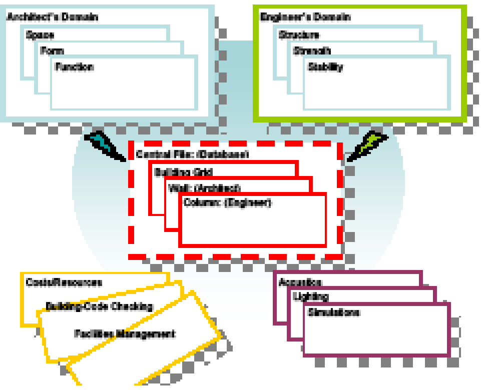


Figure 4 Single File Management

The definition of Integrated Practice (IP) is defined as:

"At its essence, it is a deeply collaborative process that uses best available technology, but goes beyond merely the application of digital tools, such as Building Information Modelling. Second, the Essential Principles are set forth as necessary assumptions in this collaborative process. Unless all parties are committed to these principles, integrated practice will not succeed. Finally, the Working Definition characterizes project workflow beginning with Building an Integrated Team and concluding with Integrated Closeout" (Eckblad, Ashcraft, et al.).

On a project in Hong Kong, the developer has even more positive testimonies. The project is Swire Tower at One Island East and here the technology is both aiding the building process, while acting and giving feedback, as the lower floors rise above the busy city streets.

"The design and procurement methods being used on the job represent a full integration of information into a single 3D Building Information Model. This 3D database is being used simultaneously to coordinate architectural, structural and mechanical design information. As well as producing detailed project specifications for cost estimation and construction scheduling".

"…discovering close to 2000 clashes leading to a cost saving of close to $13 million. The contractor is updating the virtual model as the building is being constructed, so that the model can be used for operations and maintenance once the construction is completed".

For the developers it was about project "certainty", knowing what was going to be built and at what cost. While this certainty is giving control back to the architect, it was the client who is instrumental in the procurement method. (Fong 2007)

7. Code Checking

David Conover of the International Code Council (ICC) (pConover) chairing their conference in November 2006 elaborates this whole code concept. He focuses on codes, standards and regulations. He describes Building Smart as a concept which is the opposite of building dumb. He looks at automated code compliance in the US, looking at US model codes, standards, federal state and local regulations that are based on those documents; working towards;

"…seamless communication between public and private sectors through building smart using smart codes,

"…the delivery of better and more efficient public services and enhanced public safety,

"…more timely and accurate approval and validation of design, construction and continued use"

"…who wouldn't like to get a building permit in a day or approval?"

All these claims are substantiated by the following speakers, namely Nick Nesbit (Conover) and Heather Dillon (Conover) who outline a method for abstracting the regulations into XML code, building a robust method of interrogation. This process finds out the things that apply and those which are excluded. It is then turned into XML mark-up code, embedding those concepts into the code which then can be changed into executable code.

Checking then involves testing each piece of code with the instance. Three results are possible; first is that it is not applicable, second that it is exempt and lastly that it is required and so passes.

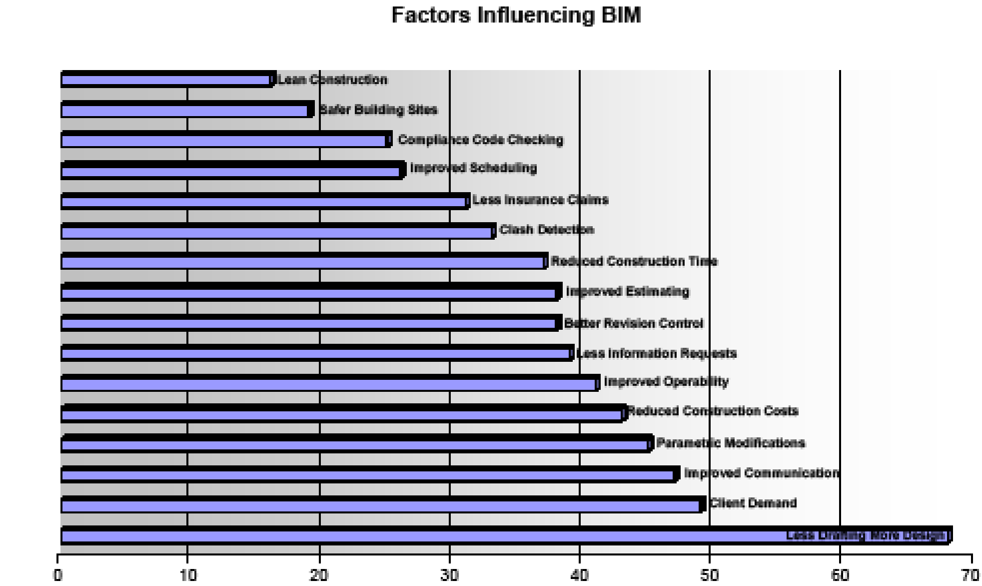


Figure 5 Factors Influencing BIM Source McGraw Hill Construction Research & Analytics 2007

8. Conclusions

This work is now entering a very exciting period. On the user front there is the modelling. It is being adopted across the board, and spearheading some major works, notably the World Trade Centre, Freedom Tower. Small firms are also becoming early adopters in a bid to offer optional services to clients.

Alan Baikie of Graphisoft argues in Building Design's 2008 World Architecture 100, an annual survey of the top architectural firms in the world, that larger firms are slower to invest heavily in terms of money, time and effort in their migration into the 3D realm, leaving the door open for nimbler firms (Littlefield 2008).

So if the pressure is not coming from within then what will drive the changes? Clients were instrumental in the DWG format twenty years ago, and they appear in the chart above as having 49% influence.

Secondly standards and regulations are being formatted and streamlined to common configurations. This can be attributed to IFC's unique position in the matrix, but it is also being driven by clients and authorities desiring to see some commonality through the mix. The fact that codes for a state in North America can be run successfully through a parser in Singapore shows much merit.

Code checking's appearance at 25% in the chart above is significant in that there is not widespread checking to date, so it must be determined as a wish-list item.

Lastly the profession is waking up to the fact that it has to change. This change might not turn out quite as they would like it but seeing the situation is half the battle. I am very fond of Jerry Laiserin's reference to Robert Heinlein's quote:

"The hardest part of gaining any new idea is sweeping out the false idea occupying that niche".

This coupled with the work that educational institutes are doing to produce technologists, leads me to believe that they will be the custodians of this new idea. This can be seen already with Frank Gehry who has established Gehry Technologies, an independent holding company that provides an indispensable service for him but who also act on their own as can be seen in Hong Kong.

Acknowledgements

This paper is taken from a doctoral study at The Robert Gordon University, supported by Copenhagen Technical Academy.

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Drivers for Change in Construction Procurement and its Impact on Management

Visualisation, 2009. VIZ '09. Second International Conference in:

Visualisation in Built and Rural Environments

Issue Date: 15-17 July 2009

On page(s): 138 - 143

Location: Barcelona, Spain

Print ISBN: 978-0-7695-3734-4

Digital Object Identifier: 10.1109/VIZ.2009.1

Date of Current Version: 04 September 2009

Drivers for Change in Construction Procurement and its Impact on Management

James Harty, Richard Laing
Copenhagen Technical Academy, The Robert Gordon University
{jmh@kts.dk, r.laing@rgu.ac.uk}

Abstract

Building Information Modelling (BIM) is transforming design and construction to achieve greater industrial-type procurement.

Both general contractors and reluctantly sub contractors are beginning to adopt both BIM and Integrated Project Delivery (IPD) to improve performance and to reduce waste due to poor information ranging from inaccuracies, delays, misplacement, inconsistencies and uncoordination right through all construction phases.

The synchronisation required to achieve this can best be supplied by technologists who have the ability to liaise with all the disciplines found in the construction process without compromising the specific roles found in the design team.

Keywords--- BIM; IPD; Sustainability

Introduction

When The Associated General Contractors of America (AGC) start talking about 'lonely BIM' and 'social BIM', to encourage Integrated Project Delivery (IPD), heads stir (McGraw Hill SmartMarket Report 2008). If I said that the association further recommends building an information model to members where the tender material is not digital, then people sit up and listen.

These are the findings of the latest BIM report from McGraw Hill where they cite better project results with fewer requests for information and less site coordination problems (79%), that there is better communication generally because of 3D visualisation (79%), and that there is a positive impact on winning projects (66%) in the first place, then the grassroots' level is beginning to mobilise.

61% of contractors are stated to hold a positive view towards BIM and one third is reporting a 100% return on investment (with several claiming 1000%). These trends suggest that while architects were early adopters of the technology (43% now are using BIM on 60% of their projects in the US), which will rise to 54% in 2009, that it is contractors who are expected to be the biggest growth this year (38% from 23%).

System Benefits

Up to 30% of construction costs (Laiserin 2009) can be wasted due to poor information in the guise of inaccuracies and delays in information, as well as the misplacement, inconsistencies and uncoordination of that information. The tab is picked up by project owners. A smart client would want to assuage this or manage it out of the equation.

BIM has always maintained that the use, reuse and exchange of information is its purpose and that its motto is to do it in the one place and only once. Once authored then it is available for analysis and these extractions are always up to date and streamlined within the model.

But the red line needs to extend all the way through the procurement process and in the same article Laiserin notes that subcontractors initially resisted the new methods because they could not see the benefits up front.

In two health care projects Santa Rosa Memorial and St. Joe's Eureka in California, the subs reluctantly adopted the procurement method. "The results in the field were such that every sub realised the benefit of all that up-front work such that every one of them came back and said I can't believe we weren't doing this sooner" (Bostic 2009).

This can also be paralleled in Terminal Five at Heathrow which was opened in 2008 on time and to budget. (Haste 17 September 2002) The project was delivered in a novel way where there was a no blame culture with proactive methods for realising the huge project.

This was presented in a Delivery Team Handbook, which as the main contract document outlined in plain English the challenges and the expectations for all parties, together with the rewards for successful completion to attain 'exceptional performance' (their terminology).

Their objectives were to manage out risk, manage in opportunity and to facilitate this to create enabling relationships. But no building project is risk free and where this risk lay and with whom was resolved by the client, BAA, becoming the owner of the project.

This is an issue I will return to because it has implications for the whole construction sector. Who is the owner, who manages it and how is collaboration delivered through all stages of the process? Is there a professional body that marshals the process or is there a relay team which passes the baton? Both scenarios have merits but neither are comprehensive solutions in their current state.

But it is not a situation for which there is no solution. Clients and developers are seeing the benefits and will not return to the wasteful ways of yesteryear. Swire Properties (Fong 2007) with One Island East in Hong Kong saved $13m on over 2000 clashes during the construction of their 141,000 m² office tower completed in 2008.

Stephen Fong, one of the directors, states that it was building certainty that impressed them most. During construction the model was constantly remodelled and updated to reflect the scheduling and processes that were happening on site, meaning the model at completion was a virtual copy of the building and ripe for acquisition for their facilities management.

At all times they were in control of time and budget, risk was therefore properly managed. This database was used simultaneously to coordinate architectural, structural and mechanical design information, as well as producing detailed project specifications for cost estimation and construction scheduling.

Policy Drivers

On a totally different tact and often from the diametrically opposed standpoint policy makers are looking for control and certainty within the built environment too. Policy makers are our politicians, lobbyists, legislators and civil servants who regulate our environment and set standards to which buildings must comply.

Sustainability is the broad term most used to describe the current state of affairs which needs addressing, and the course we must navigate if we are to reduce our carbon footprint. It is not the purpose of this paper to assess the whys and wherefores therein but clearly there is a problem demonstrating compliance and benchmarking in the new regime.

Analytical plug-ins can couple up to the model which take the model and test its compliance to various criteria. Thermal calculations and simulations, daylighting analysis, solar shading analysis, life cycle cost analysis, duct sizing and pipe sizing are, among others, some of the tasks that can be performed.

In Masdar City in Abu Dhabi (Economist 2009) the government are making a planned city which is to be carbon neutral. Monitoring systems are in place such as the Sustainability Management System (SMS) dashboard to check all materials and processes used in the city.

While the theory seems fine their biggest problem is that there is a talent shortage of people with the know-how to implement the proposals. This has led to time delays and cost overruns and a large degree of chaos in procuring this urban dream. It begs the question of how to readdress the problem and of who should manage the situation.

Management

On a company basis managing the day to day life of the business is seen as an administrative cycle, and is usually overseen by human resource personnel. The core business is usually attended by professionals, be they architects, engineers, or contractors. Within the core domain, each profession has nurtured and nourished their name, title and competences.

Each has developed its own language and protocol and each has delineated its terms of engagement with other professions, through professional bodies and codes of conduct. While each has or should have the greatest respect for its team members, and some have developed very close working relationships with other team members, there is still minimal cross fertilisation within the industry, and acceptance of the status quo.

Some would say this is a good thing as it allows the stakeholders in the project to concentrate and devote their resources 100% to the job in question. The construction industry is one of the oldest and is living proof that this works. But others point to the wastage and poor productivity within the industry and want improvements. How this is achieved is the state of play today.

Traditionally the architect was the first person of contact for any building work and as lead consultant also took on the role of assembling the design team, preparing the tender and administrating the contract (Bennett 1981). With differing types of contract today (design and build, turnkey etc...) this defined role is vanishing to be replaced by the Project Manager (PM)(Cecil 1989).

No building is a one man accomplishment and collaboration is essential to procure even the simplest of buildings, but as they grow in complexity, big issues of control raise their heads. Who is this project manager, is it a manager coming into construction or the other way around? What are a project manager's competences and education? What are their qualifications? Are loyalties served to the client, the consortium or society in general?

Winch (Winch 2002) claims that the management of construction projects is a problem of information or lack of it, for decision making. Schön (Schön 1987) reflects on how design decisions are made. He looks at how design is learned.

"Designers juggle variables, reconcile conflicting values, and manoeuvre around constraints: a process in which, although some design products may be superior to others, there are no unique right answers".

He also has the classic line "I can tell you that there is something you need to know... But I cannot tell you what it is in a way you can now understand".

Emmitt (Emmitt 2007) on the other hand deplores the state in which architects qualify, having no management skills, in comparison to other professionals, resulting in difficulties in relating with other project members and frequently finding themselves excluded from important decision making.

Design Team Communication

How is design managed? What is the process and is it linear? How is a building procured? Is it the synthesis amidst complexity as Schön claims? Whatever your opinion tools are required to accomplish or execute the work.

Dissemination of information can be done through issue of drawings with the subsequent checking and cross checking, or through the virtual model (BIM). The model is a graphic representation of essentially a database. How it is portrayed is governed by the graphical interface and a filter system.

This means that the client can be given a view of the model showing the data relevant to him, be it area take offs, colour coded accommodation, square meterage, or photo realistic renderings. The engineer can receive only the structural shell; the service engineer can have the rest of the building greyed out drawing attention only to the services and so on.

At tender stage only certain parts of the model can be released to the tenderer or bidder. It can be time managed for the duration of the tendering period through passwords on a web portal, and it can withhold the design teams own calculations or estimates without compromising the integrity of the project.

Giving access to the contractor opens a whole new world of control and certainty in that now any changes or developments in the production are intertwined to the model ensuring no clashes or collisions and harmony through the procurement phase.

Releasing the model to the sub contractors warrants that the work is compatible with other sub contractors and that the coordination of the whole operation has been held in one place, essentially the model.

Throughout there has been an understanding of the differing professional roles without compromising or hindering them.

All this is achieved through working setups. A setup is a collection of data that has specific properties. These include ownership (temporary or permanent), interference in how the object reacts to other objects (be it a column embedded in a wall or whatever), hierarchies in how different parts behave with the different disciples (meaning if the end gable is moved out three meters, by the architect then all of his domain goes with it (as in roofs, floors etc...) but that other domains must await referral, leaving the model in limbo until the conflict is resolved.

The rules and behaviours can be easily parsed using the out of the box software, or in the hands of a programmer further enhanced to adopt parametric qualities. Because it is an open architecture (open ended – IT wise) it needs careful management otherwise potentially horrendous scenarios can happen.

What all this conveys is that there is need for someone to manage the model and manage the process. That role has been fostered by the architectural institutes, seeing their role diminished in the general context of building procurement. But the question must be asked have they the technical nous to deliver it.

They have also adopted the sustainability ticket in order to try and regain their mantle at the top of the pile within the industry, but can they quantify and follow their claims with indicative measurement?

In a paper at the AIA 150 convention (Jonassen 2006) one slide asked "Do you believe that the current design and construction processes can be improved? The findings were Yes: 87%, No: 1% and Not Sure: 11% of which 46% were architects.

The following slide asked: How concerned are you about...? The spread in these answers between owners and architect showed a disparity of -27% in the inflation of construction costs. -16% in inadequate construction documents and -13% in Design Errors and Omissions.

Slide 57 develops the notion of the architect generating the model, before it is analysed for cost. Then the design engineer models the building systems followed by performance analysis. The model is then used for clash detection, pre-fabrication and sequence analysis before it is handed over to the owner for life cycle maintenance.

While appearing rational, there is no coordinator identified or manager appointed, and this is also raised by James O Jonassen (Jonassen 2006) who proposes an important new adjunct role, the model manager, which may become a business for some.

He goes on to say that "...the management of sharing, integrating, tracking and maintaining data sets ...is a new and rather awesome endeavour *(and it will require)* overall leadership."

Education

At the Copenhagen Technical Academy (CTA) in August 2007, Autodesk Revit Architecture was introduced to replace what was then Autodesk Architectural Desktop. Several alternatives were tested but with IFC compliance assured on the decision day, August 2007, Revit was picked.

It was intended to be run as a pilot with the second semester, but word of mouth spread like wild fire and by September the number of licenses converted had doubled and by the start of the next semester 840 ADT licences had dwindled to 200 and Revit had soared to 880. The residual ADT's relate to older students who had based most of their study in ADT and who elected to continue with it to graduation.

The school operates a studio like environment where the semester is project driven through group work, reflecting or simulating as far as possible a real drawing office. It is a three and a half year Bachelor degree in Architectural Technology and Construction Management, and subjects include: production, design, business economics, administration and law, surveying and recording, and general basics. This is delivered by architects, structural engineers, construction managers, technologists, project managers, mechanical and electrical engineers, facility managers and communication consultants. There is a relatively high teacher/student ratio and an intensive number of hours taught.

Teaching resources at the school reflect largely on what is found in the industry and while there are standard bearers towards this new technology, there are also naysayers who resist it vehemently. This is to be expected and it brings debate to the studio.

It also puts the ball firmly in the court of the students if they are to adopt the technology in their work, because often the theory (and practice too) is given with regard to older ordinances, effectively requiring double or parallel work (ie outside of the model) and often it requires the technical evangelists to show the possibilities of the software without knowing the precise methods. This means the student must bridge the divide balancing the well grounded theory with alternative methods.

Either way it requires an act of faith in the student, but seeing is believing and early adopters are vital in getting the new norms accepted. Often one good apple in the class lifts the general perception tenfold (thankfully, I hear my learned colleagues say).

A better synergy among all concerned would be welcome. But the students also raise issues of will they be employable upon graduation if they only know how to drive a Ferrari. Many responses are forthcoming, personally I find, through personal experience that having learned one programme, that there is a mindset that allows another piece of software to be quickly assimilated, and no one knows better that such is the situation.

Drivers for Change

Code checking has been identified as a driver towards IPD, (Conover 2008) and the recent analytical software for sustainable checking underlines the process of generating reports to reinforce or alter design decisions. This gives feedback and fosters a dialogue which can only improve the whole process.

One of the biggest issues will undoubtedly be ownership of the model. The obvious answer is the building owner since this follows the money trail. It also opens doors for client advisors and a plethora of consultant services. But there is also intellectual ownership and copyright not to mention physical changes of ownership throughout the building's life.

Drivers for change generally have a momentum of their own. Qualified observers have a responsibility to report and document that process, so that it can be monitored and debated with balanced insight. Construction procurement is undergoing a profound change, and this is patent within the school and borne out by the students work.

Already we can see students being handpicked to introduce BIM skills into the local work force. This can happen on an ad-hoc basis where students are employed to evaluate the new technology in a controlled environment, typically in a test case, or where they are hired to disseminate the new skills through the workplace on an actual job, or even to drive the new technology throughout the enterprise where management has adopted the new mantra.

Conclusion

In conclusion, there can be no doubt that change is upon us and that it is here to stay. Its impact can be seen in all aspects of the industry, from policy makers to hod carriers, and from designers to lock smiths.

Currently what is driving the band wagon is a mixture of guiding legislation and actual procurement. This might be due to a number of influential factors outside the industry and possibly a number from within. Ironically the financial meltdown is in many ways being mimicked by an equally dangerous environmental crisis.

If the technologist can establish a beach head, then the rewards can be immense. Changes to education are required to allow this to happen. Changes to the workplace will then see the adjunct manager establish a holding role in effecting project realisation.

This can eventually give the discipline professional recognition and redefine the whole procurement process. Already schools of the built environment are aligning courses to technologist undergraduate courses, coupled with management postgraduate courses. There is a ground swell of support both from within educational establishments and industrial lobbies to adopt these new technologies, and that is to be applauded.

Acknowledgements

This paper is taken from a doctoral study at The Robert Gordon University, supported by Copenhagen Technical Academy.

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Removing Barriers to BIM Adoption: Clients and Code Checkers to Drive Changes

Chapter 24 (p. 546-560) 'Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies',

Publisher: **Information Science Reference** (15 Nov 2009)

IGI Global

Author(s)/Editor(s): Jason Underwood (University of Salford, UK); Umit Isikdag (Beykent University, Turkey)

Release Date: December 2009

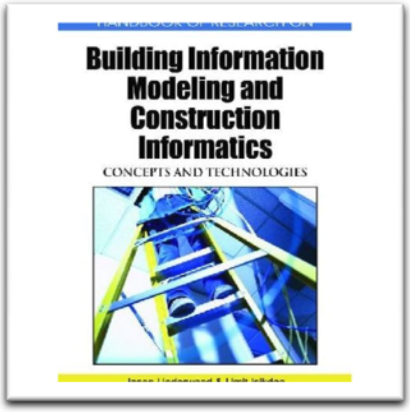
Pages: 1-756

DOI: 10.4018/978-1-60566-928-1

ISBN13: 9781605669281

ISBN10: 1605669288

EISBN13: 9781605669298



CHAPTER 24

Removing Barriers to BIM Adoption; Clients and Code Checking to Drive Changes

James Harty, Richard Laing
Copenhagen Technical Academy, The Robert Gordon University
{jmh@kts.dk, r.laing@rgu.ac.uk}

Abstract
Building Information Modelling (BIM) is not only an authoring tool for architects and engineers, but also for all stakeholders in the building programme procurement process. Analysis tools like code checking of building regulations and environmental simulations that can report on heating loads, daylighting and carbon use will push the adoption of intelligent modelling faster and further than previously thought. The benefits for clients should not be underestimated either and some are already reaping them where project certainty is to the fore. However, the professional language that architects and engineers espouse is a latent force that can run counter to fostering collaboration. An emerging professional, the Architectural Technologist, can bridge that divide and adopt the adjunct role of manager in the integrated project delivery.

1. Introduction

Building Information Modelling (BIM) has been around a number of years now but its unilateral adoption has been slow. There are a number of issues here and one is the entrenchment of the different professionals and their methodologies. While it is absolutely right for an architect to control aesthetics and space, nobody questions that it is equally right for the engineer to control the structure and/or services. What is questionable is their mindset and language, if there is to be the real possibility of shared data, and genuine cross-discipline collaboration.

Sharing data and collaboration does not sit well with the disciplines' involved in the building industry. Cicmil and Marshall (2005) elaborate and elucidate a scenario of pseudo collaboration, where a two-stage tender is hopelessly inadequate due to the intransience of the quantity surveyor (QS) in their perceived role of advisor to the client. There is no mechanism in place to allow the QS to enter into a collaborative state with the main contractor and no desire to either. Cartlidge (2002) probably summed it up best with "…quantity surveyors must get inside the head of their clients".

There are many forces at work to discourage collaboration (Porter 2007) including the treat of new entrants, the buying power of both suppliers and buyers, rivalry among existing firms and the fear of substitutes. These strong entrenched attitudes (Walker 2002) in the design construction divide were addressed in the procurement of Heathrow's Terminal Five (T5), delivered on time and to budget (Haste 2002), where such an environment was nurtured and encouraged (Ferroussat 2005). It was based on the principles specified in the Constructing the Team (Latham, 1994) and Rethinking Construction (Egan, 1998). Had BAA followed a traditional approach T5 would have ended up opening 2 years late, costing 40% over budget with 6 fatalities (Riley, 2005); this was not an option for BAA (Potts 2002). Carefully defining responsibility, accountability and liability, the focus was on delivery. Remmeration was based on reimbursable costs plus profit with a reward package for successful completion. This incentive plan encouraged exceptional performance with the focus on the issues of value and time. Value performance occurred primarily in the design phases and was measured by the value of the reward fund for each Delivery Team and calculated as the sum of the relevant Delivery Team Budget less the total cost of the work of that Delivery Team.

The time reward applied only during the construction stages. Here, worthwhile reward payments were available to be earned for completing critical construction milestones early or on time. If the work is done on time, a third went to the contractor, a third went back to BAA and a third went into the project-wide pot that would only be paid at the end (Douglas, 2005). There was a no blame culture meaning that if work had to be redone the fault was not apportioned to anybody but the rewards would either be reduced or not awarded at all. This had the effect of applying a kind of peer pressure where it was in the interest of all parties not to fail, which created a place where the vertical silos of expertise were traded for viaducts of collaborative techniques. BAA took out a single premium insurance policy for all suppliers, providing one insurance plan for the main risk. The policy covered construction and Professional Indemnity (Potts, 2002).

[Place Fig.1 here]

Figure 1. Heathrow Terminal 5 © James Harty 2008

Sadly, while T5 was collaborative it was not a virtually modelled project and when the first satellite building was recently commissioned this method was abandoned for a traditional method of procurement. Questions must be asked as to how much sway the various disciplines and the entrenched methods had in this change of mind. Or was the management chain of command too onerous. The team structure had a hierarchy of several layers of management; the development team, the project management team, delivery teams and task teams. There was no common model to reference and the level of comfort of the construction manager may not have been too cosy. Construction managers have the lowest level of comfort, working with other professionals (under 20%), while owners, architects and engineers have nearly twice that level (Eckblad, Rubel and Bedrick, 2007), meaning that while the traditional demarcations have a good *bonhomie*, issues arise if the industry can afford this luxury anymore.

2. Background

2.1 The Professional Architectural Technologist

Developments are underfoot to establish the technologist as a professional body with the ability to sign off work. The following is generally a synopsis and distillation of the relevant points in the new syllabi and proposals for content for a new course being tabled by the Dublin Institute of Technology (DIT).

To address the educational needs of the professional architectural technologist, the Dublin School of Architecture is intending to replace its three-year Level 7 Ordinary Bachelor's Degree with a Bachelor of Science (Hons.) in Architectural Technology (Level 8) together with a Postgraduate Certificate in Applied Architectural Technology (Level 9). The Postgraduate Certificate in Applied Architectural Technology is intended to lead to the award of a Master's Degree.

"New methods of design and procurement have led to changing roles within the design and construction teams, with Architectural Technologists frequently playing a key role as technical designers, and in doing so emerging as professional partners to architects, engineers and surveyors in the building design process.

...The RIAI welcomes the emergence of honours degrees in architectural technology ... and seeks to work with the educational institutions in developing a context for professional accreditation of the new degree programmes.

... Whether or not Registration is introduced, professional membership and accreditation systems will have to make provision for these developments one way or another"

- Royal Institute of Architects in Ireland, President James Pike, November 2006

The vast majority of Irish Architectural Technology Graduate Network (IATGN) members have expressed a strong interest in obtaining further qualifications at undergraduate and postgraduate levels, where among other things the technologist should maintain proficiency in emerging computer application software in information technology in general and building information modelling in particular. The technologist should play a leading role in information management and quality assurance processes (Bachelor's Degree of Science (Hons) in Architectural Technology & Postgraduate Certificate in Applied Architectural Technology: Self Study, Part A - Dublin School of Architecture January 2009).

The issues raised are many and varied. They include title, competences (limits and overlaps relative to the competences of an architect), function (responsibilities arising from competences as employee and in self employment), recognition of experience in place of formal qualification, authority to sign documentation, variable education standards, professional support for self employed technicians, and the implications of Building Control Act, especially the technical assessment process.

The impact of European Union policies and regulations on the building industry over the last decade has been considerable. Legislation in the areas of Building Control, Planning and Health & Safety, alongside the ongoing development of EU standards and other codes of practice, continue to inform and control an ever more complex legislative environment.

The EU Energy Performance of Buildings Directive (EPBD) requires the development of energy calculation methodologies and EPBD certificates of energy performance. Building Energy Rating (BER) and Dwelling Energy Assessment Procedure (DEAP) energy performance assessment have been developed in response to this, while Building Regulations have been revised to include for higher energy performance of buildings and renovations. All these developments require additional technical training.

The Bologna Declaration (1999) recognises that European higher education systems face common internal and external challenges related to the growth and diversification of higher education. Its goal is to create, by 2010, a European space for higher education in order to enhance the employability and mobility of citizens, and to increase the international competitiveness of European higher education.

Its objectives are the adoption of a common framework of readable and comparable degrees and the introduction of undergraduate and postgraduate levels in all countries, with first degrees no shorter than 3 years with ECTS-compatible credit systems

With the changing nature of building procurement and construction systems in recent years, some graduates have established architectural technology consultancy practices which offer technical consultancy services to architects in areas ranging from fire engineering and energy design to technical design and information packages. Opportunities exist for the development of technical design consultancies with the proposed new academic programmes aiming to address this need.

As a result of this, the intended outcomes are to:

Engage critically and collaboratively with the architect in the building design process, using knowledge and understanding of historical and contemporary developments in architecture and architectural technology, with an understanding of the architectural design process.

Engage critically with structural, mechanical, electrical, fire, acoustic and other engineering disciplines, applying knowledge and understanding of engineering design in the management and coordination of consultant design input in the building design process (ibid).

Engage critically with cost control consultants, applying knowledge and understanding of cost measurement, quantification and control, and the role of the QS in monitoring the cost impact of technical design decisions in the building design process (ibid).

Engage critically with domestic and nominated specialist design sub contractors, using an understanding of design and construction procurement processes and contracts in the management and coordination of contractor design input at post tender and construction stages of the building design process (ibid).

Engage critically with the building contractor in the building design and construction process, using understanding of site practice and procedures and of building contracts (ibid). No other institution is offering this degree of critical engagement at the moment in an official capacity, while many are seeking to address this new development soon. Also it should be noted that only within the technologist field is there the wherewithal or the ability to dovetail all the above mentioned collaborations in a meaningful way. Sure enough a hierarchical management structure can supervise the process but having this intricate interaction with the other disciplines is the technologist's domain.

2.2 BIM at DIT

The application of these aims is then further developed into modules for the delivery of the course content. The course modules are intended to run over the latter three years of the four year undergraduate programme. There is a progressive and comprehensive build-up to the graduate's education, which structures the exposure and presupposes achievable outcomes so that the levels are realised in tandem with the student's studio work.

Module 1 aims to develop the learners understanding of the role of the architectural technologist on the design team, using the building model to explore the collaborative roles of the architect, technologist, structural engineer, mechanical & electrical engineer and QS in the building design process.

The learning outcomes are that the digital model is used to develop the architectural design in collaboration with the architect/architectural student, that it is used to coordinate engineering design input in collaboration with the structural and mechanical & electrical engineer/engineering student, and that it is used to coordinate cost control input in collaboration with the QS/QS student.

The design process is to compare and contrast the roles of the architectural technologist, architect, engineer, quantity surveyor on the design team, and to participate in design team meetings playing a technical design development and coordination role

Module 2 aims to develop the learners understanding of the role of the architectural technologist in the construction process, using the building model to explore the input of the specialist design sub contractor / fabricator and construction manager in the building design and construction process.

The learning outcomes are to demonstrate an understanding of interoperability, to use the digital model to coordinate sub contractor design input and to use the digital model to extract and elaborate construction detail in collaboration with the construction manager/construction management student

The construction process is to compare and contrast the design roles of the design team and the roles of the domestic, nominated, specialist and design subcontractor and building contractor, to describe the sequence of principal events in the design and construction of a building, to compare and contrast traditional subcontractor drawing development coordination systems with BIM, and to participate in construction team meetings playing a technical design coordination role

Module 3 aims to develop the learners understanding of the use of BIM on facilities management, post-construction measurement and geomatic data integration using a variety of related software applications. The learning outcomes are that on completion of this module, the learner will be able to use BIM for building energy performance analysis, to compare and contrast the roles of the architectural technologist and the geomatics surveyor, and to participate in construction team meetings playing a technical design coordination role (Bachelor's Degree of Science (Hons) in Architectural Technology, Part B - Dublin School of Architecture January 2009).

2.3 PG Cert Applied Architectural Technology

The PG Cert aims to develop and deepen the learner's sense of professionalism, building on their undergraduate learning and their experience in practice, and provide the opportunity to plan career development and prepare for further study in areas of architectural technology specialism.

The aim of the Construction Legislation module is to develop and deepen the learner's understanding of construction legislation, regulations, codes and standards, building on their undergraduate learning and their experience of construction legislation in practice.

The aim of the Regulations in Practice module is to develop and deepen the learner's understanding of the building regulations in general, and the areas of fire safety, universal design, and sustainable design in particular, building on their undergraduate learning and their experience of building legislation in practice.

The aim of the Procurement and Contracts module is to develop and deepen the learner's understanding of the building procurement process and the use and application of building contracts, building on their undergraduate learning and their experience of construction legislation in practice.

The aim of the Management & Quality module is to develop and deepen the learner's understanding of the various management processes involved in the practice of architectural technology, building on their undergraduate learning and their experience of construction legislation in practice (Postgraduate Certificate in Applied Architectural Technology, Part B - Dublin School of Architecture January 2009)

Generally it can be seen that the modules mimic and duplicate the Professional Practical (Part III) exam for architects. A new post has been advertised and filled for a senior lecturer to run both courses with what seems to be identical content. The only difference is that the architect will complete this after a minimum of three (bachelor) plus two (currently a diploma) with one year practical training and two years professional practice (i.e. 8 years), whereas the technologist will require an extra year in total (9)".

Table 1. Department of Architectural Technology (DIT): Planned programmes.

[Place Tab.1 here]

These are significant changes and developments in the course structure. Likewise it also shows a definite tendency to position the technologist in a more professional light. In Spain the *architecto* and the *tecnico* sign construction contracts jointly. In The Netherlands certain master's courses allow technologists to become registered architects. Many countries have technologists that go on to complete an architectural qualification but many IATGN members see this as a damning compromise and a general disservice to technologists.

The course content also reflects the growing importance of BIM as a procurement tool.

2.4 Design and Procurement

Requests for information arise because of inadequate documentation and drawings in the first place. Christopher Alexander (Notes on the Synthesis of Form, 1964) describes three scenarios of designing content and form. The first being in unselfconscious societies where the building process has not changed through many generations and the content relates directly to the form, since the person building it lives in it where the community has established workable solutions. The second happens when artisans or craftsmen emerge to do specific tasks within the community. It is not their house so repairs and chances for mistakes become possible.

This is not due to any lack of quality in the work but because of an increase in the magnitude and complexity of the work. This is a semi-conscious state and the way the work is done with an image of the content required together with an image of the form delivered. The last scenario is a formalisation of this process where the images are formalised (a formal image of content and a formal image of form) so that they can be better recognised and controlled. This is a fully conscious state and the building industry essentially endorses this method with formal procedures for checking and controlling the work that procures a house or whatever.

This can be seen with the various parties working together to produce a building. Previously light tables would be used to correlate the various tasks, or overlays of digital drawings could provide a method for formalising the process being undertaken. But the light table does not even feature in the cartoon industry today and like the balls of twine that QS's used to take off measurement are long consigned to the trash can. More common is the emergence of technical meetings now occurring on site, often in parallel with the architect's site visit, but chaired and run by technologists. These usually comprise of the subcontractor and the technologist who puts work into context, as well as the sequence and first/second fixes required to complete the work.

This avoids witnessing such situations of a bracing member finishing up one meter inside an external wall because nobody told anybody what to do, where it was done knowing full well that there would be extras to rectify the error. Also complete facade panels being delivered on site and mounted where the openable lights clashed with the position of the stepped back columns, meaning they were unopenable. These meetings avoid the need for rework and try to keep everything up to speed and on time, if there is a critical time path. But this happens on site and increasingly the model can resolve these situations earlier in the studio. This situation also highlights the demise or the architect/clerk of works relationship.

The paradigm in modelling came when an acceptable method was found for sharing or distributing data. It allowed ownership or more importantly intellectual rights to be retained by the various design team members' work, while allowing them to remain stakeholders in the project. This cannot be underestimated. Its motto is to do the work in one place and only once, no more checking, cross checking, and red-lining other consultants' drawings in the traditional method but rather having an open source know-how which is not compromised with fears of one expert being undermined by another or lumbered with finding component collisions later in the procurement process, on site for instance.

This has now moved the debate further in that the stake-holdings (of ownership) in the model have a requirement for overall co-ordination. There is a need for the management of the sharing, integration and tracking as well as maintaining the datasets which Jonassen (2005) sees as a rather awesome endeavour. The situation is poised for the introduction of the BIM manager. There will be a need for overall management and leadership but where it will come from is now the major issue for all concerned. If the model is to be hawked from one discipline to the other then where is the co-ordination? Who ensures that it is kept functional, or merely operational, for want of a better word?

Under traditional project procurement, other disciplines in the design team could be reluctant to get involved above and beyond basic and initial observations before the architect had substantially formed the building. This was so for many reasons, primarily because it would be abortive work if the architect made a litany of changes, which was often the perceived case. Generally the other team members were there at this stage to ensure that space was allocated for when they got involved at a less turbulent stage. Typically, this would mean a structural engineer staking a need for a certain size ceiling void for the placement of structural members together with a service engineer who would place all ducting and pipework in the same void. This was seen as an appropriate level of involvement at this time and was seen as adequate cover for their involvement later. There is a professional language and protocol at work. Traditionally too this led to exactly where problems occurred on site when there had not been thorough cross checking of the various disciplines' work to avoid such errors. The effect of this initial approach meant that it could occupy much of the remaining (project) time being resolved.

To alleviate this problem the various disciplines often shared their drawing files so that overlays and references could be checked and rechecked by the differing parties. However, the problem with this was that only those areas which had been drawn could be checked. If a difficult part of the building had not been fully drawn then it could not be fully assessed or resolved until it came to light, often on site, leading to additional instructions, delays and counter claims.

This applies equally to more straightforward parts where the fault was not so obvious. Generally the experienced practitioner learnt this through hard won knowledge from previous projects; it was a 'learn-as-you-go' scenario that came at a price the industry has been happy to pay to date. Also it could only be tolerated on projects following a similar vein. New ground heralded a new battle field, with all that entailed.

Young, Jones and Bernstein (2008) see the value in BIM being the integration of the tools and the process. The AGC BIM Forum (*BIMForum.org - home*) sees this as a dichotomy where the individual users are identified as 'lonely BIM' as opposed to the IPD practitioners which it calls 'social BIM'.

BIM has intelligent objects and distributing them makes sense. Authoring tools allows design to be embedded, construction to be sequenced, and scheduling to be broken down into elemental works; while a costing model can be implemented, fabrication can soon replace traditional shop drawings and ultimately an operational model can be handed over to the client. While Young et al (2008) see architects rejuvenating themselves as the main drivers of BIM with 40%, contract managers and general contractors come in at second on 18% with a combination of both at 14%. Owners are next at 13%. However, this is the current situation. It remains to be seen if architects can remain at the controls.

2. 5 Project Certainty

On a project in Hong Kong (Fong, 2007), the developer saw things differently. The project is Swire Tower at One Island East and here the technology has both aided the building process, while acting and giving feedback, as the lower floors have risen above the busy city streets.

"The design and procurement methods being used on the job represent a full integration of information into a single 3D Building Information Model. This 3D database is being used

simultaneously to coordinate architectural, structural and mechanical design information. As well as producing detailed project specifications for cost estimation and construction scheduling... (it discovered) *...close to 2000 clashes leading to a cost saving of close to $13 million. The contractor is updating the virtual model as the building is being constructed, so that the model can be used for operations and maintenance once the construction is completed"*.

For the developers it was about project "certainty", knowing what was going to be built and at what cost. While this certainty gave control back to the architect, it was the client who is instrumental in the procurement method (Fong 2007). Aouad (2004) noted many trends against BIM adoption in Hong Kong and they are worth naming as they surmise the general thinking at the time. They included that there was no perceived need to produce BIM, existing CAD systems were adequate, BIM would not reduce draughting time as it was not flexible enough, it was not required by clients, and finally it was not required by other team members. (*Papers : The utilisation of building information ... [paper 2005/8].*)

Comparing this to the McGraw-Hill Smart Market Report on Interoperability ('Young, 'Jones, & 'Bernstein, 2007) a mere three years later there are stark differences. Under factors influencing BIM, 68% believe that there is less draughting, 49% cite client demand, 47% improved communication and out of nowhere comes code checking at 25%. There are many others but the remainder of this chapter will focus on code checking and its implications. This will also impact on client demands and hopefully make the case for the new technology.

There are many causes for this and prime among them was the American Institutes of Architects (AIA) national convention in Las Vegas in September 2005 where Thom Mayne (Strong, 2005) said the immortal words: *"If you want to survive, you're going to change; if you don't, you're going to perish. It's as simple as that"*. The AIA championed Integrated Practice, Interoperability and Integrated Project Delivery, which are all variants of the same thing; collaboration. The other significant fact was that when Autodesk acquired Revit which Chuck Eastman claims had the same effect as legitimising BIM.

3. Main Focus

An allegorical tale is of a student, returning from practical training, at a young practice that had recently won a provincial town competition for a new public building in the town square. Essentially it had no right angles and the municipality made it a priority that there was complete disabled access in the winning scheme. In the first instance it was modelled in Sketch-Up to satisfy the architects that the new situation met with their design criteria. This demonstrated a good knowledge of the relevant building regulations and their application. Then it was modelled in ADT in order to demonstrate to the structural engineers that their A4 key junctions worked precisely where they had been chosen but failed when the section line was moved a mere meter up or down.

Close collaboration with the engineer ensured a pin jointed solution could be employed resolving key parts of the building in the studio and not on site had the errors not been highlighted when they were. This was one of the reasons for the school's change to a modelling basis soon afterwards, in an attempt to minimalise the number of programmes students' needed to master. It is also an example of the technologist understanding both discipline's modes of working and responding appropriately to both. Finally, it illustrated client requirements being assimilated and the solution being fittingly presented, by the technologist (student).

Another factor, parallel to this legitimisation process, was that computers were providing a means of building previously unbuildable works for architects like Frank Gehry (*DIGITAL PROJECT - frank gehry.*). He set up Gehry Technologies (GT) to realise his unique forms.

Two consecutive projects are the Walt Disney Concert Hall in Los Angeles and the Guggenheim Museum in Bilbao. With regard to the concert hall, Gehry found himself beset with cost overruns and the project was shelved for a period due to lack of funding. It finally cost an estimated \$274 m. which is more than five times the \$50 m. budget at the start of the job.

In this situation Gehry has said that his position went from having the parental role at the start of the project where he was in control, to an infantile one when cost overruns threatened to scupper it. He says: *"...then the construction people say just that: we know what to do - straighten out a few things - we'll get it on budget. Of course the owner finds himself very confused about this…"*, and the focus moves from the architect to the contractor. The architect has lost face in the eyes of the owner and the contractor is now seen as the saviour, if the building is to be realised. He goes on to cite that: *"in our time you have the Sydney Opera House where poor Jørn Utzon gets clobbered. It's a horrible story. It practically destroyed the man's life"*.

Conversely, when tendering came about for the Guggenheim Museum in Bilbao, GT sent a member of staff over to Bilbao to train the bidders in the software prior to tender, to show them how to extract the quantities of this complex building where not one piece of steel is the same. This was pretty unique in 2004. The result was that *"...they came in 18% under budget on just the steel alone. There were six bidders and the spread between them was 1%. Now that is knockout, rare, you don't ever get that"* said Gehry seeing more than a fifth being knocked of the budgeted estimate.

In the Walt Disney instance, not having the model and being forced to overlay 2D drawings to collaborate contributes to massive cost overruns. In the Guggenheim instance, making the data available removes error and the need for contingencies because of the complexity of the building. This heralded a new dawn for Gehry where he now uses selective tendering, and to qualify he insists on their software being used and bidders learning how to use it and the virtual model to extract quantities. This has put him back in charge, restored him to the parental role in his dealings with clients, now that he can more precisely control the process. The intelligent model (BIM) has done this for him.

From the evangelistic viewpoint this is the clarion call, but from the practical position there are many other issues. Primarily there is ownership. Who will own the model, who will manage the model, and who will co-ordinate the model's passage through its turbulent growth. In the Gehry case it is a star architect and in such lofty situations those choosing or succeeding to work with him have identified this type of work and accept its challenge.

In a more standard situation there is also the temperament of the disciplines concerning when they want to get involved. Many firms have broached this new technology inhouse and are reaping the rewards inhouse. There is still a reluctance to share the model. That said the output is often shared but this is in the form of overlays not inner access to the crown jewels. This also manifests where there is no common software base. The Industry Foundation Classes (IFC's) were developed to eliminate cross platform translations but simple tests of translating the most elementary model objects show that this is far from satisfactory.

Sustainability

Recent publications from the EU have made it clear that concerted efforts to cut carbon emissions are crucial to the future of economic and social sustainability of the region. While there is broad agreement in principle, practice is entirely another matter. The shear amount of data and the shear spread of influence is enough to scare even the sincerest practitioner. Thankfully a rack of solutions are making this task a little easier.

[Place Fig.2 here]

Figure 2. Quantative Result of whether an ongoing design meets criteria or not during design proposals (does not meet current target- red text).Generated report by IES -ve software

In initiatives like 2030 Challenge and 2010 Imperative, the scientists have set goals and the politicians deadlines which make the problem more manageable. Categories and weightings have been established (including energy, water, surface water, materials, waste, pollution, well being, management and site ecology) in which ratings can be drawn. These then give an indication of how successful the exercise has been, carbon-neutral being the highest of six results.

These nine categories are broken down to credits (energy is 36.4%), and 90 out of the 100 achieves the highest score. So far so good, except that researchers are falling over themselves to provide toolkits to calculate these categories and the waters are becoming muddied again. However, of the list one British Research Establishment Environmental Assessment Method (BREEAM in the UK) stands out.

Analysis software that produces BREEAM reports can use the building information model to give quantifiable results. This has significant appeal. The Netherlands are now considering adopting BREEAM and Denmark is also seriously looking at the situation. This means that the model can provide information about compliance, and also provide a place where experimentation with values (insulation for example) can quickly render results. Changes to the model are reflected in the reports and there is a seamless interface were the toolkits plug directly into the modelling programme.

This is code checking in practice. The University of Applied Science in Berlin is using modelling and analysis software in the studio to inform the process of the design in an ongoing, way while interrogating the model with '*what-if*' scenarios and achieving sustainable solutions with scientific results.

David Conover describes buildingSMART as a concept which is the opposite of building dumb (Conover, a; b). He looks at automated code compliance looking at model codes, standards, and federal, state and local regulations that are based on those documents, working towards;

"...seamless communication between public and private sectors through building smart using smart codes,

"...the delivery of better and more efficient public services and enhanced public safety,

"...more timely and accurate approval and validation of design, construction and continued use"

"...who wouldn't like to get a building permit in a day or approval?"

Checking then involves testing each piece of code with the instance. Three results are possible; first is that it is not applicable, second that it is exempt, and lastly that it is required and so passes (Conover, a; b).

A confidential memorandum between an international well known architect and their local enablers (a large well established national firm) notes *"that the best way to exchange information for co-ordination is as 'dumb' geometry"* and that 'X' and 'Y' *"will experiment with exchange of files with differing file formats to determine the best method of exchange"*. This high level low level solution is akin to the slide rule analogy of computers by Chuck Eastman, who said *"...it (BIM) is a big a leap forward from convention CAD as a computer is from a slide rule.*

4. Future Trends

So if the pressure is not coming from within then what will drive the changes? Clients were instrumental in the DWG format being adopted as deliverables more than twenty years ago, and they appear in the factors influencing BIM as having 49% influence. Code checking's appearance at 25% in the McGraw-Hill Report on Interoperability is significant in that there was not widespread checking then, so it must be determined as a '*wish-list*' item (Young et al., 2007).

Pazlar & Turk (2008) found that moving a simple wall in and out several programmes led to data being dropped. Typically, a field would have no corresponding field in the new format and if not critical would be dropped. On passing back that field would be voided. Even using IFCs evidence was shown that all export functions were not supported. It could be as innocent as the wall hatch or pattern being lost in a vertical section, but even so it meant that the operator had to be vigilant *"not blindly trusting the mapping process"*.

Alan Baikie of Graphisoft argues in Building Design's 2008 World Architecture 100, an annual survey of the top architectural firms in the world, that larger firms are slower to invest heavily in terms of money, time and effort in their migration into the 3D realm, leaving the door open for nimbler firms (Littlefield 2008).

Conclusion

Many would say faced with this evidence that it is unbelievable that it has not been adopted in greater numbers. However, there are questions of ownership which latently must be having an effect. IPD outlines that the collaborative process demands full commitment from all parties but there is a certain amount of entrenchment from the professional disciplines towards engagement. Before each stakeholder in the supply chain makes their contribution, there can be a stand-off, with the misconceived view of avoiding abortive work.

It is seen as a baton passing exercise where there are sign-offs at each work stage so that there is a finite body of work to be tackled by the remaining team members. It harks back to traditional methods and without a custodian or manager it is stagnating. Confidence has not been established and more showcase projects are needed. With a defined role of adjunct manager the situation can be reversed.

This coupled with the work that educational institutes are doing to produce technologists, leads me to believe that they will be the custodians of this new idea. This can be seen already with Frank Gehry who has established Gehry Technologies, an independent holding company that provides an indispensable service for him but who also act on their own as can be seen with Swire properties in Hong Kong.

Project certainty was an issue for the Swire Tower. GT became the BIM process consultant for this project and used their expertise to create the model prior to construction. The contractor updated the model as the building was constructed, so that the model could be used for operations and maintenance when the building was completed.

Finally, sustainability with its need for indicators is fostering a code checking environment to deem compatibility in the carbon neutral race. Coupled with code checking of building regulations and all related laws which can be codified or enumerated, this is leading to a beach head where clients will demand the today building permit over the typical three month turn-a-round often experienced by the conventional method. Clients like certainty and will drive this cause. The latent uptake by the professionals can be alleviated by the adjunct manager, a role which can be fulfilled by the technologist, who has the unique ability to understand the professional languages of all or most of the stakeholders, together with the know-how gleaned from an intimate knowledge of the model. They are trained to know what each profession does and they are trained to know what each project needs from the other professionals.

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KEY TERMS AND DEFINITIONS

BIM: Building Information Modelling is a method of procuring a construction project through the use of a common model, or a visualised database.

IPD: Integrated Project Delivery is the collaboration of all stake holders in a project working together as a team and sharing data so as to minimalise duplication in its reuse and to facilitate exchange

Technologist: The (Architectural) Technologist is a new profession growing out of the technician's role but with wider skills and deeper knowledge of building procurement, construction management and collaborative methods p

Code Checking: Code checking is a digital method that can interrogate the model's database and using analysis tools can robustly establish model compliance with statutory legislation, local planning and building regulations as well as sustainable targets. It requires writing all rules and regulations into machine readable code which is then applied to the digital model. A report is generated or non-compliance highlighted for remedial attention

Sustainability: Sustainability is a performance demand for environmentally friendly buildings. There is a target requirement of achieving carbon neutral buildings in the very near future with quantifiable data

Model Management: Model management is the ability of sharing and integrating data while tracking and maintaining the data flow across many disciplines and from inception of the project to decommissioning of the building

Authoring Tools: Authoring tools are the means used to build the information model.

Analysis Tools: Analysis tools are the means used to interrogate the virtual model to check for compliance and highlight areas for remedial action

The Management of Sharing, Integrating, Tracking, and Maintaining Data-sets, is a New and Rather Complex Task

IV10

Visualisation, 2010. 14th International Conference

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IV10

Visualisation in Built and Rural Environments

Issue Date: 26-29 July 2009

On page(s): 610 - 613

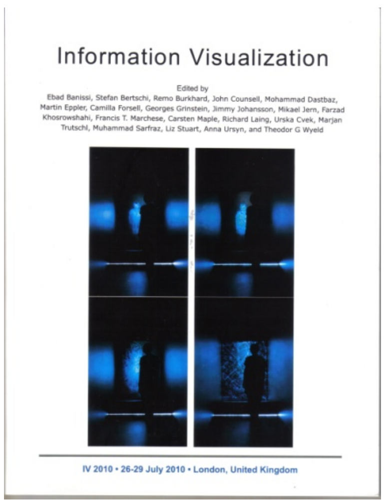
Location: London, UK

IEEE Computer Society Order Number P4165

ISBN-13: 978-0-7695-4165-5

BMS Part # CFP1044D-PRT

ISSN Number 1550-6037



The Management of Sharing, Integrating, Tracking, and Maintaining Data-sets, is a New and Rather Complex Task

James Harty
Copenhagen School of Design & Technology
KEA
Copenhagen, Denmark
jmh@kea.dk

Richard Laing
Scott Sutherland School of Architecture & Built Environment, RGU
Aberdeen, UK
r.laing@rgu.ac.uk

***Abstract:** With the improved uptake of Building Information Modelling (BIM) new issues are emerging. Prime in these tasks is how it is presented to the various stakeholders, in tailor made views to reflect their demands and requirements. In this fragmented sector strong in the concept of phased handovers new methods of feedback loops need to be developed, and other stakeholders outside the procurement process need to be included to progress and manage the practice.*

Within this scenario is the role of the facility manager, who currently operates separately to the procurement stakeholders. Bridges need to be built to bring them closer together especially in light of life cycle costing and sustainability if the buildings operations and maintenance issues are to be addressed in the design phase. The model's ability to host work phases or stages opens up a method to co-inhabit the model to accommodate both sets of stakeholders.

This filtering of the model has both tremendously positive aspects but conversely larger issues of ownership and custodianship have not to date been satisfactorily resolved. There is a major role for proper management here, which has not been appropriately identified. Initially there was a clarion call to architects to adopt this role and a few years ago this seemed to return the lead role to this noble profession.

But patently they are neither prepared nor keen to take on this role. Constructing architects however do seem to want this discipline which can raise their profile and possibly lead to professional recognition and prestige.

Keywords- Management, Integration, Collaboration

I. Introduction

Processes need to change and furthermore there has to be what many are calling a cultural change in the way we make buildings. Life Cycle Assessments (LCA) and sustainability are bringing the facility manager more and more into the procurement process, instead of the traditional method where both were divorced from each other.

This widening of the scope of procurement brings with it an increase in responsibility and adds more layers of complexity. How it can be integrated broadens the role of the model in both how it performs before a design brief is in place and how its legacy could behave after project handover.

At The Copenhagen School of Design and Technology methods are being explored to marry the divergent disciplines or at least to allow them to mutually co-exist. This paper attempts to map the issues and demonstrate a method of integration.

II. Constructing Architect

A constructing architect in Denmark graduates with a Bachelor of Architectural Technology and Construction Management after three and a half years, Pedagogically, and traditionally, the course is structured through group work in a matrix diagram on project driven semesters. This is a huge benefit where collaborative work is involved and this is the case with BIM. A broader definition of BIM is Integrated Project Delivery (IPD) where collaboration is critical (Eckblad, Rubel, et al. 2007) which is at the core of this process.

The work can be divided into two parts, one where authorship is to the fore and the other where analysis is primo (Hardin 2009). Authoring involves building the model and developing it through the various work stages of the project. Analysis allows the model to be checked and controlled so that certainty is achieved, bringing projects on time and to budget (Eastman et al. 2008). Allowing the data generated to be mined and tested is not new, it is in fact an integral part of the planning process and of great concern to the client.

While this can be described as the kernel part of the process, there is increasing concern for the lead up and post practical completion stages, essentially outside the procurement part, where Facility Management (FM) holds sway. FM is becoming a critical player in the process now that LCA casts a critical eye on the initial design decisions where most influence is placed. In the design business it is often said that 80% of the costs are determined in the first 20% of the design process (Smith and Tardif 2009). LCA is increasingly growing in its stature beyond the building procurement phase (Sapp 2010).

FM plays a major role in this initial dialogue where the 80/20 imbalance still figures large and even more so after practical completion with operations and maintenance issues accounting for up to 80% of the building life time costs. FM'ers regularly complain that the procurement model is unsuited to their modelling regimes meaning that they wait until the building is complete before moving in to begin their

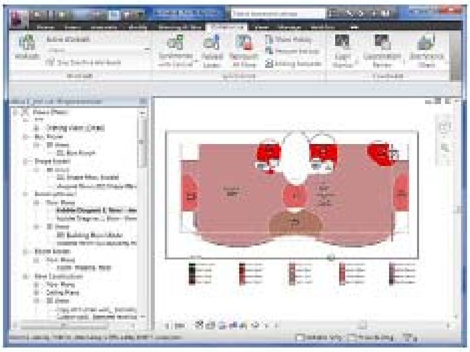


Figure 1 Bubble Diagram using Room Separators © Harty

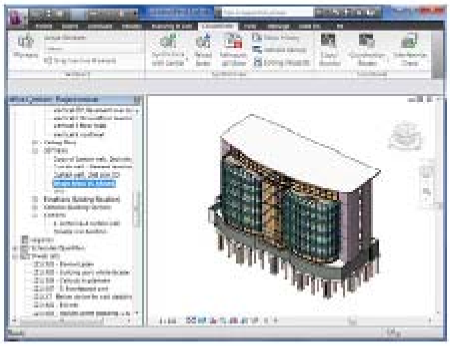


Figure 2 Building model using FM data © Harty

maintenance models. Their initial models are to date also separate and indifferent to the procurement model (Sørensen, Tom, Focus Group discussion on role of FM in BIM. 2010).

The school's new course syllabus is making inroads in this direction, looking to introduce an appreciation of sustainable mechanisms from the first semester to parallel elective classes in facility management in the fourth semester.

Sustainability tells us that there is an inefficient and excessive use of materials and energy today which needs to be addressed. FM'ers are primarily interested in alphanumeric data rather than geometry and methods need to be found to allow them an input in the early stages as well as handing over a model that can be used by them instead of them having to drive parallel models. This aspect is being tackled at the school, trying to harness the demands and requirements of the FM process within the BIM process.

III. Facility Management

So the question is can BIM host FM data? BIM can contain graphic and non graphic data, contractual information and even risk registers. It is, in general, a pool of coordinated information with the keywords being it should be shared and structured. If it is shared then the maximum value may be extracted out of it and if it is structured then as many different processes as possible can use the information in as many different ways as possible.

Moreover a feature in BIM modelling software allows for the notion of phasing in the building process, and it is important to stress that it is a process. If phasing is employed then a pre model (FM) can be hosted, the procurement model can developed as currently understood, and a post model can be prepared for future deployment after hand over. Crucially too the use of tags (whether type or instance) allows fields to be generated but only used when appropriate to do so. A good example of this is in tendering where all specifications and data should be generic unless entered as prime costs sums.

Post tender, as each object becomes defined, it is important to populate these fields so that stem data and maintenance schedules can be developed. Typically this can be seen when the contractor takes over the model and begins describing just how it will be built. This allows the contractor and project/construction manager control to administer the procurement process in earnest.

Strategically this means that objects can occur in the same 3D space of the model without interfering with the geometry but being able to share common data. This is a 4D feature. By extension having differing phases allows for differing scenarios. This feature is what is called open architecture (in terms of information technology) which can be expanded and utilised to allow flexible non-defined objects to be placed non-intrusively in the model. The model now has an architectural filter retaining the architects conceptual design, together with a detailed contractor filter showing a living organic development which can lead to the as-builts upon completion.

This allows a volume to be entered, as a data holder, having the length and breadth of the site together with the permissible height according to the local plan or desired finished gross area for the building. This volume can ultimately co-exist with the proposed building but exist separately in the virtual world of the model. The paradigm though is that data entered into one can be simultaneously used in the other.

Modelling in the initial stages allows the user to form massing elements. These are merely geometrical and as such have little or no data attached. But imagine an entity that can be tagged and the situation is now set where data can be added to the mass.

As said earlier there is a volume or 3D box with defined levels, acting as floor plates. On these levels there is a feature which bounds areas into rooms (or zones) and spaces into which we can add data.

Generally a major problem at the start up project is that showing a client, or developer or any other stakeholder drawings with line defined spaces, however well unintended, equate to bounding walls in most people's perceptions, meaning that most FM protocols tend to use bubble

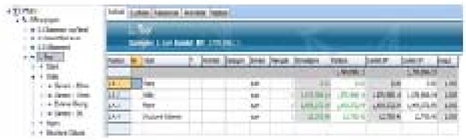


Figure 3 Quantities exported for estimating © Harty

diagrams/function diagrams to avoid the obvious misinterpretation or at best largely misleading information.

The model can accommodate this and the room boundary feature can use circles and ellipses to comply with the sensitive nature required at the early stage. The process therefore can proceed with all the functions being committed to the model in a fashion where a rough method can be enabled to get an overall picture of how many square meters of differing qualities of floor space can be designed in the project. Rough estimates can then be applied such as square meter prices together with quality weightings of the spaces into high retail/leasing or low level service types. This allows the stakeholders to play with their balances or a mix of uses to make the project a success.

This modelling means that schedules of the space can be extracted or exported to other programs to test the validity of the proposal from a financial point of view. No architectural decisions have been taken at this point. No one has committed to the buildings form other than the total square meters or volumetric studies needed to copper fasten the project.

Should this initial phase be successful then the next phase can begin. This involves the decanting of the data over to the initial building model proper. The architect's role is now to look at the agreed areas and convert them into rooms. In this phase the architect can look at the bubbles which have had data added and begins to consign rectangular spaces over these formless bubbles to begin the form making process that is the architect's role. As the forms emerge the data is kept and so the schedules are maintained and updated.

This is the first seamless transition of collaborative integration of the life cycle assessment. Later using a proprietary viewer the other phases can be added as well as

Figure 4 Export to activity, time and resource tool (note: time has not been allocated at point of import) © Harty

other model types allowing a host of differing files to co-exist which provides generative options for various reports regarding clash collision, resources and man power to be compared and contrasted.

IV. PROJECT CERTAINTY

Beyond FM, all the differing stakeholders in the project team have an agenda and a goal to both enter data into the model, and interact with the other stakeholders to progress the project through all phases to practical completion (Jernigan 2007). Issues arise in how that data has to be protected. Issues also arise in who controls the entry of data, who checks the fidelity of the entered data and who integrates and filters the entered data for the other stakeholders in the equation.

Generally the above calls for some form of management (Elvin 2007). For the model to be robust enough and to manage itself is a recipe for disaster. For each to be responsible for their own data has potential, but also challenges how well the data is entered. Finally who takes overall responsibility for the wealth and well being of the model and who owns the model all leave much unanswered and the water's muddied.

If there are two or more models, then the likelihood of uncorrelated mistakes increases. If there is one model then practical considerations come into play. Prime here is ownership. Is it part owned by each stakeholder or is there mutual or communal ownership. Ultimately ownership will resort to the client, so therefore maybe the client should adopt the model at the earliest, as in Terminal Five at Heathrow where the British Aviation Authority (BAA) took out professional indemnity insurance for the whole project and hired all stakeholders as sub contractors (Potts 2006).

Next is size and manageability, several stakeholders will have a multitude of differing needs and requirements from the model. Some will be all-consuming, others will be marginal. Methods are then necessary to marshal and protect each stakeholder's input, while making it available to the others for inspection and use. This system of bells and whistles is not thoroughly accepted and endorsed by all the disciplines and needs more work from vendors to make it transparent and robust.

Finally should all stakeholders have the same set of work tools or the same workbox of tools to author and analyse the project. The answer is no and this is the most interesting paradigm shift in building information modelling (Laiserin). The reality is that there will never be a single source and so appropriate management considerations need to come into the equation. Some form of transparency can be attained with the use and enforcement of standards such as Industry Foundation Classes (IFC's) being the lowest common denominator for all programmes. Viewers, such as Navisworks, Tekla Viewer and Solibri, also allow the various models to be assembled into a viewer where clash collision and time lines can aid a construction manager.

At the other end of the equation, the data can be also extracted in the form of quantities, allowing resources and costs to be allocated for the procurement stage of the project. Here the model is transformed from graphic data to numeric

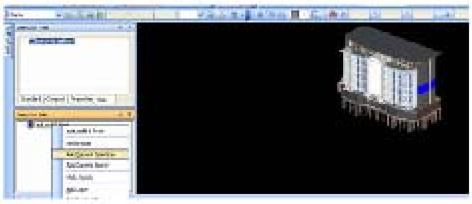


Figure 5 Viewer showing 3D/4D/5D overlaid for clash detection and timeline sequencing © Harty

data and a new set of programmes allow the fourth and fifth dimensions to be added to the model. The fourth dimension is time and the fifth resources (materials and manpower). This phase is being driven by contractors, with the Association of General Contractors (AGC) in America recommending their members not to bid on non-BIM work, and that if they do, to build their own model before bidding, in order to give a qualified bid (Young, Jones, et al.). It will also control the subsequent phase onsite. Here the previously mentioned tagging plays an important role.

It does not end there either, the next wave will see sub-contractors accessing the model to extract the material and quantities they need to complete their portion of the work and to also liaise with others as to when the work will commence and when it will be expected to be completed. This is in a formative stage but under trials electricians found that after being forced to consult with the model (akin to pulling teeth), that they found out that the guessing, the waste and the contingencies evaporated so much so that those in the trials wondered how they ever managed without it before. All in all the shape of the model at handover is looking better and better.

V. Conclusion

Bridges need to be built to align facility management with the procurement (design) phases. Collaboration and sustainability demand this. This lengthening of the model's life cycle makes more demands of the model and the modellers.

One option would be to establish the model on an independent plane, with an adjunct role of BIM manager emerging. This removal from the coal face to a more robust position, would steady the ship and offer a more consolatory arrangement. This would have the effect of making the adoption of and transition to BIM less risky. It would standardise the format and it would remove the technical obstacles which are perceived as a barrier to many at the moment.

Three levels of competence are envisaged; the first where there is a hands-on approach where resources are required to physically integrate the various programmes and process together in the project; next there is a need for managers to control access to the model across the board ensuring indemnity and safeguarding the various stakeholders stakes; finally there would be consultants who are required to advise both clients and professionals on strategies and short, medium and long term paths, to massage the model adoption through the differing disciplines, as seamlessly as possible.

Jonassen (Jonassen 2006) has stated that "…the management of sharing, integrating, tracking, and maintaining data sets that make up the total project model is a new and rather awesome endeavour. While it will be done in collaboration with many modelling entities, it requires overall leadership" I firmly believe that the discipline best suited to that role is the constructing architect.

If they can establish a beach head, then the rewards can be immense. Changes to the workplace will then see the adjunct manager establish a holding role in effecting project realisation. This can eventually give the discipline professional recognition and redefine the whole procurement process. (Harty and Laing 2010 Chapter 24).

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IV11

15th International Conference on Information Visualisation

Issue Date: 13th - 15th July

On Pages: 558 - 563

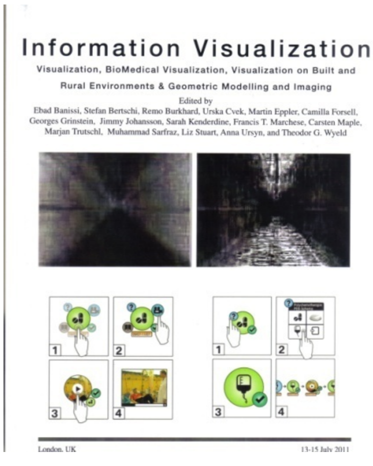
Location: London, United Kingdom

IEEE Computer Society Order Number P4476

ISBN: 978-0-7695-4476-2

BMS Part # CFP1144D-PRT

ISSN Number 1550-6037



Trust and Risk in Collaborative Environments

James Harty, Richard Laing,
Copenhagen School of Design & Technology, KEA, Copenhagen, Denmark; Scott Sutherland School of Architecture & Built Environment, RGU, Aberdeen, UK

{jmh@kea.dk, r.laing@rgu.ac.uk}

Abstract

Many commentators and analysts are now saying that we are reaching the tipping moment in the adoption of building information modelling. By this they mean that the uphill struggle for implementation is finally falling into place and that it is beginning to gather its own momentum. This is to be welcomed.

But the construction industry is very fragmented and how implementation can be accomplished is appearing sluggish. Certain drivers like owners and developers are beginning to have an impact while others like architects and planners remain somewhat listless.

How to manage this risk, engender trust and make worthwhile collaboration can be helped with rated 'levels of detail' and calibrated 'metadata'.

Keywords--- Trust, Risk, Collaboration & Metadata.

1. Introduction

Initially it appeared that architects would herald the new process with the American Institute of Architects (AIA) thoroughly scrutinising the possibilities while proposing robust models of deployment [1]. But the response was middling. Architects are reflective types when designing [2] and boxing them into prescribed methods of designing is not easy. A designer cannot and possibly should not use contractual methods of procurement and application during concept phases just as there has to be development in the procedures by the time production information is at hand [3, 4]. There has to be a de facto acceptance of the data at each stage of the procurement and a method of improving or altering data if and when necessary. [5].

Practically speaking this can occur in two places, either within the model using the model phase's properties, or in a viewer programme such as Navisworks, Solibri or Tekla Viewer, which holds all the diverse entities, allowing them to be overlapped, collision tested or time line compared.

The former, permits objects to co-exist in time and space without displacing each other, but allows the data to be shared. This is a paradigm shift. Within the free viewers many formats can be assimilated into the same virtual time and space, allowing many operations to be completed and reported. Integrity and ownership is not challenged but everyone from planner to environmental activist can access the data for whatever reason [6, 7, 8].

2. Risk and its Assessment

Next with BuildingSMART it appeared that code checking would lead the assault [9], but to date it has only been implemented in Singapore with on-going trials in Norway. Tests are showing that government legislation, local planning controls and building regulations can be assessed in circa twenty minutes for specific types of permission and approval [10]. The only variable not included is the political lobbying and bargaining that can go on in mitigation circumstances. But planners appear unprepared to consign large municipal planning departments to the wayside.

As certainty came to the fore the merits of such a process became more apparent. Showcase projects were on time and to budget, which was virtually unheard of under traditional methods of procurement. Client demands therefore should be driving the implementation of modelling [11]. This should be the mainstay of adoption but word has not been as widespread as hoped, with contracts in this current recession occasionally reverting to traditional design-bid-build procedures [12, 13].

Vendors have also been slow to roll out compliant standards like full Industry Foundation Classes (IFC's) reading and writing, to adopt or offer better standardisation to users. This would reduce the implementation threshold that discourages acceptance [14]. The lack of standards also works on another level where not having compliant work necessitates vigilant translation processes with undependable outcomes [15]. It is also appearing that the lack of open standards clashes against a robust plateau where confidence could be nurtured and developed [16].

Sustainability is being pushed globally and by national legislatures meaning it is being implemented across the board in the developed world and this will ensure its uptake. Following the current recession, those firms who can document sustainable solutions will gain a clear advantage over more traditional operators [17]. With energy costs increasing and resources being finite, global warming has forced policy makers to implement targets and table deadlines to save the planet [18].

Having a virtual model allows performance analysis and climatic testing before deployment. Having quantifiable data from a direct analysis tool gets results [19].

3. Benefits of Adoption

Finally contractors and developers are reaping the rewards of modelling, because they can extract quantities and assign resources. This together with control on site is critical in leveraging the new mindset. The Association of General Contractors (AGC) recommends to its members not to bid on work that is not modelled and recently building contracts are penalising subcontractors who are not stakeholders in the model. This is done by excluding them from the site until those who have collaborated together have completed their work. A late comer too has been contractors and more importantly sub-contractors who now can see that a virtual model allows for better control regarding both collisions and time planning in the procurement process [20].

A follow on from the above is *'augmented reality'* where data can be superimposed on situations to give better information in both time and place [21]. As Geographic Information Systems (GIS) improve in their accuracy the virtual model can be superimposed on to the reality, meaning new projects can be assimilated on site before execution and on-going work can be checked for delays and/or improvements.

Augmented reality also means Bots (a form of virtual robot) can mine information, and properly filtered, provide it conveniently to qualified personnel or place it in relevant data holders, all quietly in the background [22]. Within the model this could be product related where doors and windows are found to meet client/designer requirements and demands.

For a designer this can be generic or it can be initial prime cost sums. For the contractor it can compile a list of all products that meet the performance criteria so that when the product needs to be identified a qualified list exists to aid procurement. Outside the model it might be where utilities like water, electricity or gas can be identified below grade or where neighbouring buildings can be included to show context and terrain.

4. Collaboration

Parallel to this, financial viability is finding its way into building information modelling where computed area schedules are being mapped in early versions of the model which can be maintained and updated through the procurement of the project. Linking this to indexed price books ensures better cost control and improves project certainty. Facilities managers are also finding ways to map their requirements into the model which is giving life beyond procurement, making it possible to conduct life cycle analyses [23].

The early massing can also be tested for sustainable comparisons meaning that even at the early stages various options can be tried and tested leading to better informed designs. Similarly to sustainability, Life Cycle Assessment (LCA) is and will have a significant part to play in the procurement of buildings [24]. This is even more so, when the initial planning and post operations and maintenance issues are added. Suffice to say that best practice currently has three models running concurrently, one for the strategic policy makers or investors, one for the designers and procurers and finally one for the operations and maintenance people who pick up the pieces after practical completion. This is not optimal or efficient at all, because repeated input of data increases the likelihood of error, and encourages a knowledge drop at each point of the saw tooth knowledge acquirement diagram.

Better informed designs are possible, by bringing all stakeholders on board sooner in the process than previously. But while this is a bonus, it is also a potentially problematic issue. Not least is how this collaboration is managed. While there is clearly a need for a manager, there is also a need for bells and whistles, with regard to authorship, quality and level of detail, but this could well be dealt with using metadata.

The benefits of the model are not lost on some flexible entrepreneurs, already there are stakeholders who are entering into mutual agreements to work together to reap the rewards of completion on time and to budget. The biggest issue here is risk and how much or how well you trust your partner. Building trust in a business environment and especially in a fragmented market requires new skills and new procedures. Changing work practices from the adversarial to the collaborative, requires major changes in mindsets and even social behaviours [25].

Methods of integrating these diverse methods will improve how we make buildings and how we use them. Facilities Management (FM) has a critical role to play here and methods of facilitating designers without alienating them will consume many resources before an acceptable solution can be found. The driving force will be collaboration and already we are beginning to see consortia being formed where certain players can work purposefully and profitably together to mutual gain [26].

5. Trust

The major obstacle to collaboration is how trust is nurtured, how new blood can enter the mix and finally how information, competences and knowledge is shared for the benefit of the team, the project and society at large. Initially there were calls for sharing or giving away data for free, but with contractual obligations and recovery of costs there is a great reluctance to do so by the players and those who have invested so much into the project, to see others in the supply chain capitalise handsomely on their endeavours [27].

How this can be remedied rests with the client and the appointment of all the stakeholders in the project. First principles say that work effort must be remunerated, and secondly there cannot be subsequent adversarial disputes about the quality and correctness of the data.

The correctness of the data needs to be calibrated and one method is metadata [28].

6. Metadata

Metadata is data about data. It is typically embedded and is only of use to specific persons or things. This might be the size and quality of an image. Its dimensions, colour definition or the date it was created and by whom, the date modified and by whom. From this it can easily be seen that generally the interest is only in the image but occasionally more is needed for whatever reason, and especially when it is to be used by another downstream in the process [29].

This too can be applied to modelling and components of models so that the validity of any piece can be verified [30]. This is the first step in trusting a collaborator whether known or unknown. It is abstracted information and can be seen or hidden until required. It now makes the virtual element accountable for want of a better word, and it marks or informs the end user whether it is complete or just a holding-place for better informed data. This allows the authorship to be tagged and any information about amendments subsequently made or commented upon to be archived within the element.

7. Level of Detail

The process of architectural design is the moving from approximate information to more precise information [31], But digital model elements tend to be exact, whether or not intended. This can give false indications about the precision of the data. Coupled with its intended use, the author might not be qualified to release or stand over the data in its present form. All this needs a framework defining its precision and suitability, and this is called a Model Precision Specification (MPS).

The framework is essential for two reasons; the first *'that phase outcomes, milestones and deliverables be defined succinctly'* so that team members *'understand the level of detail at which they should be working, and what decisions have (and have not) been finalized'*, and the second; *'the idea of assigning tasks on a best person basis, even when that differs from traditional role allocations'* [32]. This caveat is purely because procurement is a process, and when the process is most vulnerable is when it is most open.

Five levels are defined. The first is *'Conceptual'* where there is little geometric data, typically block models, and only notional ideas about time and cost. There can also be analysis about programme, strategies and performance.

Next is *'Approximate Geometry'* where generic elements are shown, duration and cost estimates are better informed, specific functions and requirements are in place and the conceptual design is finished.

'Precise Geometry' as it suggests is a point where quantities can be extracted, the building can get approvals and permits issued and traditionally it can go to tender.

'Fabrication' is where shop drawings and production happen, where building parts are located, and components and assemblies are known. There is a committed price and specific manufacturing is in place.

Finally there is *'As Built'* which is the actual building with recorded costs and purchase documentation, where the building has been commissioned and performance can be measured.

8. Management (the Technology)

The cultural change required to implement integrated practice delivery is an enormous challenge defining *'true partners and collaborators with a mutual interest in a successful outcome'*. Essentially it alters the way and amount of time consumed in being adversarial and in expecting litigation. Increasingly contracts are explicitly saying that stakeholders will not sue each other, that future legal action is a no-value task and that trust with verification mechanisms will become standard, as in banking. The principle cause of a bank failure is often a loss of trust rather than insolvency, there is very little difference between a failed bank and a healthy one, Smith tells us.

How this impacts technology is principally in the transfer of information and the risk it imposes on the authoring party, who could be held responsible for the quality, completeness and accuracy of the handed over data. If a *'no fault'* policy is in place each stakeholder accepts the data as *'found'* and must validate it, appropriately to their needs. Validation consists of two parts, determining if the data is from a trusted source and confirming the integrity of the information itself. Smith calls this stewardship [33]. Where there are errors or omissions, methods will have to be effected to compensate the corrector or rectifier instead of identifying the responsible party or assigning blame. The blame culture interrupts the process and causes delays. There has to be a hand off of responsible control.

This greater dependence of stakeholders on each other can cause strain within the working relationship if trust is not present or more importantly earned [34, 35]. In order to minimise and in an endeavour to make the process more transparent standards are invariably required. This allows for a form of benchmarking and acts as a quality management control for all those involved. It covers the data richness, life cycle views, roles or disciplines, business process, change management, delivery method, timeliness response, graphical information spatial compatibility, information accuracy, and interoperability support. But it is only a skeleton which can offer the stakeholders an index to measure or check each other out, and to bolster their own pitch by giving them the tools to build their own argument and set out their own stall.

9. Partnering (the Business)

A compendium of principles as an application allows the stakeholders to value themselves, but value is added to projects through people [36]. Therefore the management of relationships becomes very important. The construction industry is accepted as being fragmented, rarely do the same people work together on subsequent jobs and often they do not complete the current job through either disruptions in the work phases themselves or the sheer length of the project which sees personnel either replaced or decanted to other projects.

Also the magnitude of small firms involved and the whole culture of sub contracting out engenders a state of flux and conversely a vested interest in protecting niches and expertise in the market. This is a huge element of risk in the construction industry.

But positive relationships do add value, improving project performance and client satisfaction. They also as mentioned induce less adversarial behaviour from the top down, and offer procurement led measures for proactive behavioural management throughout the enterprise. Relationship contracting is best seen in partnering and supply chain management.

One of the best examples is Terminal Five at Heathrow, completed on time and to budget, which is rare for a building of its size and complexity. T5 nurtured and encouraged such an environment [37]. It was based on the principles specified in the Constructing the Team [38] and Rethinking Construction [39]. Had BAA followed a traditional approach T5 would have ended up opening 2 years late, costing 40% over budget with 6 fatalities; this was not an option for BAA [40].

Conversely Eurotunnel had difficulties in motivating the suppliers once the contract had been awarded. Winch calls this moral hazard [41] where the client is somewhat unsure that the contractor will fully mobilise its capabilities on the client's behalf, rather than in its own interests or for some other client. The preferred option he calls consummate performance instead of more likely perfunctory performance.

The root to this situation can be found in the negotiation of the contract, essentially between banks and contractors. Here two cultures collide, on the one hand; the banks prefer to move the contractor to a fixed price which reduces their risk. On the other the contractor works on the basis that the estimates have to be low, to ensure that the project gets commissioned. *'In banking you bid high and then trim your margin: in contracting you bid low and then get your profits on the variations'* or as another said *'the project price... was put together to convince the governments, it was a variable price , a promoter's price. What it was not was a contract price'.*

10. Enlarging the Scope (Facility Management)

As if this was not enough to muddy the waters; beyond procurement, lies both appropriateness and life cycle assessment, -both of whom impact outcomes. Operational maintenance and on-going developments have an incredible bearing on how things are presented. The lengthening and enlarging of the scope and the focus and merit of the objective, mean that simple decisions taken in good faith can have a detrimental effect on the success of the project. If we accept that the first 20% of the design decisions impact eighty per cent of the life cycle costs then the bottom line has to be to accept and moderate this situation [42, 43].

The International Facility Management Association (IFMA) defines FM as *'a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology'.* They are seen in a secondary function as supporting the core business.

Out of necessity FM adopts architectural floor plans for viewing the built environment [44]. But with the emergence of GIS scaling moves far beyond individual buildings and site maps. Traditionally it focused on the exterior environment and neither technologies ever crossed. But Enterprise Resource Planning (ERP) does not have such boundaries, and this introduces the holistic view that is now required [45].

GIS has now matured and is called a foundation technology that seamlessly provides *'world-to-the-widget'* scalability. This means that it can both drill down to very small scale (from the larger geographic scale) while also bringing layering of data into the matrix. On the one hand it can tell you how many unoccupied offices are within 500 meters of a parking space, or how many employees will have to travel more than half an hour to get to an office location, to the other extreme of mapping a property by building, floor, room - all the way down to the equipment and its usage in a Building Information Spatial Data Model (BISDM). *'This spatial data is the primary thread that holds together such functions as project, space, maintenance, lease and portfolio management,'* Rich et al tells us.

In his critique of BIM he sees it as being an ever enlarging file system, rather than a relational database, and that it works in a multi-user/concurrent user environment requiring highly specialised skills to implement and use. This might be true but what he fails to appreciate is that the entities created in BIM have the ability to hold property fields and property values. These properties can be blank (no value) and beyond the scope of the design team or they can be imported and read-in when making critical decisions.

These decisions might not be relevant or comprehensible to the design team directly but the Bots, mentioned earlier [46], might see fit to implement the data in the decision making process for someone else in the enterprise to use or act upon. The requirement of appropriate tools and software is being negated currently by the use of model viewers, which function similarly to PDF files, where they can be authored or read-only, depending on the need, meaning they are accessible to all.

Conclusions

Just as in design-and-build or partnering, collaborative consortia will go through a process of pre-qualification but not necessarily or singularly only project driven. It will be for a longer haul and over or through many projects. This pre-qualification will see the various members of the consortium indexing themselves with a view to both internally establishing their own worth and externally finding a compatible niche or setting the rate or level of engagement desired with the other members.

Central to this process will be the expectations of the collaboration and this will be built on faith and hope [47], giving rise to confidence and resulting in trust. The characteristics of trust were derived from the work of Lyons and Mehta (1997) bringing the economic and social analysis of trust to relationship management. There are essentially two elements involved, the first is the self interest part and the second is the socially orientated part which demands certain obligations in a social network of relationships. This introduces reputation and advocacy into the mix and it is prolonged through experience.

Already in the United States the National Building Information Modeling Standard (NBIMS) of America has deployed a compendium of principles called a Capability Maturity Model (CMM) to facilitate this process, but where the National Institute of Building Sciences (NIBS) see problems is how to bring the strategists and the operations and maintenance people on board the grand coalition of consortia. Essentially there are three pipelines and each has a different model and a different purpose. But they all serve the same client and there is a need now for the client to step up to the plate and knock heads together.

Legislature has also a role to play here and as we have seen with sustainability it can be done. Those authorities with clout, like the major agencies in the States such as the military or the state agencies in Norway who actually commission work and have a portfolio of properties to maintain are beginning to set demands which require a broad response possible only through consortia.

The strategic alliances made through these consortia will see like minds using the same tools to use, reuse and exchange data. There will be an acknowledgement of each stakeholder's worth and expectations for each stakeholder's input. The rewards will be significant and in proportion to each stake. There will also be continuity as the same methods and processes are honed and improved with each project. It will transcend procurement, involving the strategists and developers at start-up, the procurement team through construction and the facility managers through operations until decommissioning and ultimately demolition.

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Building Information Modelling

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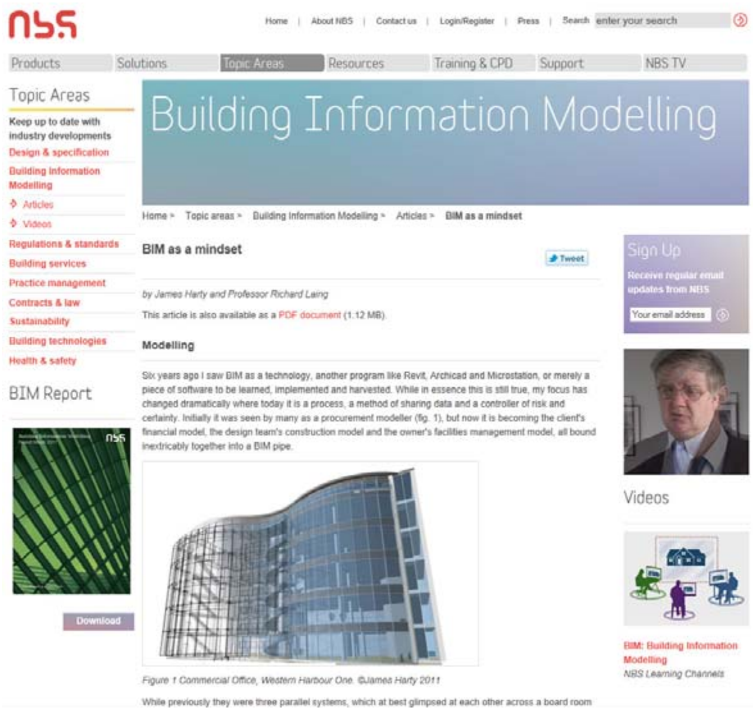
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BIM as a mindset

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by James Harty and Professor Richard Laing

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Modelling

Six years ago I saw BIM as a technology, another program like Revit, Archicad and Microstation, or merely a piece of software to be learned, implemented and harvested. While in essence this is still true, my focus has changed dramatically where today it is a process, a method of sharing data and a controller of risk and certainty. Initially it was seen by many as a procurement modeller (fig. 1), but now it is becoming the client's financial model, the design team's construction model and the owner's facilities management model, all bound inextricably together into a BIM pipe.

Figure 1 Commercial Office, Western Harbour One. ©James Harty 2011

While previously they were three parallel systems, which at best glimpsed at each other across a board room

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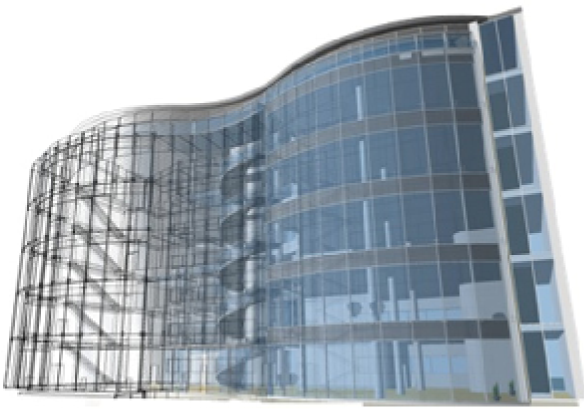
James Harty
BArch MArchSc PPCert PGCert RIBA MAA

e-mail: jmh@kea.dk
tel: (+45) 2148 7035

Professor Richard Laing
BSc PhD MRICS

e-mail: r.laing@rgu.ac.uk
tel: (+44) 1224 263716

The Scott Sutherland School of Architecture and Built Environment
The Robert Gordon University, Scotland
Garthdee Road, Aberdeen, AB10 7QB, UK



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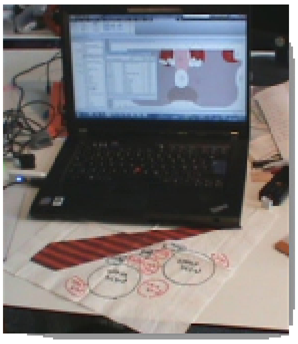
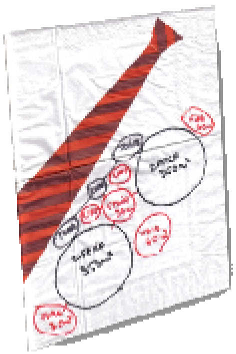




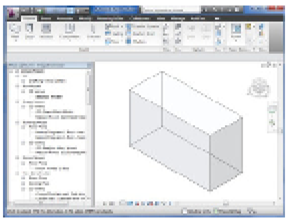
MODELLING

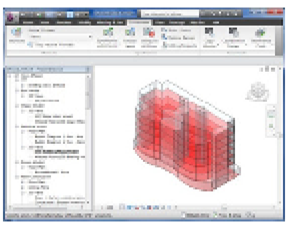
Six years ago I saw BIM as a technology, another programme like Revit, Archicad and Microstation, or merely a piece of software to be learned, implemented and harvested. While in essence this is still true, my focus has changed dramatically where today it is a process, a method of sharing data and a controller of risk and certainty. Initially it was seen by many as a procurement modeller (fig. 1), but now it is becoming the client's financial model, the design team's construction model and the owner's facilities management model, all bound inextricably together into a BIM pipe.

While previously they were three parallel systems, which at best glimpsed at each other across a board room table and at worst never fell into enemy hands, now there is a new culture growing, where how we can best use our models, reuse them and finally share them is to the fore. This is being adopted and propagated to deliver projects on time and to budget which are sustainable and accountably so.

A model is an incredible concept. Whether it is a pair of leggy pins on a catwalk or the ethereal notions of a mad scientist, it is a representation of a perception or a performance which can be paraded and tested before implementation. Fashion designers use a model to show off their designs, to mould the minds of the consumer to the next seasons offerings and to build prestige. Scientists on the other hand use models to limit their scope, to test their findings and to resolve problems. Both have huge validity, whether it is through authorship or analysis.

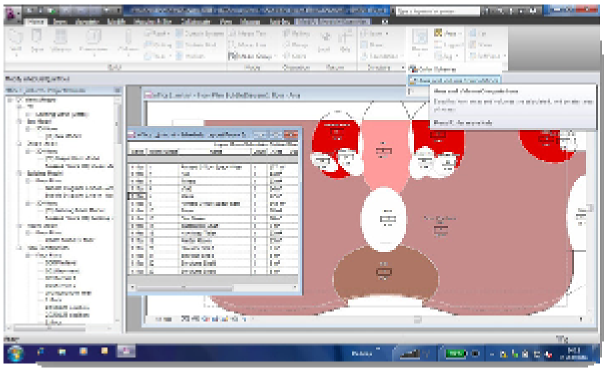
In construction and architecture it is the blueprint for the building, the embodiment of the design and the contractual currency for execution. It is the planning; the drawings, the specification, the quantities and the scheduling required to make a building a reality. But it's more. With digitalisation a whole new panacea has opened.

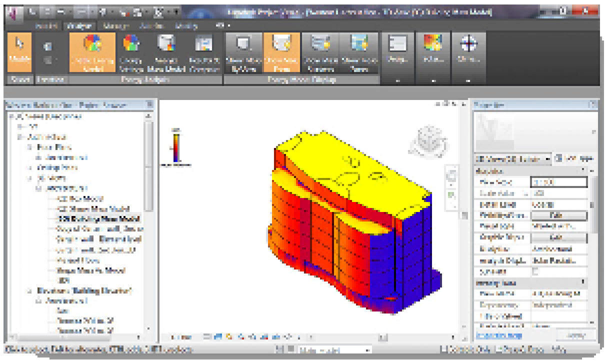


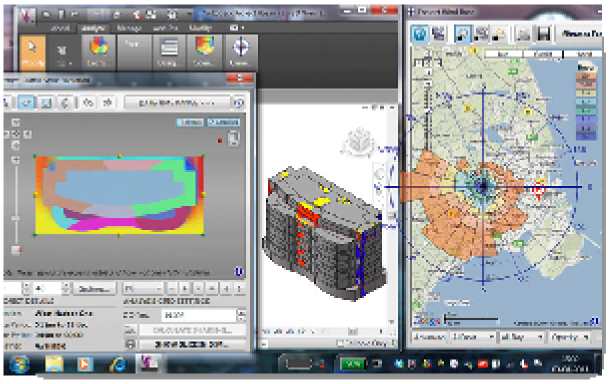


THE FINANCIAL MODEL

The decision to build usually involves a financial institution or at least a financial plan. What is it going to cost, what is the budget and how is it going to be paid all come into the mix. To appraise these issues a notional building is addressed where occupancy, function, location and their impact is assessed on a spread sheet, where the building's form is not part of the equation, at least not until the money is approved. The people making these decisions are usually not spatial or graphical in their prowess and any hint of form is unwelcome and ill-advised.



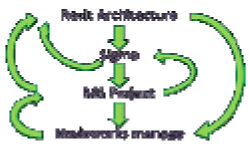


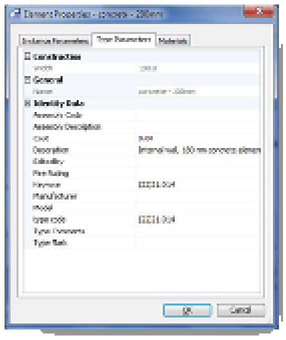


But adjacency and interaction can be an important part of this process and this is often represented in a bubble diagram (fig. 2), for want of a better word. Large bubbles represent large spaces and often are accompanied by notional areas or numbers of occupancy, and these can be overlapping or connected by lines.

As described this work is separate from and lies outside any usable model for further work. But now it can be done within a modelling programme (fig. 3) such as Revit which can drive the process right through to procurement. Placing a massing element on the site with the desired height (fig. 4), or placing a parametric volume which maintains the square meters floor area (fig. 5), room separators can be used to generate circles and ellipses (essentially free forms). This process happens without defining rectangular areas which can often be misread as definitive spaces so that the abstract nature of the forms can be maintained. Tags are now added, which are as simple as name and size, so that schedules of accommodation are instantly available (fig. 6). When the correct mix is found, price books can be associated with the data and budgetary figures are determined.

This work is phased within the model as preconstruction work. This means that it can co-exist within the model proper when construction work is subsequently prepared. The benefit of having it here is that specific climatic data can be added to this conceptual form and feedback given, regarding shape, orientation, shading, heat gain, exposure (fig. 7) and energy performance (fig. 8). A report can be generated containing all the above data and if several forms are tested, several reports can be generated and cross referenced in a compare and contrast fashion,

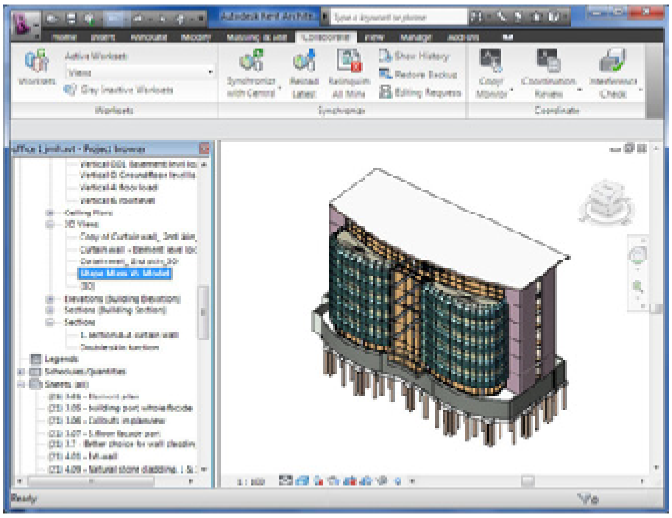




giving informed comment.

The Design Model

Armed with this data the next phase of procurement is better prepared. I know some would say that this is tangential to my design methods or that this cannot, or will not affect my design process, but it can inform it. Designing for large corporate clients often means devouring volumes of standards, branding and methods that the corporation has developed so that a corporate image is presented or that certain prestige is conveyed, which during the Appraisal and Design brief (A & B) can be very time consuming.



As the design progresses the early work is not lost and as each form becomes an entity the early data is kept and updated and reports can affirm compliance with the initially agreed proposal. For the client this gives a greater amount of certainty to the project which can be lost in tradition procurement methods. As the project goes through Concept, Design Development and Technical Design (C, D & E) these can be saved into phases in the model and through filtering of the views in the model, targeted drawings can be formatted to targeted audiences.

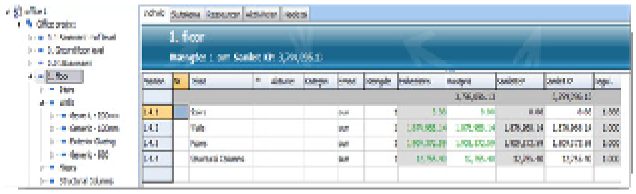
Typically this might mean showing existing, demolition and new proposals tailored to whom the drawings are intended. This means the client gets colour coded legends, the planners code compliant sets of drawings and the contractor location, component and assembly drawings along with the schedules, quantities and specifications, all generated from the model.

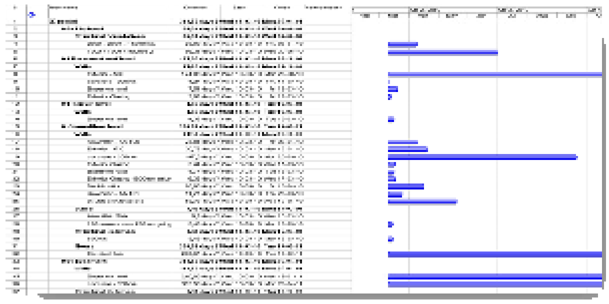
Whether the output is paper format (drawings) or filtered sets (views) from the model raises a new situation, the sharing of information. The former is of no interest here as it has caused no end of checking, cross checking, red lining and revisions that eats away the fee and demoralises design teams. But how is the exchange of information handled? Who owns it, who manages it and who is responsible for it regarding errors, omissions and corrections.

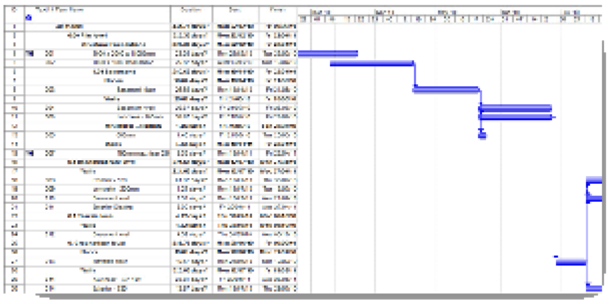
If the architect makes a generic wall of 450mm width, does the contractor sue or request further information when it transpires that it has to be 520mm consisting of brick, insulation and load bearing reinforced concrete later in the design? Who is responsible for detailing the design, who is getting paid for it, or when does it come into the model following the phased work stages?

Architects or those who generally start the project mean their model is a chargeable extra. Contractors or those who take over the project feel it should be free or at no charge as it is part and parcel of the procurement. Initially the call was to give it away as it would come back in spades, but this clearly has not happened.

Under Design and Build or Partnering contracts this is abated by having all involved under the same umbrella, but even here when the work goes further down the supply chain, vested interests find it very difficult to give away trade secrets or bespoke expertise to erstwhile competitors outside of this contract. So the new benchmark that the construction sector must address is collaboration and with whom and how.

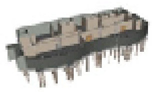


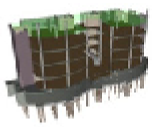


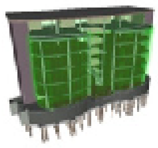


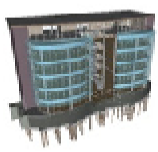
Quintessential to collaboration is the first line of the contract, that signees will not sue each other. While sounding innocent this is a major step. Methods have to be found to remunerate work at a fair rate. Competences need to be appraised and rewarded appropriately. Changes and error rectification needs to be awarded to who is best placed to do the work. There has to be an incentive to complete on time and to budget. There has to be mutual respect for all in the supply chain, and this is called plain and simply, trust.

This in turn is seeing a phenomenon of Capability Maturity Matrices (CMM's) appearing, where differing parties tabulate their competences, their bond values and their ambitions or experience, and others compare and contrast it with their own, so that strategic alliances can be formed. This is not unlike speed-dating, and the metaphor does not end there. These collaborations are not for a singular project but are related to the longer term. If a team comes together and competes and









completes on a hospital (say) then they will try and corner that market and capture all related work.

Comparisons can be seen in large legal firms for architects, and also in major contractor/developer firms and large consulting engineers who feel they have the momentum to carry this off. But there is room for small players too and smaller targets but this is ongoing. When it filters all the way down to sub-contractors who can take off quantities from the model then significant progress has been made.

Typically these consortia comprise a design team (architect, structural and service engineer) who use or plug into the same model. From this a surveyor or estimator can extract quantities from the model and together with a price book or work rates and material costs can price the work. Moreover once each component is type coded it has a classification which can be linked to specifications clauses to generate full building part specifications. Following this a contractor or project manager can begin sequencing the work so that there is control on site with proper manning and resources.

During procurement, packages can be taken off so that sub-contractors can find out how much piping, cabling or materials that needs to go into the van every Monday, and to where it is destined with how much time and how much money is allocated. This does not require the sub-contractor to have expensive authoring software (like Revit) but to only have a reader (Navisworks Freedom, Tekla Viewer or Solibri) not unlike Adobe Acrobat Reader which is free to the user, meaning they can open the file and interrogate it. This is also indispensible to the project manager in accessing the data.

If a project is authored in Revit or similar, through a process of tagging data, type codes, can be allocated (fig. 9). Using quantity extraction programmes (Code Group - Sigma) a classification system can be selected and applied (fig. 10). This can be CAWS, Omni-class or any internal in-house system. The tagging of elements in the Revit model when complete (fig. 11-13), can be exported to Sigma where all the entities can be updated against a price book such as SPONS (fig. 14). This gives a priced bill of quantities which can be linked back to the model so that any changes are updated in both places.

After this process the quantities can be exported to a Gant chart programme (MS Project) where all the resources com e in with the current day's date (fig. 15). A Gant chart allows these entities to be placed either through critical path of sequentially so that a start date and practical completion date can be calculated (fig. 16). Currently this is not bidirectional with the previous work. A added chart column sequences the construction time line. Armed with the Revit model (3D) the Project chart (4D) and the Sigma schedules (5D) these three models can be imported into Navisworks (or Tekla and Solibri). This is done by exporting the 3D model from Revit and linking it from within Navisworks to the resources and time. A time line feature (fig. 17) will sequence the work in a movie or the project manager can move the sliding time line bar to see the progress of the work. Selecting an element brings up when it will be built and other data like delivery and storage can be accessed or noted here.

The added benefit here is that the slider bar can be moved to today's date and the expected work can compared to the actual work, meaning the manager can see if the work is ahead of schedule or behind. Navisworks will also allow him to make clash detections which can be implemented earlier in the process eliminating many architect's instructions and requests for information on site.

THE FACILITIES MANAGEMENT MODEL

If the above has been carried out as described then the final virtual model should be a replica of the actual building. This is of significant relevance to the owner or whoever is responsible for running the facility. Previously the Facilities Manager started from scratch building a maintenance model, because often what was handed over bore no relationship to what was initially proposed.

Within the model each element has a right click properties dialogue box built up of parameters and values. Simply said a place holder is identified and a value entered, so that the 'height of a door' might have the value of '2100 mm'. During the early work stages of the project it is of no relevance to the architect who the manufacturer is, but at some point in the process it will become relevant, typically when the contractor is placing an order. If the contractor uses the model to enter the supplier, then other data can be added such as durability, colour, model number as well as all ironmongery and key identification numbering. Or if it is not done then that the ability is there for later or whenever appropriate. This is the beauty of a centralised point of contact.

Although not implemented at time of writing, there is research saying that once a door is placed in a model, that it should be possible to elicit information about it for later use. Just as smart telephone use Apps (Applications) to do things, Bots (Robots) are waiting to do other things. Search engines are very well advanced today. Enter a word or topic in your browser search engine and a meaningful response is returned based on others who made the same search and relevant to you location. All this happens in the background and without going into the algorithms we all use it and are relatively pleased with the hit rate and response. That's why we come back.

Imagine a Bot placed on a door going off quietly and finding all the doors that meet the requirements demanded for that door. Initially it might only be an internal single leaf door, with twenty three manufacturers that fit the bill, but by the time it is fully commissioned it might have a gained fire rating, sub master key with particular hinges, a particular type of wooden veneer, a specific model and price, with a specified life expectancy with inbuilt inspection periods or repair schedules. This data is only relevant to those who need it but at each stage of the process there is finger tip informed data at the ready awaiting selection.

All in all there are fascinating developments happening, and they are happening at a rate of knots. Patrick MacLeamy has engaged us with his *'BIM, BAM, BOOM'* scenario where for every dollar spent in the design phase, there are $20 spent in the assembly or construction, which leads to $60 in its operation and maintenance. If clients and users are not demanding this consideration in their projects then we are failing them. If we are not looking at sustainable issues through all phases, then we are failing ourselves.

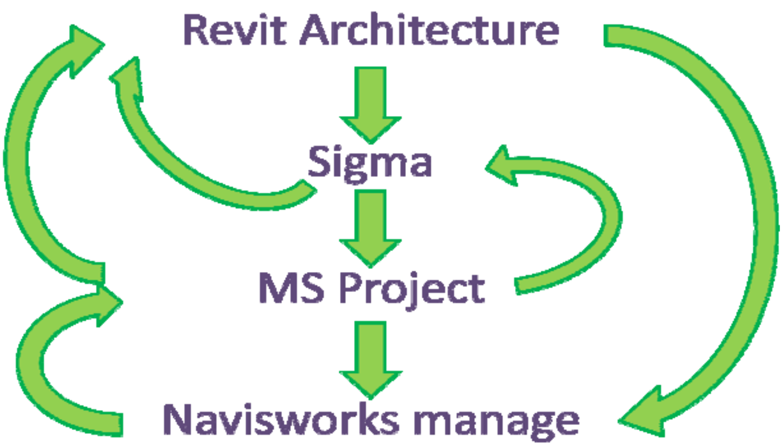
Finally I would like to thank my students; Mike Coombe, Peter Erler and Sean Termansen for their help in developing this model (fig. 18) and whose work has been used to demonstrate its application at the Copenhagen School of Design & Technology.

Method

Getting from Revit to the Fourth Dimension

Here follows a step-by-step guide in how to implement the workflow to bring the 3D model, 4D time and 5D resources into Navisworks where a time line of the project's construction can be executed.

Workflow from Revit to Navisworks Manage



Assisted by Mike Coombe and Peter Erler

Semester 5, Constructing Architect students, KEA (February 2010)

The most important aspect of this process is to:

'be aware of the end goal when starting the Revit project, for example clash detection requires different set-up to time-line scheduling, which is again different to a standard Revit set-up. Ensure all software and plug-ins are up-to-date. (especially Revit to Sigma and Revit to Navisworks)'.

Figure 1 Western Harbour, Malmö. 4th Semester Student Project by Mike Coombe, Peter Erler, Kristel Reseke and Juan Cai 2009

Revit, Type Codes

In Revit, after starting a project go to Project Parameters and add a parameter called *'Type Code'*, (if this isn't already in your template).

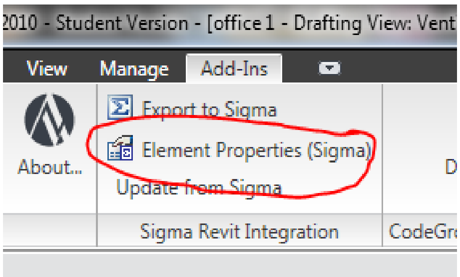
When creating your model it should be broken down into elements and components as they are intended to be built, for example walls should be split by their levels, (as should curtain walls and floor slabs), so that they can be labelled in accordance with the project schedule. This is because in the schedule, walls will be placed by floor and large floor slabs will be divided into sizes that can be poured per day etc.

Sigma, Price Books

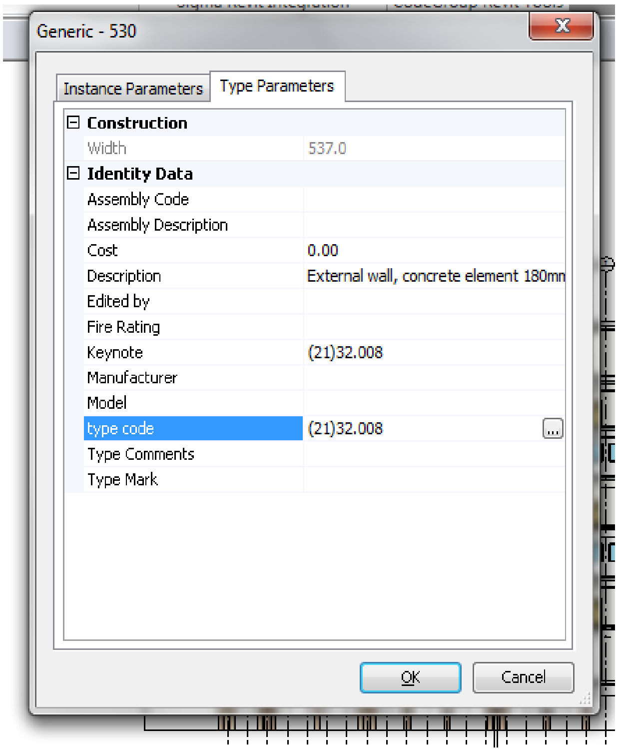
Begin by compiling a project library for the current project, using the relevant elements from V&S (DK) price books or Spons (UK), or your own, if you are an estimator (QS). Adjust them to suit the project (with increased insulation or whatever). This library can be a very fluid document in that it will change and update as the project progresses.

Revit, Integration

Select an element in the project and go to the *'Add-Ins'* tab, select the *'Element Properties (Sigma)'* option in the *'Sigma Revit Integration'* tab.



Select the *'Type Code'* tab and then *'Setup'* to add the location of the Sigma library that was saved earlier (or directly to the V&S book you wish to use).

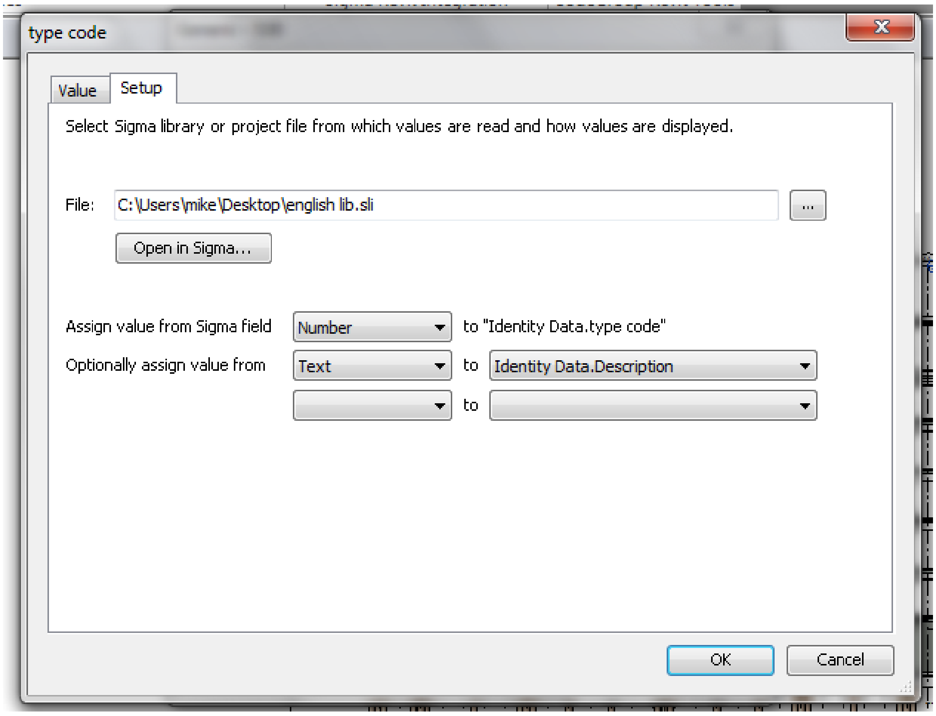


Sigma Libraries are denoted by the *'.sli'* extension, and the assigned value from the Sigma field is *'Number'* (the *'Type Code'*). The *'Text'* is then *'Identity Data, Description'*, which identifies the code and describes it briefly. This is done merely as an aid to the work's process. For example:

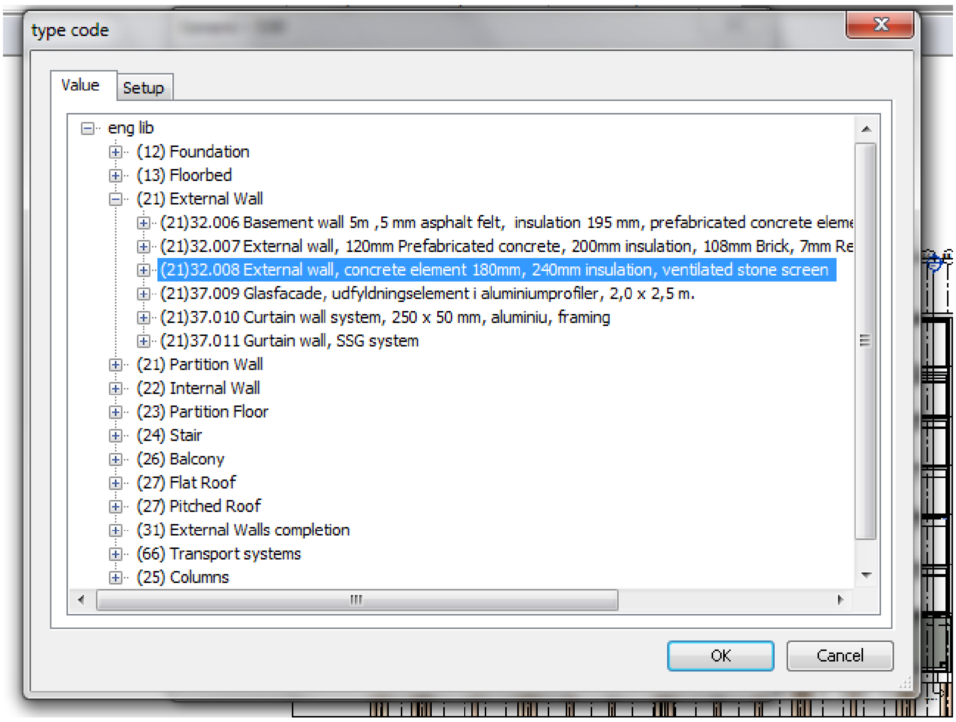
(21)32.008 External Wall, Concrete Element 180mm, 240mm Insulation, Ventilated Stone Screen

Refers to the following:

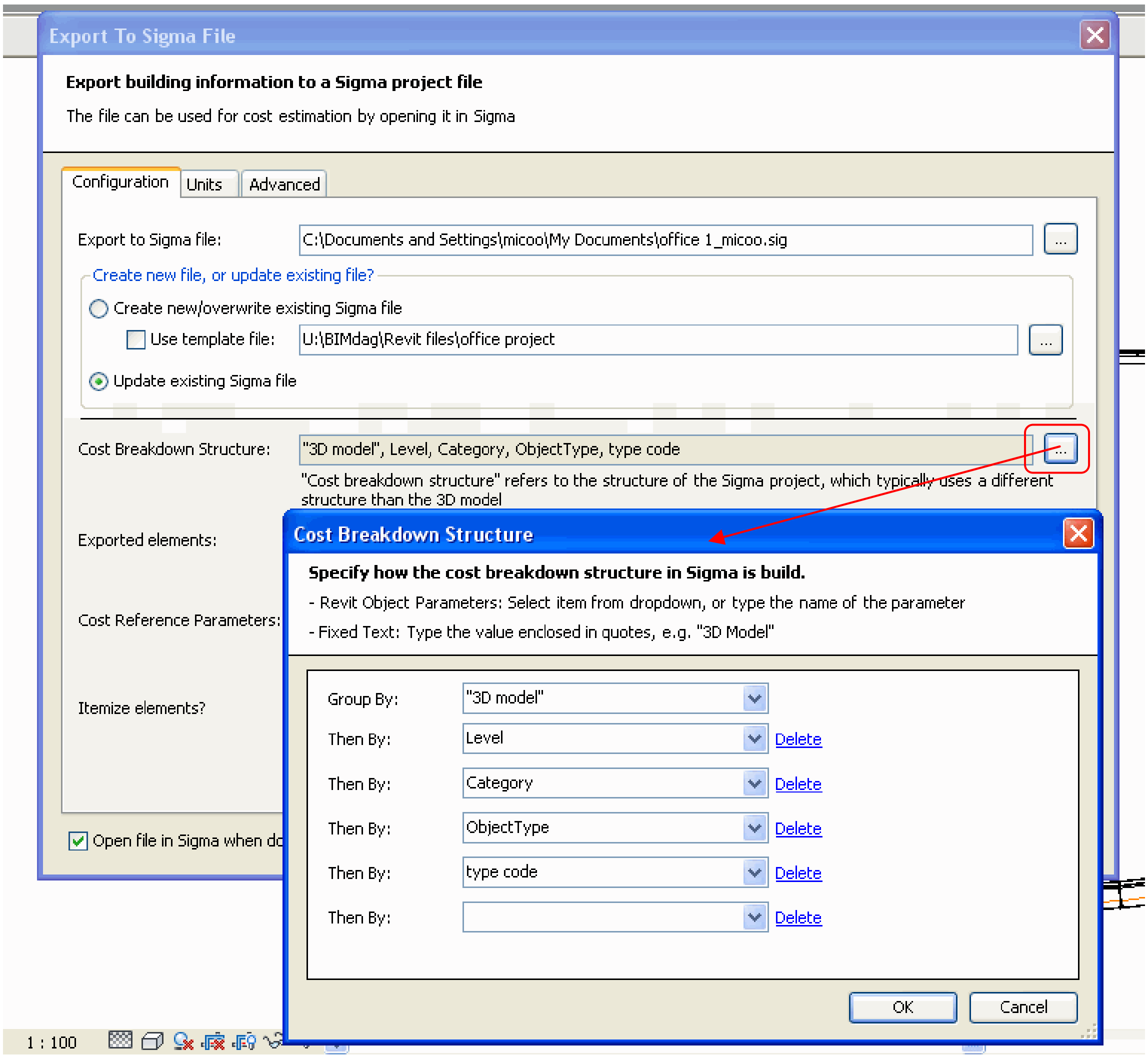
- *'Type Code'*: (21)32.008
- *Identity Data'*: External Wall
- *'Description'*: Concrete Element 180mm, 240mm Insulation, Ventilated Stone Screen



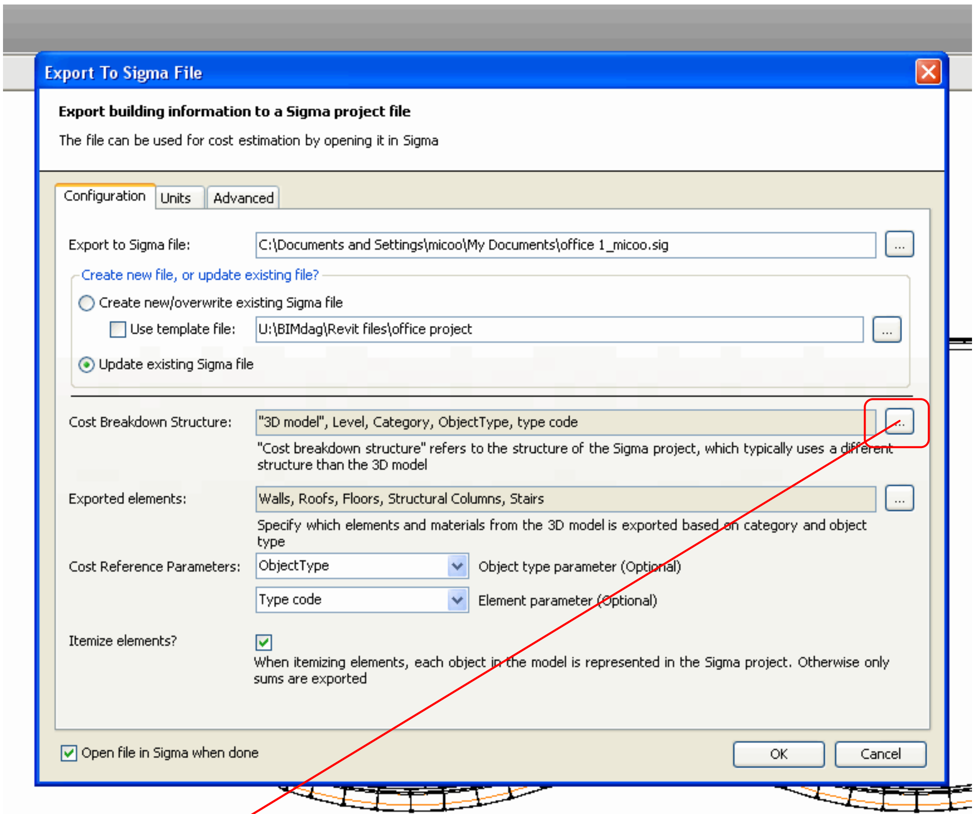
Switching to the *'Value'* tab, you can scroll through to the element from the Sigma library, and attach it to the *'Type Code'*. This then applies to all elements in the project of that type.



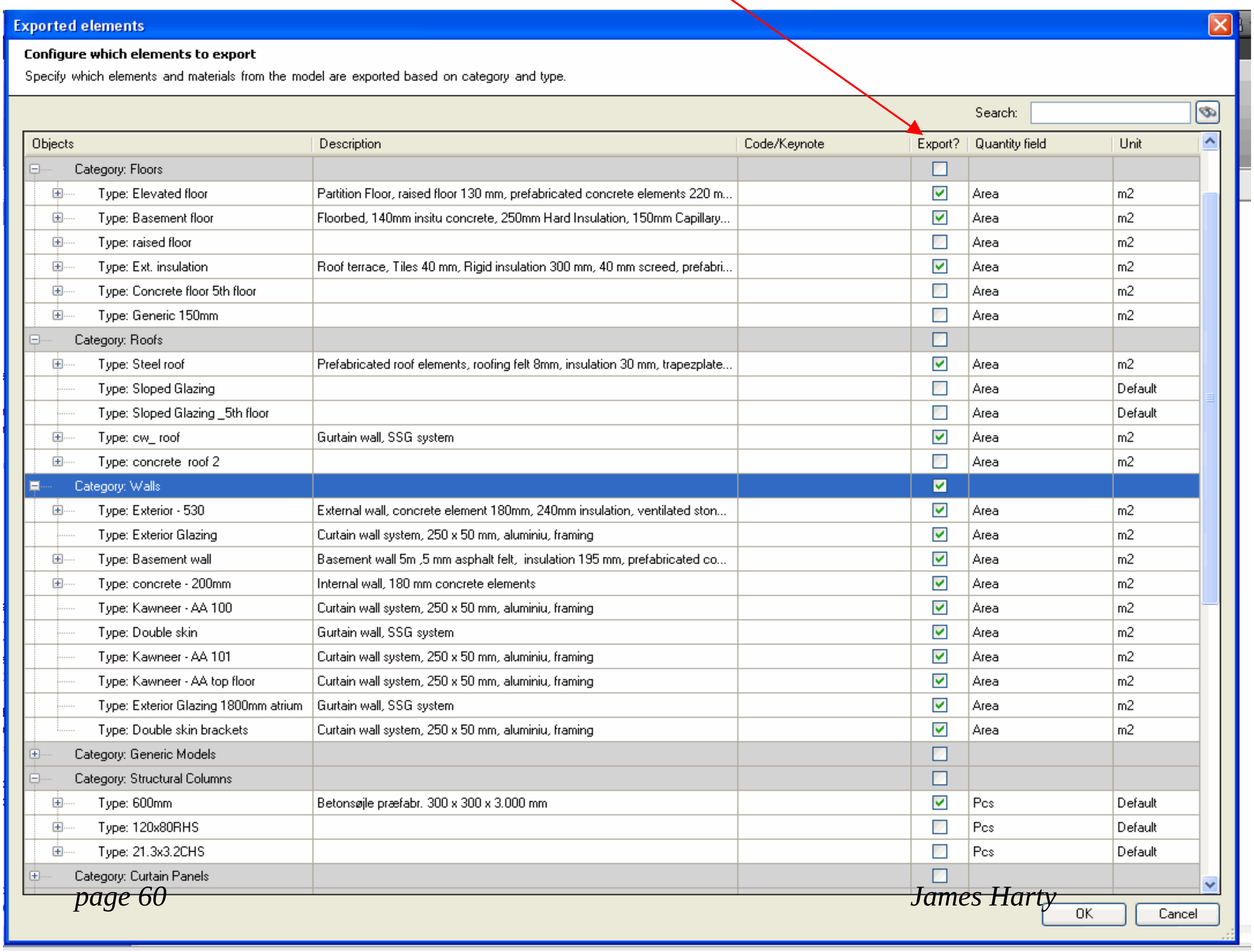
When this is done for all the relevant components, go to the *'Export to Sigma'* button, on the *'Add-Ins'* tab and click on *'Export to Sigma'* (all the elements that have been *'Type Coded'* will correspond to a similar element in your Sigma library).



The following settings describe how the Sigma project is set-up The Group is the Revit *'3D Model'*. This is then broken down by *'Level'*, *'Category'*, *'Object Type'* and *'Type Code'*.



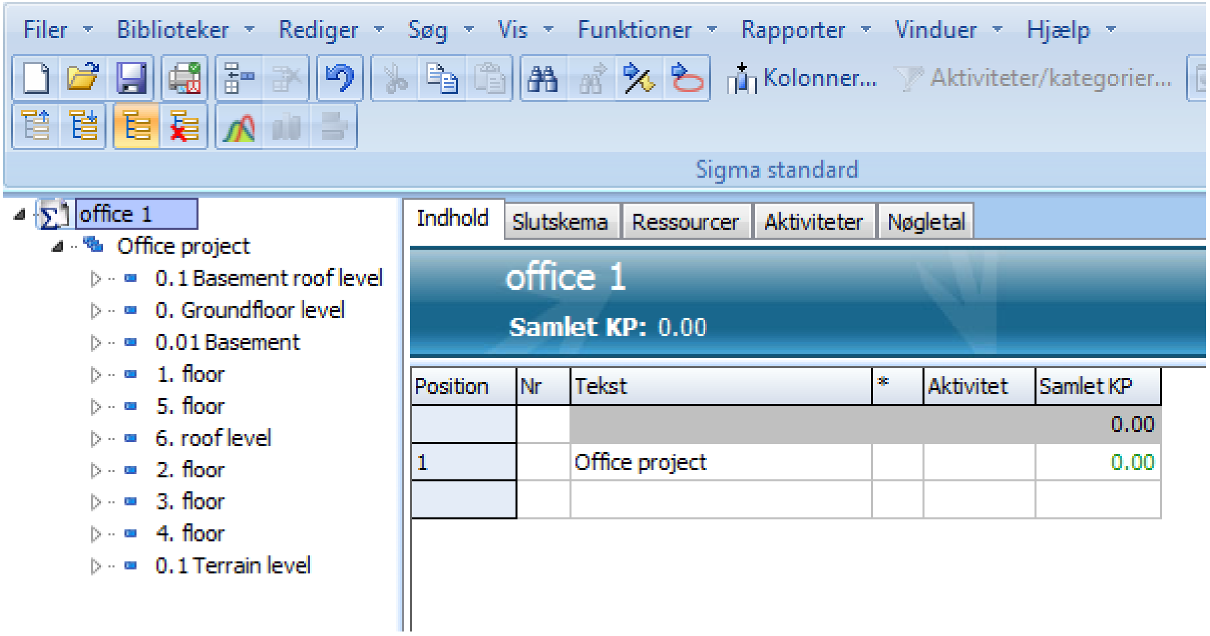
Check which elements are going to be exported, depending on how detailed the cost and subsequent schedule is required.



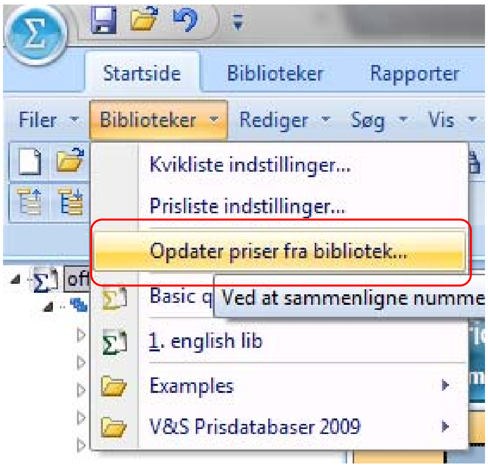
In addition, check in the *'Units'* tab so that any conversions from Revit that are needed in Sigma are listed correctly, for example *'pcs'* in Revit is *'stk'* in Sigma. (pcs refers to pieces, stk refers to stykke, Danish for piece). This is a bug fix.

Then export the project...

Code Group Sigma



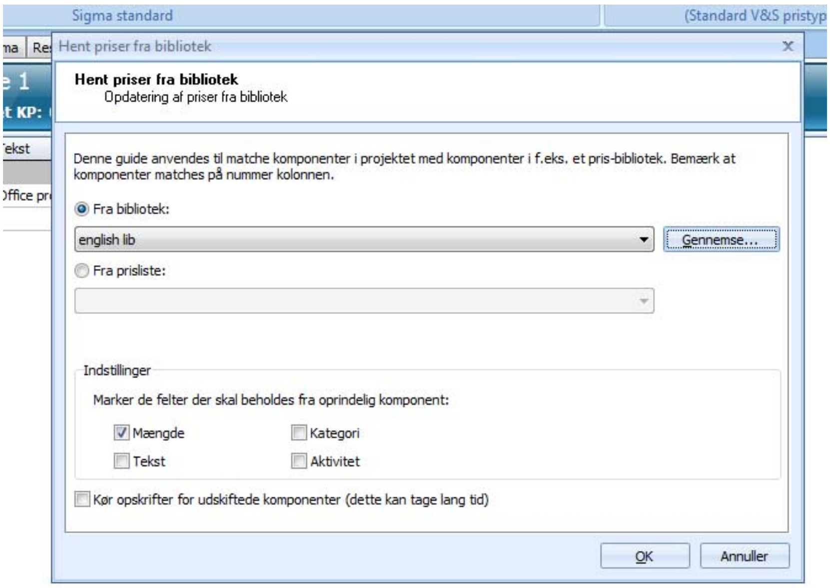
The new project opens in Sigma, and the levels etc are shown in the browser pane, but at this moment all prices are zero. The prices are then update from the Sigma library created earlier.



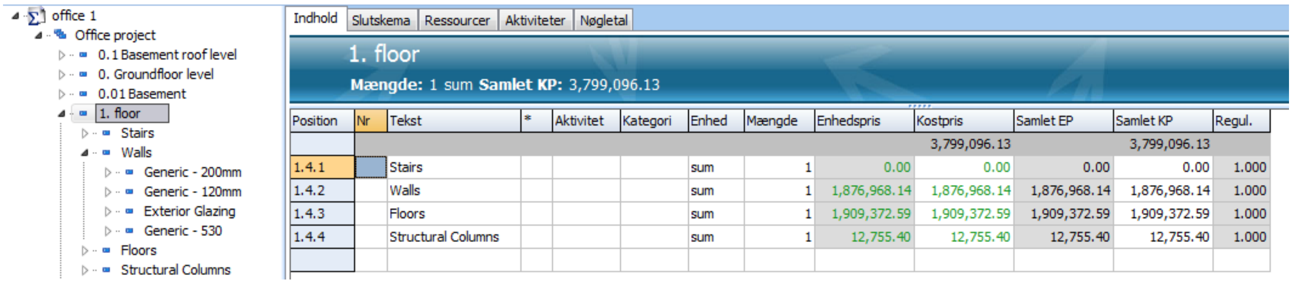
Note, this part is in Danish, due to a problem with the Sigma software.

- *'Biblioteker'* means *'Libraries'*,
- *'Opdater priser fra bibliotek'* means *'Update prices from library'*.

- *'English Lib'*, is the moderated library generated from the V&S price books, but tailored to the Project's parameters.

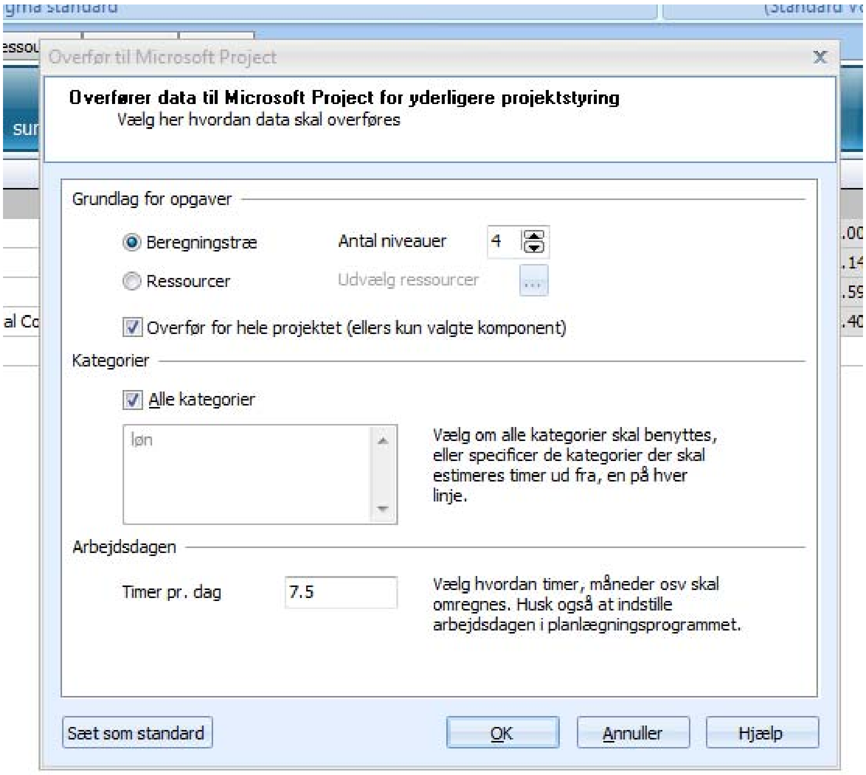


This prices the project, with the levels and detail that was chosen in exporting from Revit, which can drive right down to the individual elements within a wall, or just a complete wall element.



It is now possible to export to MS Project. Select *'file'*, and *'export'* and select *'MS Project file'*.

The former settings, which to determine how much information that was wanted to be carried over into MS Project, can be reused. Four levels of detail were chosen, which equates to the first four levels of the Sigma project as the set-up for the project file.



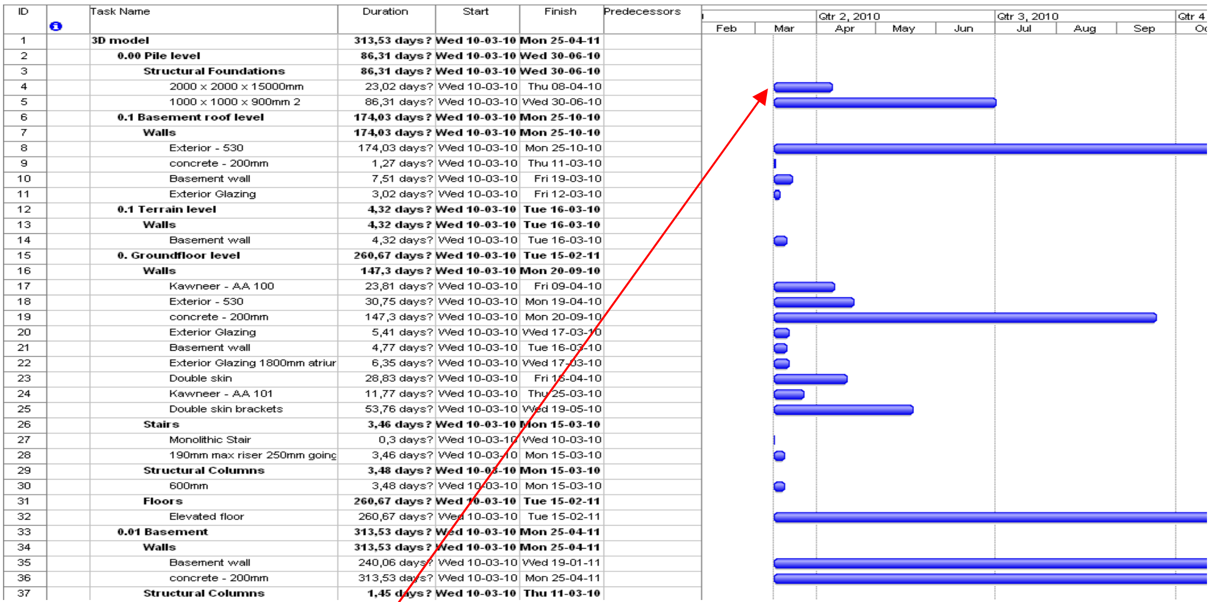
Note, this part is in Danish too, due to a problem with the Sigma software.

- *'Overfører data til Microsoft Project for yderligere projektstryring'* means *'Transfer dato to MS Project, for additional project control'*
- *'Beregningstræ'* means *'Calculation tree'*
- *'Antal niveauer'* means *'Total number of levels'*
- *'Alle kategorier'* means *'All categories'*
- *'Timer pr. dag'* means *'Hours per day'*

MS Project:

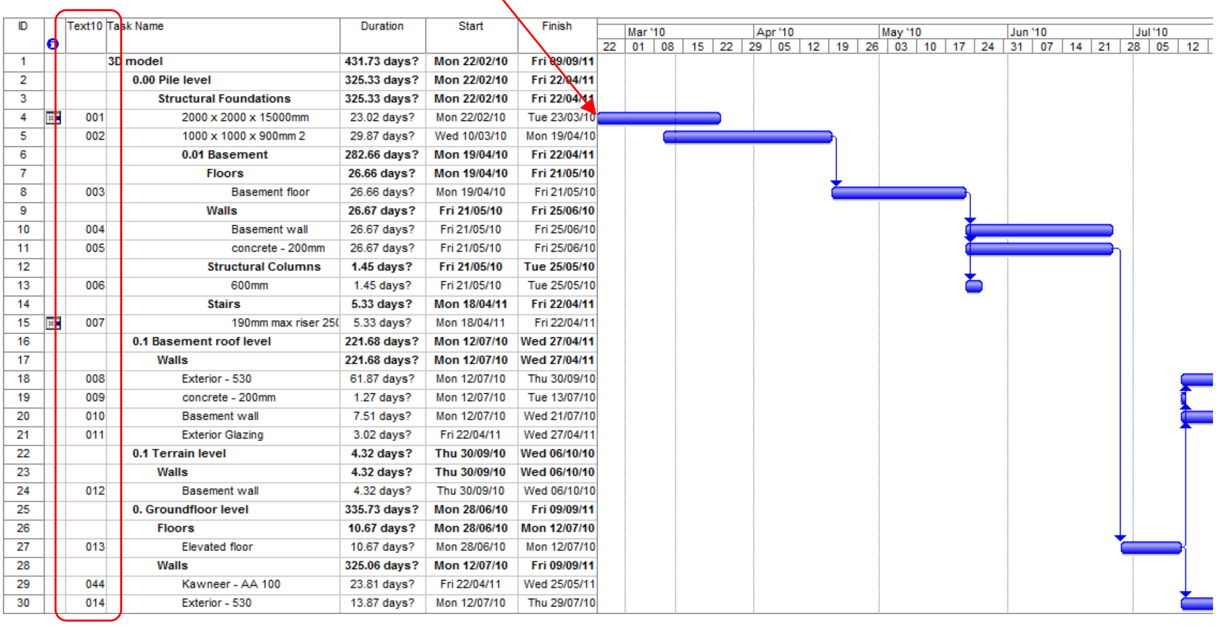
Once the list of the elements and the levels etc, has been brought in from Sigma, everything is shown at today's date... Therefore, it is necessary to update the schedule to fit the time and resource planning required. This can be achieved using a *'critical path'* method where the most essential tasks are plotted in sequence, meaning the less crucial ones are fitted around them, or each task is linked to the next and a chain of events transpires, resulting in a start and completion date.

The one drawback currently is that this part is not bi-directional. This means that the work executed here cannot be exported back to Sigma, and by extension to Revit. This also means that if the former stages have changes or revisions, then this latter process must be repeated.



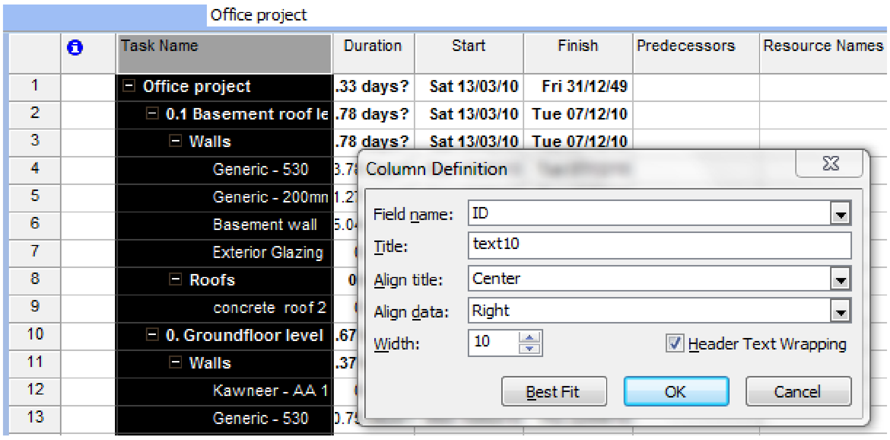
ID		Task Name	Duration	Start	Finish	Predecessors
1		**3D model**	**313,53 days?**	**Wed 10-03-10**	**Mon 25-04-11**	
2		**0.00 Pile level**	**86,31 days?**	**Wed 10-03-10**	**Wed 30-06-10**	
3		**Structural Foundations**	**86,31 days?**	**Wed 10-03-10**	**Wed 30-06-10**	
4		2000 x 2000 x 15000mm	23,02 days?	Wed 10-03-10	Thu 08-04-10	
5		1000 x 1000 x 900mm 2	86,31 days?	Wed 10-03-10	Wed 30-06-10	
6		**0.1 Basement roof level**	**174,03 days?**	**Wed 10-03-10**	**Mon 25-10-10**	
7		**Walls**	**174,03 days?**	**Wed 10-03-10**	**Mon 25-10-10**	
8		Exterior - 530	174,03 days?	Wed 10-03-10	Mon 25-10-10	
9		concrete - 200mm	1,27 days?	Wed 10-03-10	Thu 11-03-10	
10		Basement wall	7,51 days?	Wed 10-03-10	Fri 19-03-10	
11		Exterior Glazing	3,02 days?	Wed 10-03-10	Fri 12-03-10	
12		**0.1 Terrain level**	**4,32 days?**	**Wed 10-03-10**	**Tue 16-03-10**	
13		**Walls**	**4,32 days?**	**Wed 10-03-10**	**Tue 16-03-10**	
14		Basement wall	4,32 days?	Wed 10-03-10	Tue 16-03-10	
15		**0. Groundfloor level**	**260,67 days?**	**Wed 10-03-10**	**Tue 15-02-11**	
16		**Walls**	**147,3 days?**	**Wed 10-03-10**	**Mon 20-09-10**	
17		Kawneer - AA 100	23,81 days?	Wed 10-03-10	Fri 09-04-10	
18		Exterior - 530	30,75 days?	Wed 10-03-10	Mon 19-04-10	
19		concrete - 200mm	147,3 days?	Wed 10-03-10	Mon 20-09-10	
20		Exterior Glazing	5,41 days?	Wed 10-03-10	Wed 17-03-10	
21		Basement wall	4,77 days?	Wed 10-03-10	Tue 16-03-10	
22		Exterior Glazing 1800mm atriur	6,35 days?	Wed 10-03-10	Wed 17-03-10	
23		Double skin	28,83 days?	Wed 10-03-10	Fri 16-04-10	
24		Kawneer - AA 101	11,77 days?	Wed 10-03-10	Thu 25-03-10	
25		Double skin brackets	53,76 days?	Wed 10-03-10	Wed 19-05-10	
26		**Stairs**	**3,46 days?**	**Wed 10-03-10**	**Mon 15-03-10**	
27		Monolithic Stair	0,3 days?	Wed 10-03-10	Wed 10-03-10	
28		190mm max riser 250mm going	3,46 days?	Wed 10-03-10	Mon 15-03-10	
29		**Structural Columns**	**3,48 days?**	**Wed 10-03-10**	**Mon 15-03-10**	
30		600mm	3,48 days?	Wed 10-03-10	Mon 15-03-10	
31		**Floors**	**260,67 days?**	**Wed 10-03-10**	**Tue 15-02-11**	
32		Elevated floor	260,67 days?	Wed 10-03-10	Tue 15-02-11	
33		**0.01 Basement**	**313,53 days?**	**Wed 10-03-10**	**Mon 25-04-11**	
34		**Walls**	**313,53 days?**	**Wed 10-03-10**	**Mon 25-04-11**	
35		Basement wall	240,06 days?	Wed 10-03-10	Wed 19-01-11	
36		concrete - 200mm	313,53 days?	Wed 10-03-10	Mon 25-04-11	
37		**Structural Columns**	**1,45 days?**	**Wed 10-03-10**	**Thu 11-03-10**	

Upon completion, we go from this to this:



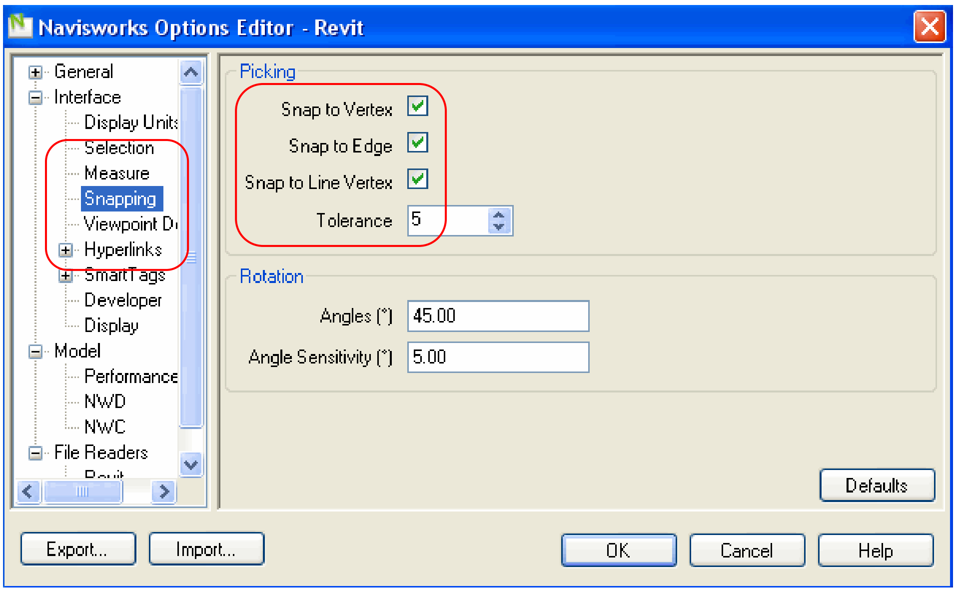
ID		Text10	Task Name	Duration	Start	Finish
1			**3D model**	**431.73 days?**	**Mon 22/02/10**	**Fri 09/09/11**
2			**0.00 Pile level**	**325.33 days?**	**Mon 22/02/10**	**Fri 22/04/11**
3			**Structural Foundations**	**325.33 days?**	**Mon 22/02/10**	**Fri 22/04/11**
4		001	2000 x 2000 x 15000mm	23.02 days?	Mon 22/02/10	Tue 23/03/10
5		002	1000 x 1000 x 900mm 2	29.87 days?	Wed 10/03/10	Mon 19/04/10
6			**0.01 Basement**	**282.66 days?**	**Mon 19/04/10**	**Fri 22/04/11**
7			**Floors**	**26.66 days?**	**Mon 19/04/10**	**Fri 21/05/10**
8		003	Basement floor	26.66 days?	Mon 19/04/10	Fri 21/05/10
9			**Walls**	**26.67 days?**	**Fri 21/05/10**	**Fri 25/06/10**
10		004	Basement wall	26.67 days?	Fri 21/05/10	Fri 25/06/10
11		005	concrete - 200mm	26.67 days?	Fri 21/05/10	Fri 25/06/10
12			**Structural Columns**	**1.45 days?**	**Fri 21/05/10**	**Tue 25/05/10**
13		006	600mm	1.45 days?	Fri 21/05/10	Tue 25/05/10
14			**Stairs**	**5.33 days?**	**Mon 18/04/11**	**Fri 22/04/11**
15		007	190mm max riser 25(	5.33 days?	Mon 18/04/11	Fri 22/04/11
16			**0.1 Basement roof level**	**221.68 days?**	**Mon 12/07/10**	**Wed 27/04/11**
17			**Walls**	**221.68 days?**	**Mon 12/07/10**	**Wed 27/04/11**
18		008	Exterior - 530	61.87 days?	Mon 12/07/10	Thu 30/09/10
19		009	concrete - 200mm	1.27 days?	Mon 12/07/10	Tue 13/07/10
20		010	Basement wall	7.51 days?	Mon 12/07/10	Wed 21/07/10
21		011	Exterior Glazing	3.02 days?	Fri 22/04/11	Wed 27/04/11
22			**0.1 Terrain level**	**4.32 days?**	**Thu 30/09/10**	**Wed 06/10/10**
23			**Walls**	**4.32 days?**	**Thu 30/09/10**	**Wed 06/10/10**
24		012	Basement wall	4.32 days?	Thu 30/09/10	Wed 06/10/10
25			**0. Groundfloor level**	**335.73 days?**	**Mon 28/06/10**	**Fri 09/09/11**
26			**Floors**	**10.67 days?**	**Mon 28/06/10**	**Mon 12/07/10**
27		013	Elevated floor	10.67 days?	Mon 28/06/10	Mon 12/07/10
28			**Walls**	**325.06 days?**	**Mon 12/07/10**	**Fri 09/09/11**
29		044	Kawneer - AA 100	23.81 days?	Fri 22/04/11	Wed 25/05/11
30		014	Exterior - 530	13.87 days?	Mon 12/07/10	Thu 29/07/10

The next step then is to add another column, called *'Text10'* (as below) by right clicking on the column header bar and adding an *'ID column'* calling it *'Text10'* (this is not a requirement but it will make our linking work in Navisworks a little easier.). The *'Text10'* column is then filled with a unique ID number or code, in sequence, for each process in our schedule. It is this column that is used for reference in Navisworks. This is then saved to a convenient location.

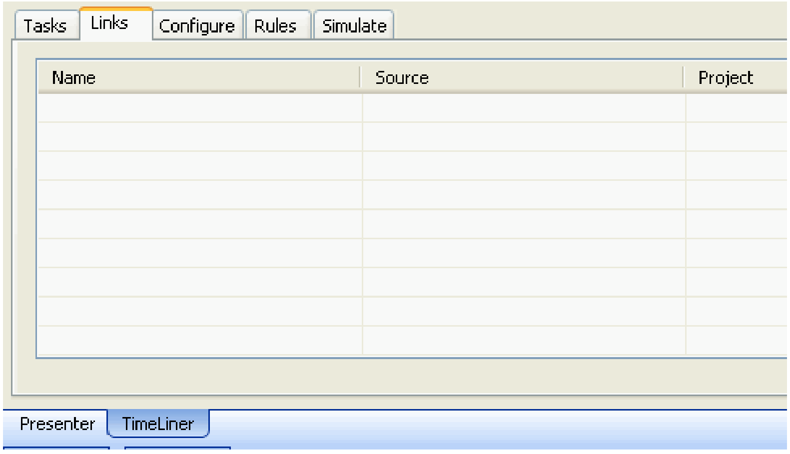


Navisworks Manage

Back in Revit, go to the *'Add-Ins'* tab and select *'Export to Navisworks'* (ensuring that it is a 3D view) and in the options ensure that Metric (and not Imperial) is selected, then export to the chosen location.

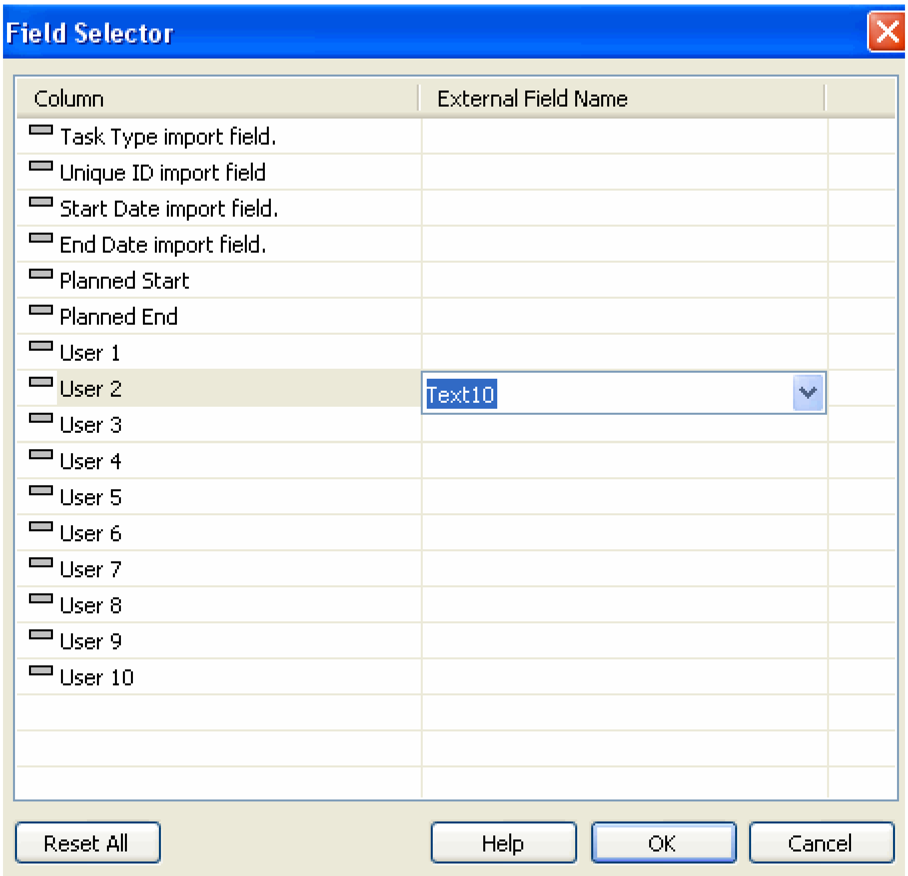


With Navisworks launched, go to *'open'* and find the Navisworks file that was exported from Revit and open it. Then go to the *'Timeliner'* tab, and then the *'links'* tab, right click, and select *'add link'* and find the MS Project file.

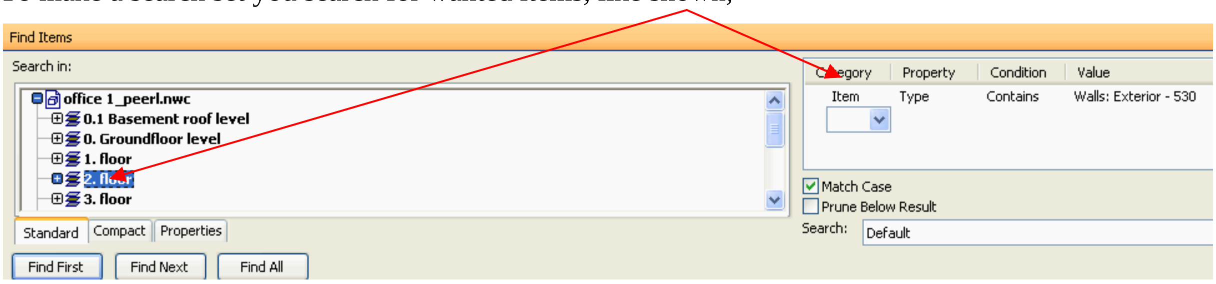


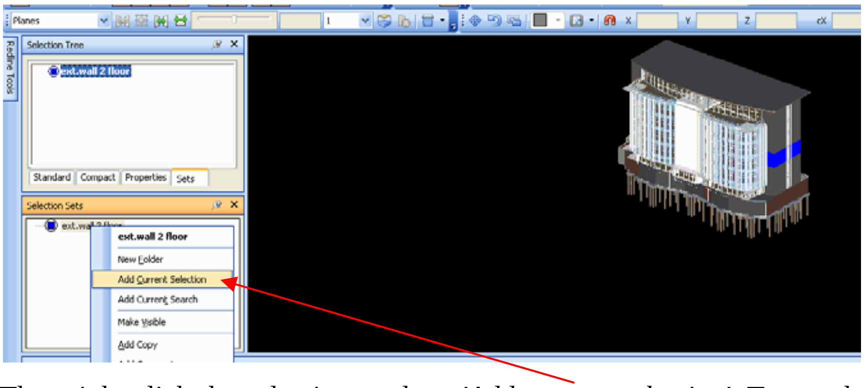
Now select *'Text10'* under *'User 2'* to get the required information from the MS Project file.

Then right click on the link and to rebuild the task hierarchy from the link.

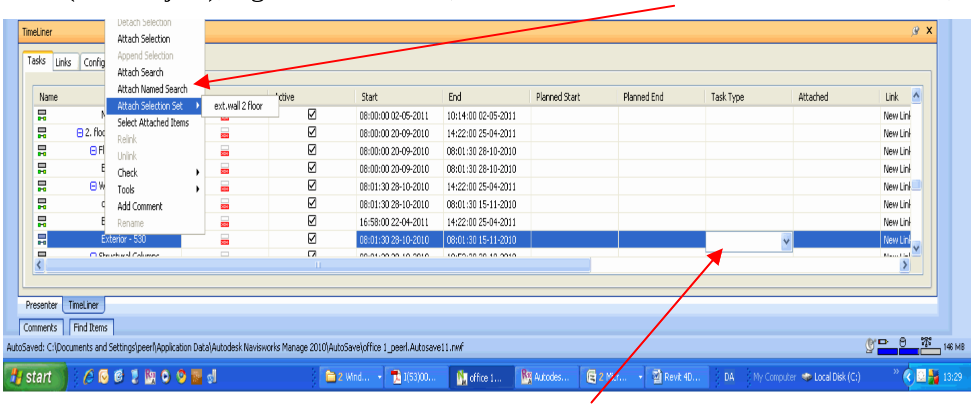


To make a search set you search for wanted items, like shown,





Then right click the selection, and set *'Add current selection'*. To attach a set to the Timeliner (MS Project), right click the task, and choose it under *'Attach Selection Set'*,



It is important for the Timeliner to be set to *'Task type'* to construct.

Once this is in place the sequence can be run, it can be recorded and it can be saved as an animation file for distribution to other team members. The slider bar can also be moved to see the extent of the construction at any particular time. Elements or components can be selected, and their details can be called up regarding when they are scheduled or completed. It can also be saved and distributed to contractors and sub-contractors who, using *'Navisworks Freedom'*, which is a free programme, can examine the model and extract data from it. This functions very similarly to Adobe Acrobat and Acrobat Reader where one is an authoring programme and the other is a viewer.

As proficiency improves, more functions can be added including temporary tasks, (site work, plant and machinery) as well as clash detection, top quality rendering and overlaying of differing files from a host of differing programmes. Although this method illustrates a particular product, Solibri and Tekla offer similar programmes with differing strengths and weaknesses. The benefits though are that control is exercised over the procurement process.

2008c) 2010)